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#icli2016

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# EDITORIAL

## On the technology of Liveness

Thor Magnusson, Chris Kiefer and Sam Duffy

The diversity of submissions for the 2016 International Conference on Live Interfaces has demonstrated that there is a demand for an interdisciplinary conference that focuses on the role of technology in artistic expression. The biennial ICLI conference was first held in Leeds in 2012 and then Lisbon in 2014, chaired by Alex McLean and Adriana Sá respectively. The conference has engaged with how artists apply interface technologies (a word equally denoting methods and objects) in live performance. The question is one of the interface and its manifold relationships, for example between the performer and the work, between a composer and the audience, between a choreographer and a dancer, or indeed between audience members. With the omnipresence of digital technologies in artistic practices, questions regarding the real-time become increasingly pertinent, as the technology itself can be embedded with intelligence, script, or learning mechanisms.

When employing computational interface technologies in the performing arts, we face diverse problems in relation to how meaningful the performance technology is to the audience. Topics of liveness, immediacy and presence, as well as mediation, signification and expression are critical and questioned in order to gain a deeper understanding of the role contemporary technologies play in contemporary human expression. With this conference on live interfaces we explore the philosophy of interface design in its instantiation in the diverse art forms, convinced that an interdisciplinary gathering of people will produce insights and dialogue difficult to achieve otherwise.

Following the broad themes and concerns enveloped by live interfaces, our call for participation carried an expansive list of conference topics. We felt the breadth of this list was necessary to cover the rich spectrum of practices in live interfaces, and also to reflect the wide interests of our keynote speakers, coming from fields as diverse as those of puppetry, dance, magic/illusionism, and musical instrument design. The call attracted a large volume of submissions, 142 in total across all submission categories. We felt that each submission should have at least three reviewers in order to maintain a high standard, so we sought additional reviewing expertise from the community of academics and artists who submitted work to the conference. With this fresh influx we were able to give at least three peer reviews to all submissions, and we would like to extend our gratitude to all of our Programme Committee members for contributing their time and expertise to the peer review process.

For us, it has been a privilege to see the quality, creativity and diversity of work that was presented at ICLI 2016. In particular, different interpretations of ‘interface technology’ challenge our preconceptions of how digital media and computing might shape the future of live performance. This raises questions of how interface technologies establish themselves as integral parts of performance and where in the creative process they sit. The presentations, performances, and installations during ICLI 2016 explored the concept of ‘interface’ through many forms of expression; including philosophy, design, craft, sound, music, visual art, sculpture and dance. We are excited to be involved in creating this platform for an interdisciplinary dialogue on topic so essential to contemporary artistic practice.

# PAPERS

## Introduction

Chris Kiefer

The academic programme spanned three paper sessions and a poster/demo session. The presenters approached the conference themes from diverse angles, often musical, and also enveloping audiovisual arts, coding, dance, education, machine listening, virtual environments and tangible interface design. Many submissions also included interactive demos; the demo/poster session was a lively, loud and engaging event, and a hands-on meeting point for the academic and performance strands. Together, the interdisciplinary mix of projects at ICLI 2016 highlighted and exposed thought provoking themes for future research in live interfaces.

# **Dark Matter**: Co-Reading as a Generative Ontology

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**Abstract.** This paper discusses the immersive full-body motion tracking installation *Dark Matter*, developed by the author and completed in early 2016. The paper outlines the conceptual focus of the project, including the use of the metaphor of dark matter to explore questions around interactive systems and assemblage. The primary technical considerations involved in the project are also outlined. 'Co-reading' is proposed as a framework for a generative ontology, within the context of assemblage theory, deployed within a multi-modal multi-agent interactive system.

**Keywords:** Co-reading, generative ontologies, dark matter, hidden information, interaction, assemblage.

## Introduction

*Dark Matter* is a fully immersive, physically interactive, three-dimensional video projection environment. The artwork explores whether the body might be perceived as an absence, inferred from the physical and cultural information around it. In this context, employing multi-agent interaction, people are proposed as emergent 'co-readers' within the context of a dynamic assemblage (DeLanda 2006).

The artwork employs the metaphor of dark matter; not only that of a physical character but also cultural. Just as dark matter is believed to bind the universe together it can be proposed that our society is bound by cultural 'dark matter'. This might be considered information we 'don't know we know', to extend the widely reported statement by Donald Rumsfeld, concerning evidence linking the Iraqi government with weapons of mass destruction, proposing a matrix of the known knowns, known unknowns and unknown unknowns.

Drawing together Rumsfeld's statement and psycho-analytic theory, Slavoj Zizek observed;

> What he [Donald Rumsfeld] forgot to add was the crucial fourth term: the "unknown knowns", things we don't know that we know - which is precisely the Freudian unconscious. If Rumsfeld thought that the main dangers in the confrontation with Iraq were the "unknown unknowns", the threats from Saddam we did not even suspect, the Abu Ghraib scandal shows where the main dangers actually are in the "unknown knowns", the disavowed beliefs, suppositions and obscene practices we pretend not to know about, even though they form the background of our public values. (Zizek 2005)

In *Dark Matter* textual material directly linked to events at Abu Ghraib and, more specifically, Guantanamo Bay, is employed to explore the nature of the things we don't know we know, representing a kind of cultural dark matter or collective unconscious.

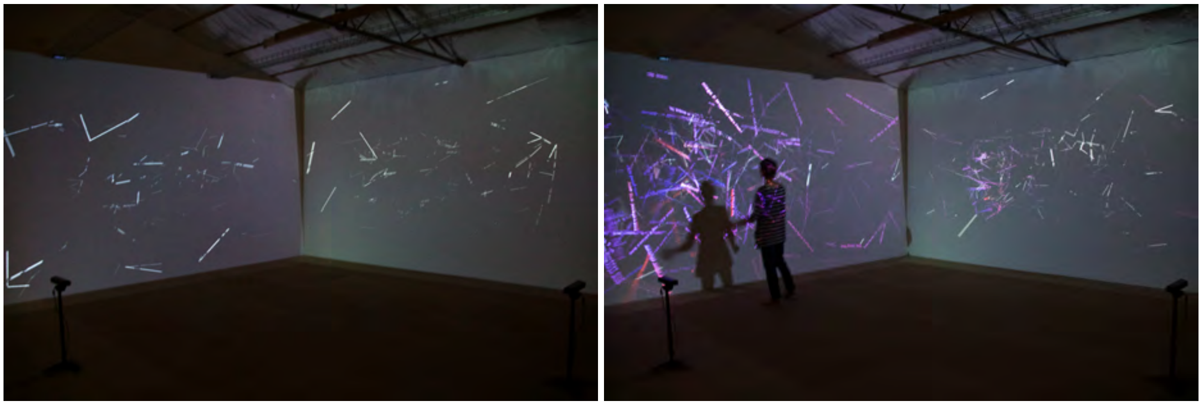
Dark matter is a term used in physics to refer to the hypothetically larger part of what constitutes most of the matter in the universe. It is understood that dark matter, including dark energy, constitutes nearly 95% of all matter in the universe (Ferris 2015). Dark matter has never been directly observed but its presence has been deduced from its interaction with light, due to its gravitational effect, bending space and thus light, behaving in a similar manner to a lens. Similarly, we might imagine that 95% of that which constitutes our culture - that which shapes us individually and collectively - is never observed, existing without interacting with us in a manner that we would phenomenally or intellectually comprehend.

The proposition explored in *Dark Matter* is that we exist as motile assemblages rather than stable individuals, a subset of a larger assemblage that could be considered a form of 'collective unconscious'. That assemblage is explored here as shaped by the forces of dark matter, in the form of the cultural information and patterns that we don't know that we know. This is considered a generative ontology, manifest in the artwork through multi-agent interaction with liminal visual and textual information.

## The Work

*Dark Matter* utilises the Microsoft Kinect motion tracking sensor, the SimpleOpenNI interaction library and open source Bullet physics engine (prepared as a Java library for this and related projects by Hadi Mehrpouya), integrated and programmed with the Processing JS programming language, to create a 3D simulated space containing a (invisible) model of interactor bodies and numerous invisible objects. In this installation the manner in which we understand dark matter, as something we cannot measure that nevertheless mediates and modifies all that we can perceive, is inverted.

*Dark Matter* employs real-time motion tracking of the human body, within a very dark installation space surrounded by immersive, but visually liminal, projections. The interactor's body is co-located within the computer generated 3D space. Initially the material that makes up the objects in the virtual space is not visualised. Only the mediation of the space by dark matter, not the dark matter itself, is visualised. The body of the interactor is also not visualised. When the interactor is at a distance from the projections, and the interactive space between them, all that is visible are faint vectors of light that describe interactions between what appears to be a multitude of invisible objects.



Figures 1 & 2. On left: Dark Matter installation running with no interactors. On right: An interactor approaches the left screen, illuminating elements of the virtual environment with hands and head.

The vectors of light are not random but clearly arise from some kind of order. That order is the energy generated by the numerous invisible objects in the virtual three dimensional space colliding with one another, as determined by the calculations of the physics engine. Whenever one object contacts another object a frisson of energy is created, visualised as a fleeting laser-like flash of a vector of light, its brightness a function of the velocity and mass of the objects involved in the interaction and its direction a result of the angle of incidence. The visual effect is reminiscent of an ever folding and re-folding crystalline structure composed of dark material, invisible in an environment where there is no light source to illuminate the objects that are creating the phenomena.

As the interactor approaches the projected images that comprise the visual aspect of the installation the quality of the projected imagery faintly changes. The closer the interactor gets to the projections the deeper they enter the virtual space that the projected imagery is comprised of. As the interactor moves through the space they can observe that their physical presence is directly affecting the vectors. The objects and the interactor's body-model interact, objects ricocheting off the virtual body and each other in a complex cascade of interactions. The complex web of connections between these interactions are initially visualised as barely visible vectors of light that have both a fluid and crystalline quality - fluid in their movement, flowing around the body of the interactor, and crystalline in the folding shapes that flicker in and out of existence.

Figures 3 & 4. On left: Screen-shot of the right-hand screen when no interactors are present. On right: Screen-shot of the right-hand screen with one interactor present.

As the interactor penetrates deeper into the space objects become visible, illuminated by faint virtual lights that emanate from the head (white light) and hands (respectively a blue and red light) of the interactor's body-model in the virtual space. The interactor is able to see that the objects that have been generating the vectors of light are actually textual fragments, moving about as they collide with one another and the interactor's virtual body, in a gravity-free three-dimensional volume. At this stage the interactor is able to read the texts that comprise the objects in the space, although this is not necessarily an easy task, as individual texts fly, spin, float and tumble through the space, their trajectory and dynamism a function of their interactions with all the other objects in the space - including that of the interactor's virtual body.

This barely visible dark matter, that constitutes all the objects within the virtual space, is composed of a large number of textual fragments, consisting of short phrases of typically three to six words, although there are a small number of phrases consisting of fewer or more words. The phrases have been created by cutting-up[1] an interview with Fawzi al Odah, a prisoner, or so-called 'enemy combatant', held at the USA's Guantanamo Bay military complex in Cuba. The interview was undertaken at the request of the BBC by attorney Tom Wilner (Honigsberg 2009, pp. 107-112). In the interview the interviewee is asked questions about their detention and they respond with a detailed description of the torturous nature of incarceration within the facility and the psychological relationships that develop between torturer and prisoner.

This text was chosen for use in *Dark Matter* as in many ways it represents the kind of knowledge we don't know we know. The topic it addresses - human on human inhumanity - is one that most people would consider dark cultural matter; information many of us know we don't want to know. Another key factor in selecting the interview as source material for the cut-up texts was the centrality of the human body in the discussion. The body is described as the site of interaction between torturer and prisoner, the thing that is acted upon and which is, through this process of abjection, disassociated from its person.

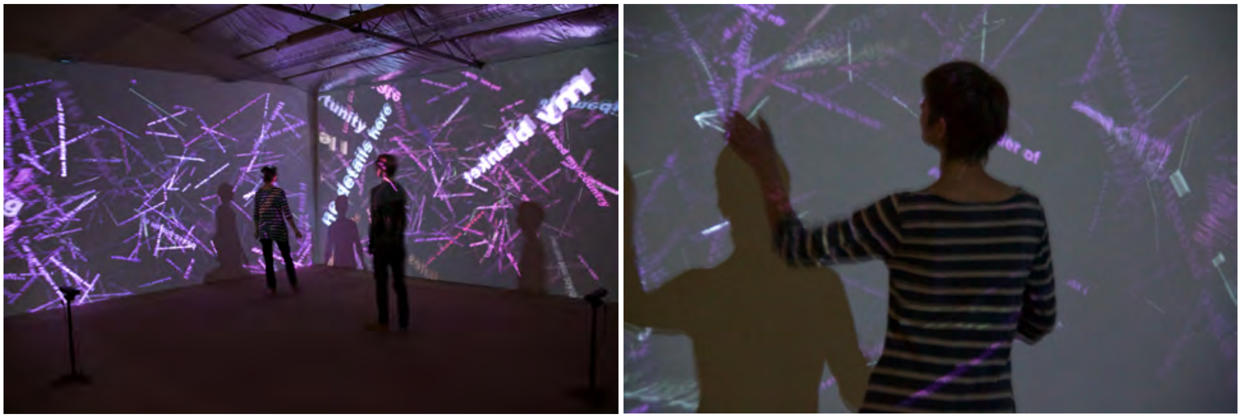
A factor that the interactor within *Dark Matter* might have observed at this point, although it is a very subtle effect, is that the space, as a whole, seems to have a rhythm. There is a slight but regular alteration in the overall dynamics of the space, which seems to occur at a tempo not dissimilar to that of a slow human breath. An invisible force is being regularly applied to all the dark matter objects in the space. At regular intervals a force equivalent to the inverse of the

[1] As observed, in a discussion of Brion Gysin's use of the cut-up technique, the method is "a technique itself based on earlier experiments of the surrealists, which in turn had their origins centuries before" (Wardrip-Fruin and Montfort). As such, "there is nothing new under the sun [...] that they are not novel should not deter writers from use of these techniques" (ibid). The key to the cut-up is the manner in which it allows new combinations of existing fragments to produce novel meanings. In Dark Matter the cut-up is navigated not by randomly selecting textual fragments from a hat or throwing the I-Ching (as John Cage liked to do) but by the interactor being an active participant in all the interactions occurring within the space.

momentum of each individual object is applied to each object. The effect creates something like a micro-cosmic version of the big-crunch, the hypothetical corollary of the big-bang - the theory that ultimately the mass of the universe will cause the process of expansion that eventuated from the big-bang to cease and a process of contraction to begin, causing the universe to implode upon itself. In this manner all the objects in the space, whether visible or invisible, oscillate between an expanding and contracting dynamic that underpins and inflects all the movement in the space. One side-effect of this, which was intended, is that this ensures no object, no matter how intensely acted upon by another object or interactor, is able to achieve escape velocity from the space and thus all the objects within the space remain within the proximity of the interactor(s). Visually the effect creates a faint trace of waves through all the visualised elements in the space, which might be appreciated as a poetic form of 'dark energy', manifest as waves of gravity or human breath.

Whilst the installation has two modes of viewing when there is one interactor, initially distant (observing the environment from the outside and only able to see the light vectors describing the interactions between the invisible objects) and then immersed (illuminating the objects that comprise the dark matter inhabiting the space) there is a third mode of engagement. This mode is engaged when there is more than one interactor immersed in the interactive area of the installation. Each interactor carries their own light to illuminate what they see, attached to the head and hands of their virtual body in the virtual space displayed in the projections. Thus the more interactors which are present results in more light being created and the easier it is to read the texts. However, another important factor is altered through having the presence of multiple interactors, and that is the point of view from which the virtual space is rendered for projection.

The default point of view for rendering the 3D scene is from a point outside the interactive space, where the virtual camera is located, roughly where the interactors first enter the installation space. This point of view is static and produces a conventional outsider's viewpoint of the three-dimensional scenario (an idealised third-person's view). However, when more than one interactor is in the interactive area of the installation the position of the virtual camera is immediately relocated to the head of the first interactor (the interactor who has been in the environment the longest) and its focal point becomes that of the second interactor (the second longest person to have inhabited the interactive space).



Figures 2 & 6. On left: Installation shot with two interactors present. On right: Close-up of the left-hand screen with an interactor illuminating texts with their hand.

In this situation what is rendered in the surrounding three-dimensional projections is a function of a point of view determined by the position of the heads of two of the interactors. Not only does this mean that the texts are now all around the interactors, and appear much larger as they are immersed in the dense mass of textual objects that comprises the space, but the entire geometry of the visualisation becomes a function of the interactors' co-joined movements. In effect, the vector that determines what is rendered, and thus what is seen, is a function of both interactors' behaviour.

This point of view resembles a first-person point of view in that the three-dimensional space is rendered and viewed from the point of view of a specific interactor but, significantly, what is seen (and read) is equally dependent on the second interactor, who co-controls the orientation of that point of view. Thus rather than considering this a first-person reading of the installation it might be considered a 'first-persons' reading.

In the first-person multi-interactor mode it is possible for the interactors to work together to focus their joint attention on specific volumes of the space, or even specific objects. By co-organising their movement the interactors can bring into legibility various textual objects, allowing them to navigate and read the space. How the space is organised around the interactors is clearly apparent, both visually and physically, as even small head movements cause the camera location and orientation to shift and the entire visualisation on both screens to move. At times this can be quite disorienting, producing an effect of vertigo in the interactors.

When interactors leave the space, leaving one interactor alone in the space, the rendering of the visual field reverts to the 'distant' (third-person) point of view. Other observers in the space can witness how the interactor, or interactors, interact with the space and its content without themselves entering the interactive space, and thus occupy this third-person role.


Figures 7 & 8. On left: Screen-shot of the left-hand screen with two interactors present. On right: Screen-shot of the right-hand screen with two interactors present.

## Collaborative Reading

The implication here is that reading can become a collaborative and multi-modal process. We are familiar with collaborative models of writing, whether in the form of the surrealist's 'exquisite corpse'[2], in some examples of digital literature (perhaps most notably in Douglas Davis's collaborative sentence[3]) or as found in many academic articles, but collaborative reading is perhaps a less explored aspect of literary practice. It is significant, in the instance of *Dark Matter*, that the processes of reading and perception are one and the same - each a function of the behaviour of the two interactors. It is the creation of this ontological complexity which is the key objective of the work.

[2] The surrealists "played a collaborative, chance-based parlor game, typically involving four players, called Cadavre Exquis (Exquisite Corpse). Each participant would draw an image (or, on some occasions, paste an image down) on a sheet of paper, fold the paper to conceal their contribution, and pass it on to the next player for his contribution" (MoMA 2016). An example of this can be seen in the online collection of the Museum of Modern Art (ibid).

[3] In 1994 Douglas Davis produced what was at the time described as the World's first collaborative sentence - an endless sentence composed of numerous contributions gathered from thousands of 'reader-writers' via the internet. The work has been restored and is in the collection of the Whitney Museum, New York. Davis wrote "The Sentence has no end. Sometimes I think it had no beginning. Now I salute its authors, which means all of us. You have made a wild, precious, awful, delicious, lovable, tragic, vulgar, fearsome, divine thing". (Davis 2000)

In *Dark Matter* collaborative reading is not employed as it might be in a pedagogical technique, like Collaborative Strategic Reading (Klingner and Vaughn 1998), but it does have certain similarities in how the interaction of readers affirm or deny particular interpretations or, indeed, the possibilities for emergent interpretation. The interactors have to work together to generate readings of the texts. This is a non-trivial activity. A similar method was developed by the artist in an earlier collaborative interactive performance environment, Crosstalk (Biggs, Hawksley and Paine 2014). As was observed by the authors of that work, the co-joining of perception and reading along a vector controlled by both performers is challenging, and

> ...allows the creation of a vector along which vision can be 'performed' by the two dancers. The movement possibilities of the performers in this section become highly contingent and interdependent. In order to read the words spoken by the other, one performer must adjust their position, and so then the other must move again. While making these constant readjustments of their relative positions, both must also attend to their position and facing relative to the Kinects, taking care not to occlude the other [...] the movement vocabulary is functional, determined by the practical requirement to see and to be seen and maintain a relative connection between people and technology. In an environment where the contingent relations between things is foregrounded we can witness the system making itself make itself.

The proposition in *Dark Matter*, acted out in the co-dependent interactions of the interactors who are required to perform their co-reading of the work, is that this is how we read all texts and understand all phenomena. The suggestion is that we only see the world, and ourselves within it, along vectors of perception that are a direct function of our relationships with others, whether those others are human or other agents. A popular example of this is what is sometimes referred to as 'group-think', where like-minded people, in group discussions, have a tendency to converge in their thinking and arrive at shared outcomes (that implicitly exclude those who are not members of the group).

Another applicable example of this polymorphous ontology is Freud's notion of the super-ego; a hypothetical aspect of the self that operates as our moral conscience, established early on, through social interaction, in a child's development:

> ...they [others] regularly make important contributions to the formation of character; but in that case they only affect the ego, they no longer influence the super-ego, which has been determined by the earliest parental imagos (Freud 1933).

In science fiction we might also consider the fictional species known as the Borg, in the Star Trek TV series, as an example of self as an assemblage formed from our constant (contingent) interactions with things and each other. The Borg have the capacity to add others to their collective being, Captain Jean Luc Picard (a lead character in Star Trek: The Next Generation TV series) being subject to this process of assimilation.

## Conclusion

Gilles Deleuze argues that the differentiation of the individual cannot be fully understood through the differences between persons but, rather, that difference be considered a condition of the individual. This shifts our understanding of individuation away from the concept of individual bodies and minds to one of vectors and relations, functioning as ontological dynamics, that flow through what we had considered separate persons.

> In effect, the essential in univocity is not that Being is said in a single and same sense, but that it is said, in a single and same sense, of all its individuating differences or intrinsic modalities [...] The essence of univocal being is to include individuating differences, whilst these differences do not have the same essence and do not change the essence of being – just as white includes various intensities, while remaining essentially the same white (Deleuze 1994).

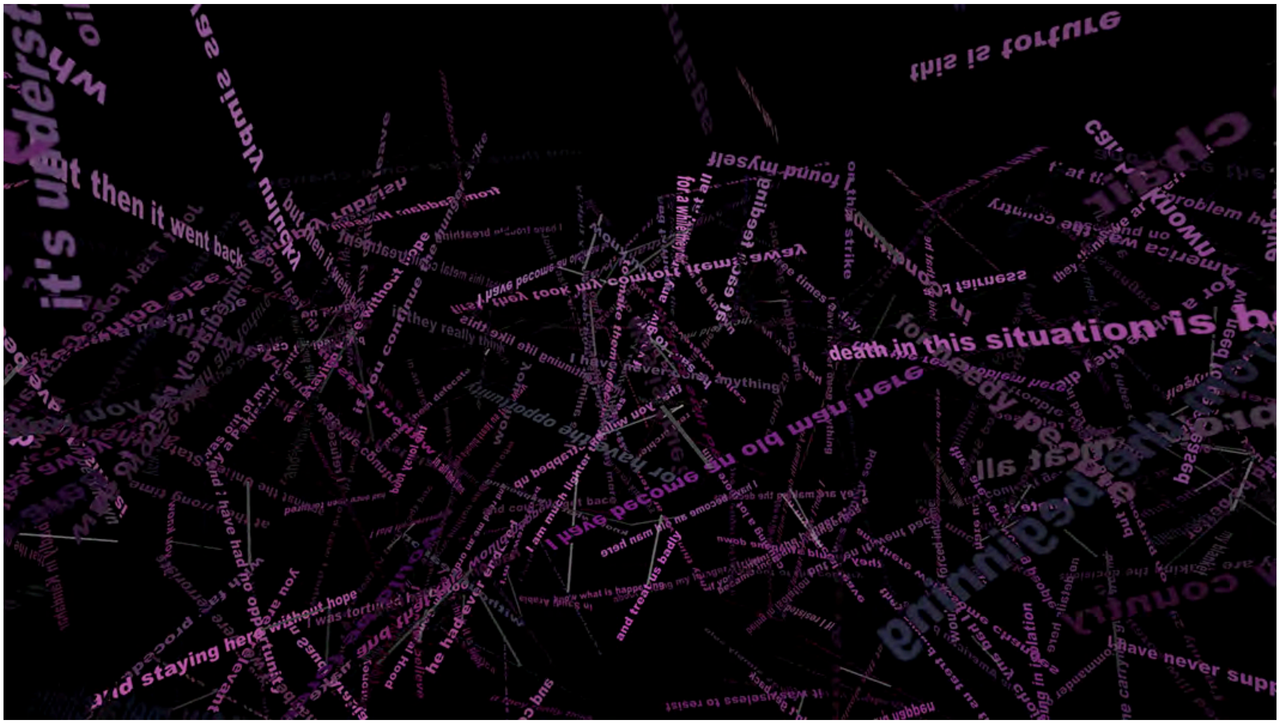



Figure 3. Screen-shot of the right-hand screen with two interactors present.

In the context of *Dark Matter* what we perceive as difference, that which distinguishes us, becomes fluid, flowing through the porous boundaries of differentiation, our unknown knowns. In this manner we are seen to be interconnected with one another, as a mesh-work, within the emergent social space we co-create. *Dark Matter* enacts and presents this process as a form of co-reading - not a shared interpretation but a co-construction of a world where interpretation and understanding are contingent on physical and social interaction. This is represented as vectors of interaction (and complicity in what is done, even when unaware - as at Abu Ghraib and Guantanamo) between various agents; people, information and dark matter.

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# Designing Mechatronic Sound Systems Inspired by Sinusoidal Mathematics

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**Abstract.** This paper describes three sonic mechatronic systems designed with the influence of sinusoidal properties and the intention to produce a sonic result. The main purpose of this paper is to illustrate the various techniques taken in constructing such systems by analyzing the process of translating natural phenomena recurring in nature into physical emulations with a sonic aspect. The three mechatronic systems described in this paper are categorized into three parts: sculpture, musical interface, and a hybrid of the two. Post-Wave is an interactive robotic interpretation of Redwood Wave, a kinetic sculpture by Reuben Margolin. Sinu serves as a circular sequencer utilizing photocells and LED's to trigger MIDI. Lastly, Cymbalic is a hybrid sculptural interface inspired by the findings of mathematician Leonard Euler.

**Keywords:** Post-Wave, Sinu, Cymbalic, mechatronic, sculpture, musical interface, sinusoid, kinetic

## Introduction

Within the understanding of modern day acoustics, the sine wave remains to be the fundamental root of its study. (Benson 2007) The mathematical function describes a pure repetitive oscillation. This oscillation pattern occurs frequently in nature: light waves, water waves, shock waves, radio waves, X-rays and most importantly sound waves. (Rossing 1990) Although sound waves are extremely different from radio waves or ocean waves, all waves contain certain common properties. The simple fact that these waves occupy the space within you are sitting in, in a variety of formats, explains the reasoning behind adopting the sine wave as the overall aesthetic approach to designing these systems.

The purpose of this paper is to explore aesthetics driven by mathematical relationships. The following section will familiarize the reader with similar works in which sinusoids are used as a source of inspiration. Section 3 presents a mechanical wooden sculpture, Post-Wave, the first in a series of sinusoidal pieces. Sinu, a circular musical interface, is explained in detail in section 4, discussing aesthetic motives along with technical procedures. Section 5 completes the series with the presentation of Cymbalic.

## Related Work

There are several kinetic artists and engineers who have used similar mathematical qualities in their work to recreate these naturally occurring phenomenas. Reuben Margolin's work is heavily based on waveforms. Initially, inspired by the crawling qualities of a caterpillar's movement, Margolin utilized mechanized actuators to simulate complex motions visible in nature. (Pop Tech 2014)

The Round Wave consists of nine concentric circles, each tied to a pulley system with a precise offset (figure 1). The result is a physical emulation of an expanding system of ripples formed by the dropping a small object into a pool of still water. Waves by Daniel Palacios is another example of a piece of related artwork. Waves is a sound installation consisting of a long piece of rope and two turbines (figure 2). The long piece of rope takes the shape of a complex wave form as the turbines rotate. The result is a three dimensional series of waves floating in space. The physical action of the rope cutting through the air creates the whistling sound heard by the observers. Not only does the sound sculpture visualize a harmonic series, but it also reacts and changes shape based on the presence of people around it (Palacios

2007). Another example with a more tangible aspect is a rotary sequencer inspired by the monomer (figure 3). The custom-made rotary sequencer stores a melody on a 10” acrylic disk embedded with small magnets arranged on a circular grid. Concentric circles are centered around a spindle and rotate over a line of magnetic sensors. The device is an attempt to replicate while improving the function of a traditional mechanical music box (Monomatic 2010).

Figure 1. The Round Wave by Reuben Margolin

Figure 2. Waves by Daniel Palacios

Figure 3. Modular Music Box by Lewis Sykes and Nick Rothwell

Mesmerized by a constant rolling ball entrenched within a metal rim in a hardware store he walked past every day on his way to work, Trimpin, a fifteen year old at the time, questioned how a ball can continuously roll around the rim if perpetual motion is non-existent. After further investigation, he was able to determine the display was pneumatically powered. Small holes blew out a puff of air when the ball passed over it, just enough to continue to momentum to drive it in circles. This fascination stuck with Trimpin, as he would later describe that he “was mesmerized by the sound and sight of this perfectly round ball constantly rolling in Zen-like repetition, and from that moment on I wanted to do something with spheres. I didn’t want to use anything fake- there had to be another way to keep a sphere in motion, probably using gravity.” (Focke 2011) Der Ring’s appearance is based on the display from the hardware store, although it’s functionality is completely different. The sculpture functions like a puppet, its’ angle is tilted around in a circle, causing the balls to orbit due to gravity. Each ring is attached to cable that runs through a set of pulleys and then into a sophisticated gearbox (figure 4).

Figure 4. Der Ring by Trimpin

These mechatronic systems collectively share sinusoidal and sonic properties. Each utilize repetitive features found in our environment, and transcribe their dynamics into a kinetic representation of their physical behavior.

## Post-Wave: Mechatronic Sculpture

Figure 5. Post-Wave

Post-Wave is the first in a series of sinusoidal-inspired sound projects. Post-Wave is highly based on Reuben Margolin’s Redwood Wave. It served as an introductory study of mechanics and electronic design, in addition to being an assessment of carpentry skills (figure 5).

### Design

The mechanical design is composed of two metal rods intersecting a set of 30 6” circles, each offset by one another. Then a set of 1” x 30” strips treated with dado cuts beneath sit on a pair of circles. To prevent the wooden strips from slipping off the circles, a rectangular strip of wood is mounted in the middle of the 1” x 30” dado strips, which is then secured between two wood strips perpendicular to its position.

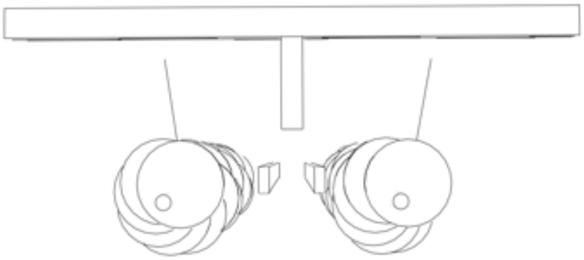

Figure 6. Profile Sketch

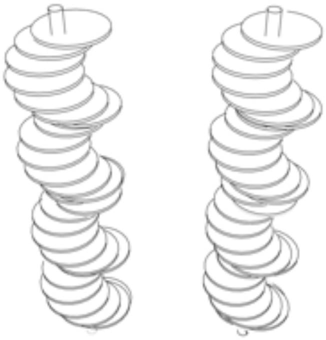

Figure 7. Sketch of Cams

## Implementation

The two rods are then coupled to two separate DC gearhead motors. The two motors are powered and controlled with an Arduino Uno using Polulu's Dual VNH5019 Motor Driver Shield. A Microsoft Kinect is used via Processing to detect blob depth and position using the SimpleOpenNI library. Depth and X-position data is sent via serial to Arduino. Thus, depth controls the speed of the motors, and X-position determines which motor is being controlled.

Figure 8. Interaction with Sculpture

The result is a surprisingly well executed mechanical acoustic emulation of the sound produced by waves on a body of water. The physical action of the wood strips sliding back and forth on top of the wood circles makes for a soothing hypnotic audible result. The wave moves slowly when a user is not present, yet as soon as a user place his hand on top of the wave, a reaction is immediately identified, engaging the observer to discover his or her ability to control the sculpture (figure 8).

## Sinu: Musical Interface

Sinu is an attempt at producing a rendition of the traditional music box. This particular rotary sequencer uses a set of eight photocells suspended above a set of eight LEDs. A 11" acrylic disk is divided into 16 slices, each containing 8 holes for the LED to shine through as it passes the "playhead" (figure 9). The circular disk is place onto a direct-driven turntable motor mounted on the main enclosure. A set of nine LED push buttons, 3 rotary potentiometers, 1 linear potentiometer, 1 LED power indicator, and two switches are also mounted on the enclosure.

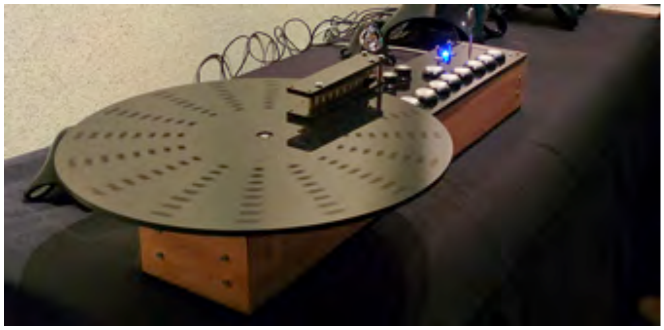

Figure 9. Sinu

## Functionality

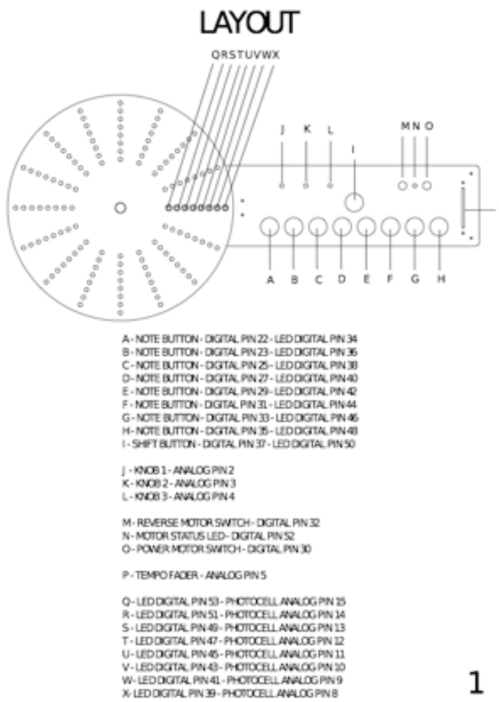


Figure 10. Arduino Pin Assignments

The functionality of the buttons A-H are to act as steps of a conventional sequencer. Button I functions as a shift button that enables the user to switch between sequences. When first powered, a sequence can be entered by pushing buttons A-H. Once this has been done, LED Q will turn on and the position marker of the sequence will flash at position 1 (LED in button A.) A second sequence can be entered by holding down button I and selecting any button B-H. When a sequence is entered on any pattern I+A-H, the corresponding LED Q-X will turn on. Each pattern I+A-H corresponds to a note in the scale specified in the program. Basically, as LED Q-X passes through the playhead containing photocell Q-X, the position marker of the sequencer iterates through the sequence. Switch O turns on the motor, and switch M reverses its direction. Linear pot P controls speed of the motor. Rotary pots J-L can be midi mapped to control any parameter desired.

### Implementation

Sinu is controlled using an Arduino Mega with an Arduino Motor Shield Rev3. The design consists of four custom made PCBs: a photocell board, LED board, button board, and a custom Arduino shield to direct all connections to the Arduino pins. Voltage readings from the photocells and buttons are directed to the main Arduino shield with 10 conductor ribbon cable. The LEDs that are located beneath the photocells are controlled through the digital output pins of the Arduino. The button PCB houses all the buttons, its' LEDs, switches and pots found on the face of the enclosure. All of the connections are then routed, via ribbon cables, to the main Arduino shield. An Arduino sketch determines how the sequencer functions. When a trigger is received from a photocell, Arduino sends a midi note number to ChucK. ChucK then sends out a midi note message through an IAC Midi Bus to be received in Ableton to control any MIDI instrument. The final result is a circular sequencer with the ability to perform alternative forms of musical expression.

## Cymbalic: Hybrid Interface-Sculpture

Figure 14. Cymbalic

Cymbalic is the third mechatronic sound sculpture in this series of sinusoid inspired works. The realization for this particular mechanical sound study came from the novelty science toy, Euler's Disk. The disk is used to demonstrate the dynamic system of a spinning disk on a flat surface. The smoothed disk is made up of thick and heavy chrome-plated steel. The mirrored base by which is spins on has a slight concave, keeping the spinning disk centered on the plate. Mathematician Leonard Euler was the first to study this phenomenon in the 18th century. (Moffatt 2000) The sculpture is a naive approach in recreating the motion taken by the Euler's disk.

## Design

At the core of its design, four cams are used to manipulate a larger flat 16” disk (figure 15). Two 1/2” metal rods, coupled to DC gearhead motors, each intersect a pair of cams. Each pair consists of two different sizes to make up for the offset in height of the intersecting rods. On the large disk suspended above, four equally spaced tuning pegs each hold a sitar string which then travels through a pulley, down to a cymbal. The sitar strings are fed through equally spaced holes in a cymbal which is mounted to the bottom metal frame, and then tied firmly. The intention is to have the cymbal take the motion of the Euler disk.

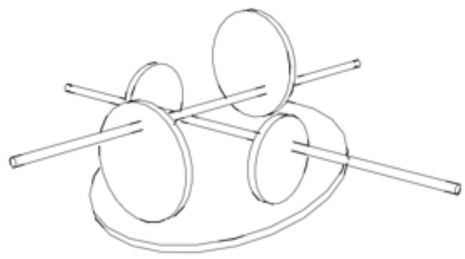

Figure 15. Cam Mechanism Sketch

The distance from the center of the circle at which the rod intersects determines the amplitude of the linear motion converted from by each cam. Each rod intersects the cam 7/8” from the center in order to prevent the larger disk from hitting the outer metal frame.

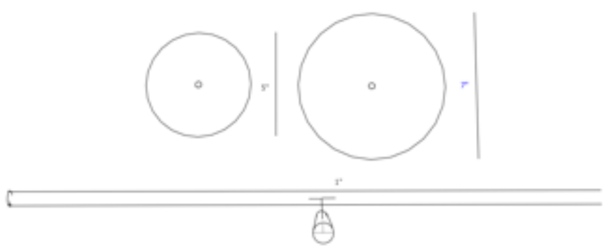

Figure 16. Cam Dimensions
*circle2 = circle1 + 2offset*
*7 = 5 + 2(1)*

# Implementation

In order to create an element of human interaction, the increasing frequency that the Euler disk produces when spun is programmed to control the speed of the motors. An Arduino Uno paired with a Polulu Dual VNH5019 Motor Driver Shield is used to operate the sculpture. To detect the frequency of the disk, Adafruit’s Electret Microphone Amplifier MAX4466 is placed under the concave mirrored platform. Since the Arduino analog read rate samples at about a quarter of audio rate, an alternative approach was taken in order achieve more reliable results. A threshold on the amplitude is set to initiate the start of the motors. The speed iterates faster as long as the amplitude remains above the threshold. As soon as the amplitude falls under the threshold, the motors come to a sudden stop. The electric microphone proves to be very sensitive, enough to create a sudden movement when the disk is touched. This way, the user immediately experiences the interaction.

## Conclusion

This collection of projects were completed at California Institute for the Arts. Each being a cumulation of the skills learned during the successive years. Repetitive motion can clearly be seen as the driving force of inspiration throughout each system. Circles are heavily used throughout each system as a means to convert or translate motion. The series of offset circles in Post-wave modulate the angle at which its corresponding wooden strip is positioned. When the succession of circles' phase is altered from one another, a wave motion is translated. In Sinu, the circle is the object that defines the recurring feature a sequencer functions by. A sequencer has the tendency to loop at a certain point in its array of values. The circle is the ideal visceral representation of that quality. Cymbalic is an impulsive reaction to a fascinating phenomenon. Another set of circles with an offset in attempt to emulate a naturally occurring motion. Circles here are a means of translating rotary motion to a series of offset linear motions to recreate a wobble motion. Each technique varies, yet with a similar intention to utilize a fundamental sequence such as the sine wave, and develop a unique interpretations of objects which inhibit a relatable kinetic.

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# Designing Interactive Audiovisual Systems for Improvising Ensembles

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**Abstract.** Since 2009, I have been working on real-time audiovisual systems, used in many performances with improvising musicians. Real-time audio from a performance is analysed; the audio descriptors (along with data from gestural controllers) influence abstract animations that are based on generative systems and physics-based simulations. The musicians are in turn influenced by the visuals, essentially in a feedback loop. I will discuss technical and aesthetic design considerations for such systems and their integration into the practices of improvising ensembles, and share some experiences from musicians and audience members.

**Keywords:** Interaction design, improvisation, audio descriptors, generative systems, physics-based simulations

## Introduction

For years I have been involved in free improvisation with both acoustic instruments and live electronics. As a performer, software designer and listener, I have been very interested in the associations made by myself (and others) between sonic events/gestures and visual/physical phenomena. I am attracted to visual systems that exhibit the oppositions and tensions that I enjoy in improvised music.

Since 2009, I have been working on real-time audiovisual systems for non-idiomatic free improvisation. I have used these systems in over 50 performances with improvising musicians, including Chris Burns, John Butcher, James Fei, Gino Robair, Birgit Ulher, and many others; many such events were evening-long concerts involving up to six different systems/pieces. Performances have been hosted at a variety of venues, such as ZKM (Karlsruhe), STEIM (Amsterdam), CNMAT (Berkeley), the Songlines series at Mills College, the San Francisco Electronic Music Festival, and the NIME and SMC conferences.

Figure 1 shows a typical block diagram of my systems. In performance, two or more channels of audio enter the system from microphones or the venue's sound system. The audio is analyzed by a Max/MSP patch that extracts estimates of loudness and tempo, and some timbral features. Audio descriptors are sent via OpenSoundControl messages to an animation environment, usually implemented in Processing or OpenFrameworks. These interactive animations are influenced by the real-time audio descriptors from the musicians' performance, and by physical gestures from controllers.

Video generated by the animation environments is usually projected behind or above the musicians. Figure 2 shows a typical stage setup, from a set by EKG (Kyle Bruckmann and Ernst Karel) at the 2013 San Francisco Electronic Music Festival, with video generated by my system *Tes*. The animations are visible to the musicians and influence their performance, thus forming a feedback loop. Each system has both components that I control, and autonomous components with their own behavioural rules. Performing with one of my systems involves ongoing negotiation between the controllable components and the autonomous modules.

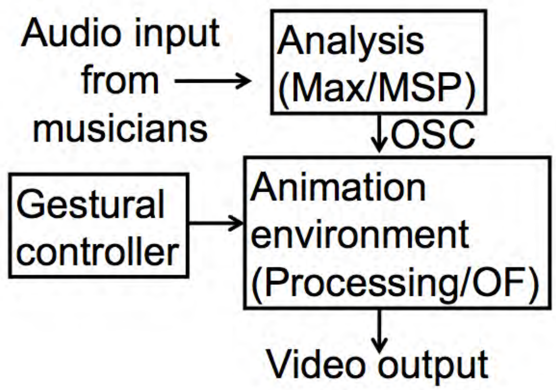


Figure 1. Block Diagram of Interactive Audiovisual Performance System

## Design Goals and Practical Considerations

These are the initial goals for my systems:

- Each system will be primarily used in the context of abstract free improvisation.
- There will be minimal use of looping/pre-sequenced materials; each system will behave like a component in an improvising ensemble.
- Each system will be a "playable" visual instrument; system behaviour can be influenced by physical controllers.
- Each system has autonomous components that guides its behaviour; this behaviour may be influenced by real-time audio.
- Each system should evoke the tactile, nuanced and timbrally rich gestures common in free improvisation.
- There should be cross-references between audio and visual events. However, overly obvious mappings should be avoided.


Figure 2. Performance by EKG with video by Bill Hsu, 2013 San Francisco Electronic Music Festival.
Photo: PeterBKaars.com

Non-idiomatic free improvisation is a social music-making practice, producing open sonic conversations that tend not to be easily interpreted or analysed in non-musical terms. Gaver et al. (2003) discuss the role of ambiguity in interactive design; some of their comments are useful for understanding the practice and experience of free improvisation, and how one might approach audiovisual design for concerts of improvised music. For example, the authors could easily have been referring to sonic gestures in improvisation, which "may give rise to multiple interpretations depending on their precision, consistency, and accuracy on the one hand, and the identity, motivations, and expectations of an interpreter on the other." Another comment would find resonance with many fans of improvised music: "… the work of making an ambiguous situation comprehensible belongs to the person, and this can be both inherently pleasurable and lead to a deep conceptual appropriation of the artefact."

To preserve the essential openness and ambiguity of a free improvisation, I feel that the visuals should not over-determine the narrative of the performance. Hence, most of my work utilizes generative abstract visual components that exhibit a range of behaviours. My preference is for unstable, evolving forms that facilitate setting up tensions between abstract and referential elements, for a richer visual experience. For example, a particle swarm or smoke simulation may move in complex, pseudo-random configurations, or self-organize into recognizable structures. These transitions evoke Friedrich Hayek's concept of "sensory order", wherein observers organize raw chaotic stimuli into perceptually recognizable objects (Hayek 1999).

Each of my systems is primarily based on a single complex process, usually a generative system or a physics-based simulation. The movement and evolution of the visual components in each system follow the rules of the underlying process. Audio descriptors from the real-time performance audio affect mostly high-level parameters of the base process; they do not map directly to low level details of the visual components. From my experiments and observations, allowing the underlying process to determine the low level details of the visuals results in more "organic" and aesthetically consistent movements and transitions.

Each system receives several input streams, representing events occurring at (often) widely different rates. For example, an audio descriptor representing a well-defined percussive onset may occur extremely infrequently, while one that represents loudness or a continuous timbral characteristic may be presented at regular intervals of (say) 100-200 milliseconds. In addition, events in the interactive animation subsystem also have a range of temporal distributions. A rapid onset visual event, such as the sudden "birth" of a small cluster of tiny objects that expands into visibility, may take a few hundred milliseconds from the initial trigger to its final, relatively stable state. On the other hand, a broad sweeping gesture, representing (for example) a tidal flow in a fluid system, may take several seconds to complete, with its effects being visible long after the gesture initiation. Hence, care must be taken with each system to manage each event type based on typical rates of occurrence. For example, it may be intuitive for a percussive audio onset event to trigger the formation of a small object cluster in the animation. However, if the live performer is a busy percussionist, the visual environment may quickly become cluttered and overwhelmed with objects. A certain amount of thresholding is always necessary for managing the rates of automatic events; the system operator should also have the option to adjust the responsiveness of the animation system to selected event types.

There is a core of experienced musical collaborators who have worked with my systems regularly. When working with regulars, it is easy for us to quickly converge on a "set list" of pieces for an evening's concert. A brief minute or so before the performance with each piece is usually sufficient for musicians to re-familiarize themselves with the system. I also collaborate with musicians who have never worked with audiovisual performance software, with minimal time for rehearsals before an evening's concert. Hence, interaction modalities have to be intuitive and easy to explain; with only a few minutes' preparation, a musician should understand a system's behaviour sufficiently to explore and improvise with it, on top of the cognitive demands of negotiating an improvisation.

Collaborating musicians have taken several approaches to working with my audiovisual systems. A few have chosen not to look at the video at all; they felt that they wanted to focus on sound. Some have mentioned the temptation to try to "push" the animations into specific outcomes, via their sonic gestures; this temptation may obviously distract from music-making. Most of my fellow performers have preferred some conversations about the chosen systems before a performance, and actively engage with the video when playing.

## Related Work

Audiovisual performance is widespread in the club music community. The VJ Labor website (http://vjlabor.blogspot.com), for example, showcases such work. The music is often beat/loop-based, with relatively stable tempos and event rates, and little variation in space or use of silence. The visuals often incorporate loops and simple cycles, and work with pre-recorded footage that may be manipulated in real-time.

Interactive video is also a component in many compositions. For example, violinist Barbara Lueneburg's DVD *Weapon of Choice* (http://www.ahornfelder.de/releases/weapon_of_choice/index.php) includes a sampling of composed pieces with live or static video, by Alexander Schubert, Yannis Kyriakides, Dai Fujikura, and others. Some of the pieces incorporate live audio or sensor input.

In my experience, interactive visuals tend to be significantly less common in free improvisation. The strategies that work well in the VJ and composer communities, in my opinion, often do not map well to non-idiomatic free improvisation, with event densities that may vary widely in short time windows, use of space and silence, and overall conversations that develop from moment to moment, with little or no pre-arranged compositional structure. The technologies and internal details of these systems also tend to be poorly documented.

A major early audiovisual performance project involving improvisers is Levin and Lieberman's *Messa di Voce* (Levin and Lieberman, 2004). The project appears to be primarily designed around Joan La Barbara and Jaap Blonk, two vocalists who are renowned for their exploration of extended vocal techniques in performance. Real-time camera and audio input from the performers drive an array of generative processes, including particle systems and fluids. *Messa* comprises twelve short, theatrically effective sections over a total of 30-40 minutes; my own work tends toward longer sections of 8-10 minutes each, with each section based on a distinct generative process, for more extended "conversations". In *Messa*, La Barbara and Blonk are always the centers of visual attention on stage; camera-based tracking of their bodies is a significant component of the live interactions. With my systems, my collaborators tend to focus on working with abstract sound; while the musicians are visible on stage, their movements are not tracked, and the visual attention of the audience tends to be primarily on the live video. From the online documentation, it is not clear if *Messa di Voce* has been performed with improvisers other than La Barbara and Blonk, or whether it has been revived since the 2004/5 performances and installations.

More recent projects include the performance duo klipp av, focusing on live audiovisual cutup/splicing (Collins and Olofsson, 2006); trombonist Andy Strain's audiovisual pieces for school children (http://andystrain.com); Billy Roisz's live video work which incorporates relatively minimalist transformations of still images, found footage and analog artifacts (http://billyroisz.klingt.org/video-works); and William Thibault (http://www.vjlove.com), who often manipulates dense data network visualizations in performance with free improvisers.

## Example Systems

To date, I have built over a dozen distinct audiovisual performance systems, some with numerous variants. Most of these systems have participated in numerous performances with improvising musicians. The first was the particle system *Interstices*, introduced in (Hsu 2009). I will focus mostly on four of the later systems: *Flow Forms*, *Flue*, *Fluke*, and *Leishmania*.

*Flow Forms* is based on the Gray-Scott diffusion-reaction algorithm (Pearson 1993), which has been widely used in the generative art community. Two simulated "chemicals" interact and diffuse in a 2D grid, according to simple equations. Parameters that control the concentrations of the simulated chemicals are modified by and track activity from the real-time audio. Sonically active sections result in more robust visuals; long periods of silence will result fragmentation of the patterns, eventually to leave a dark screen. In addition, hidden masks representing shapes or images can be introduced to guide the formation of visible patterns. Figure 3 shows an example of a simulated chemical flowing into a pre-loaded image mask.

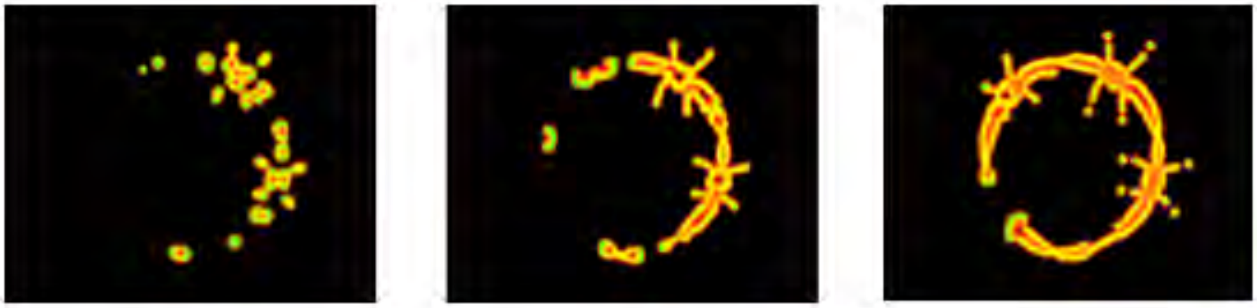

Figure 3. Gray-Scott Diffusion Reaction Process with Transition into Hidden Image Mask

*Flue* is a smoke simulation, based on a port of Jos Stam's stable fluids code (Stam 1999). Two smoke sources move through space, each activated and pushed by a real-time audio stream. Again, activity levels in the visual simulation tracks roughly activity levels in the audio, but there are no simple mappings of low level behaviors. Hidden masks can be introduced to constrain the movement of the smoke. Figure 4 shows simulated smoke coalescing into the shape of a skull, then dispersing.

*Fluke* is based on Stephan Rafler's extension of Conway's Game of Life (Rafler 2011). The algorithm is very compute-intensive; I adapted Tim Hutton's OpenCL implementation that runs on the GPU. Real-time audio activity triggers the formation of structures in a 2D space; algorithm parameters are constantly modulated for the visual activity level to track activity levels in the performance audio.

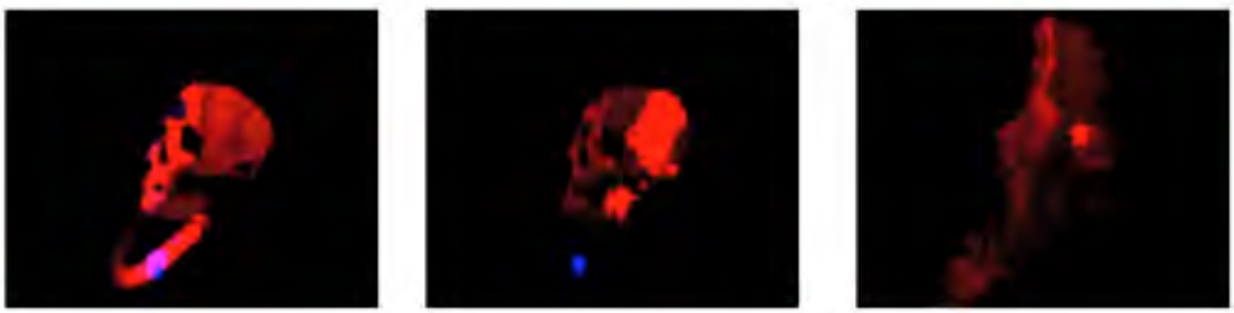

Figure 4. Smoke Simulation with Smoke Sources filling Hidden Skull Mask

*Leishmania* is an interactive animation environment that visually resembles colonies of single-cell organisms in a fluid substrate. Each cell-like component has hidden connections to and relationships with other components in the environment. The colonies evolve and "swim" through the substrate, based on a combination of colonial structure and inter-relationships, and flows in the fluid substrate that might be initiated by gestural input. *Leishmania* has been used extensively in performance with Christopher Burns' *Xenoglossia* interactive music generation system. These two systems communicate with one another in a variety of ways. The animation is influenced by the real-time analysis of audio from Xenoglossia. In addition, the two systems exchange OSC network messages, informing each other of events that are difficult to extract from automatic analysis, such as pending section changes, structured repetitions with variations, and the configuration of animation components.

## Reactions

So far, I have mostly focused on building complex audiovisual systems for live performances “in the wild”; little time has been spent setting up laboratory-like situations for more formal evaluations. Evaluation procedures such as those described in (Hsu and Sosnick, 2009), targeting interactive music systems from the points of view of both the performing musicians and audience members, might be adapted for interactive audiovisual systems; the presence of complex visual components, with disparate behavioural types, significantly complicate such evaluations. Instead, we will summarize some generally positive feedback on performances, from musicians and audience members; they appear to support some of our original design goals.

Frequent Oakland-based collaborator Gino Robair (percussion/electronics): “What I find fascinating is how the interactive pieces challenge the musicians who play them. One immediately wants to figure out how to "game" the system, and control it with what we are playing. Yet the algorithms confound that, forcing the musicians to treat the computer system as a real duet partner who is "listening" but not necessarily responding in a predictable way (Robair, personal communication).”

Another frequent collaborator, Hamburg-based Birgit Ulher (trumpet/electronics): “What I especially like about [Bill’s animations] is the strong connection to the music without being too obvious or illustrative. Working with Bill's animations opens up a lot of new levels of communication, the audio input of the musicians are transformed into visuals which can be seen on a screen while playing, so it is a kind of seesaw of influences. The visuals influence the players and vice versa, also the communication between the musicians has an additional level since their interaction is seen on the screen as well (Ulher, personal communication).”

London-based John Butcher (saxophones), who with Robair and myself comprise the audiovisual trio *Phospheme*: “The systems' responses may be subtle or striking, but always seem organic. There's a creative, two-way encounter where the musician is only partly driving the process and the inspiration they take from the evolving visual reactions opens space for some of the more unpredictable consequences one hopes for with human interactions. From a structural point of view it's interesting that this can happen within the consistent "flavour" of a particular visual idea, giving each improvisation a valuable coherence (Butcher, personal communication).”

Robair, Ulher and Butcher have all worked with a range of my audiovisual pieces. Michigan-based Chris Burns (electronics) has mostly worked with *Leishmania*, on a number of occasions; he shares his experiences: “[Leishmania] offers a rich variety of visual behaviors within a focussed, consistent, admirably stark and unapologetically digital aesthetic. That variety makes it a suitable accompaniment for a wide range of musical choices; it also makes the system unpredictable, with musical stimuli leading to a number of possible visual reactions. Leishmania provides stimulus as well as response. The animations are evocative without being commanding - the visuals inspire formal and gestural ideas in my performance, but they never feel constraining, limiting, or demanding of a particular type of musical response. In short, Leishmania feels like a very sophisticated, capable, and provocative duo partner - which has everything to do with duo partner who constructed it (Burns, personal communication).”

Reviewer Stephen Smoliar wrote about a performance in 2014 with James Fei, Gino Robair, and Ofer Bymel: “… It seemed clear that [Hsu] was “playing” his interactive animation software following the same logic and rhetoric of free improvisation… What was most striking… was how Hsu could use visual characteristics such as flow and pulse to achieve animations that probably would have been just as musical had they been displayed in silence.” (Smoliar 2014)

## Summary

I have been lucky to work with many inspiring improvising musicians on audiovisual projects. Their creative and fascinating approaches to performance situations, from managing textural and gestural materials, to working with space and pulse in the context of non-referential abstract materials, have informed my audiovisual system designs at many different levels. I’d like to thank my collaborators who have been generous with their time and feedback. I have shared some notes and experiences here, but highly encourage viewing one of the performances on video or (especially) live; free improvisation, with or without visuals, is very much a social music-making practice that is best experienced in live performances. A selection of video documentation is available online:

Set with James Fei (reeds) and Gino Robair (percussion) at Outsound Summit Festival 2014, San Francisco: https://www.youtube.com/watch?v=NLFj26zfqsI

Performance with Chris Burns (electronics) of *Xenoglossia/Leishmania* in Computer Music Journal online anthology (requires login): http://www.mitpressjournals.org/doi/abs/10.1162/COMJ_x_00276#.VJtz6LiALw

Short demo of *Fluke* (music by Birgit Ulher and Gino Robair): https://vimeo.com/106125702

Short demo of *Flow Forms* (music by Chris Burns): https://vimeo.com/78739548

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# Hacking the Body 2.0: Flutter/Stutter

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**Abstract.** *Flutter/Stutter* is an improvisational dance piece, part of the *Hacking the Body 2.0* project, that uses networked soft circuit sensors to trigger sound and haptic actuators in the form of a small motor that tickles the performers. Dancers embody the flutter of the motor and respond with their own movement that reflects this feeling. This research explores using the concept of hacking data to repurpose and re-imagine biofeedback from the body. It investigates understandings of states of the body and hacking them to make new artworks such as performance and costumes. Through performance we aim to communicate to the public new ways to engage with their bodies and technology with intimacy and sensation embedded in wearables.

**Keywords:** Wearable tech and e-textiles, Performance, Sustainable garments, Ethical data collection.

## Introduction

The *Hacking the Body 2.0* project explores using the concept of hacking data to repurpose and re-imagine biofeedback from the body. It investigates understandings of states of the body and hacking them to make new artworks such as performance and costumes. Through performance we aim to communicate to the public new ways to engage with their bodies and technology with intimacy and sensation embedded in wearables.

*Flutter/Stutter* is one piece within the larger Hacking the Body 2.0 research project. As such, dancers embody the flutter of the motor and respond with their own movement that reflects this feeling. The sensors and actuators, along with the garments they are embedded within, are bespoke designs by Becky Stewart and Tara Baoth Mooney that interact, influence and interrupt the dance and hack the body.

## Context

The current technology fervour over wearable technology that collects users' intimate body data, under the pretense of medical or fitness monitoring, highlights that it is time that critical questions were raised. The ethics of corporate ownership of body data for consumerist agendas is rarely discussed beyond the fine print on these devices. More awareness and education on these issues, would potentially allow more access, ownership, and creativity in the use of one's own body data, and ways to express personal identity through this data.

This project questions how body data may be able to demonstrate who we are, through movement, through our physiology. How does access to personal data enable the performer to show their identity, rather than what is subscribed by the corporation making the sensing device? How can we explore these issues while enabling people access to their own data, especially in performance contexts, in order to interact with it?

The new iteration of the collaborative project *Hacking the Body 2.0* brings performers together to attempt to address the ethical issues around identity and data ownership when using wearable tech in performance. The project develops methods to use and hack commercial wearable devices, as well as making handmade e-textiles sensing devices for performance. As such, we aim to engage performers to access their own physiological data for personal use, but also to create unique and interactive performances.

## Performance Investigations

The latest iteration of the collaborative project *Hacking the Body 2.0*, by media artist Camille Baker and media artist/choreographer Kate Sicchio, attempted to address the ethical issues around identity and data ownership when performers use wearable tech in performance. The project has used various methods to use and hack commercial wearable devices, as well as making handmade e-textiles sensing devices for performance as was done for *Flutter/Stutter.* As such, we aim to engage performers to access their own data for personal use, but also to create unique and interactive performances. This collaboration has been evolving since 2011, and the approach is influenced by previous projects in a similar vein, such as that of Thecla Schiphorst and Susan Kozel's *whisper(s)* project, as well as Baker's and Sicchio's individual PhD research projects, not to mention the haptic, biofeedback and wearable music performance works, such as those such as Loke, Donnarumma and Tanaka, and many others now working in this field. Yet this piece and its partner performance piece *Feel Me* (also part of *Hacking the Body 2.0,* but not discussed here), stakes out a singular new terrain in its exploration of ways to address ethical issues of data collection, use of the technologies to represent personal identities of dancers, develop non-verbal communication interaction methods and incorporating a live coding of the dancers by the choreographer into the work.

The goal is to: enable dancers to interact or respond to worn sensors and actuators; to instigate new movement 'dialogue' or interaction between performers; and to explore their identities. By using the technologies developed for gathering personal data, but circumventing corporate data collection, we facilitate direct communication between each body/dancer to create a conversation. At the same time, the choreographer can also intervene directly with and participate in the dialogue between dancers' bodies and their movement responses, by triggering the chimes directly for the computer controlling the interaction. In this way, the performers reclaim the data sensing and collection by using the technology as another tool to them help devise movement and co-create or choreograph performance works. This work puts into new light, the ethical issues of corporate ownership by putting the ownership back into the hands of the user. This in turn may be considered a critical act of making and confrontation of the issues of surveillance and data control.

In February 2016, we were able to take the project to the performance stage, with performances in London and Sheffield. *Flutter/Stutter* was performed once at each location in front of an audience. The choreographic side of the piece focuses on two technological aspects. These can be used as methods for both developing movement as well as a structure for improvisation. Firstly, the dancers were responding to actuators on their costumes and to each other through movement. By moving in reaction to these impulses on their body, the rhythm, timings and dynamics were affected in a feedback loop. A more subtle approach to movement was taken by the dancers, to reflect the sensation of being tickled on the neck by a ribbon on a motor triggered by the other dancer. The relationship between data and subsequent reactive movements by the performers is that touch on the shoulder pieces and the subsequent actuation responses are meant to initiate movement by the dancer receiving the vibration or tickle, as the response in the "call and response" non-verbal dialogue. Each dancer also has to take into consideration how to initiate the trigger of the actuation on the other dancer, as part of the "conversation" between them.

The second way the technology is repurposed into the choreography, was through the structure of the interaction design. The system was developed to adapt and provide several opportunities for user interactions by the dancers. The score for the dance improvisation was then structured around time and a variety of these dancer interactions. Each one led to a distinct moment in the piece and allowed the overall composition to build over time. The audience was able to understand the interactions not only through the expressivity by the dancers and the way in which they had a 'call and response' behaviour when activating the devices, but also by the sounds the garments also triggered, to create a improvised soundtrack of variously pitched reverberant chimes. The operating modes of the sensors and actuator may not be clearly discerned by the audience through these pitched chimes, as the intention of the piece is not to make improvised music, but to allow the audience to understand that the interaction and the actuation is live and created by the haptics. We chose to restrict the system to use a single sensor and actuator at this point in the research due to funding and time limitations, but intend to introduce more sensor/actuators as the project progresses, in order to  increase the performance potential in future iterations.

## Wearable Performance System Implementation

The sensors and actuators were built into garments worn on one shoulder of each dancer and incorporated into a complete costume worn during performance. The network connecting the sensors and actuators utilised the infrastructure tools, emerging as the preferred protocol for 'Internet of Things' applications, while the visual design of the garments actively distanced itself from a technological aesthetic.

Figure 1. Images from performance of the piece in February 2016 in London, UK

## Garment Design

The garments, which have been created for this research project, explore the idea of making and designing for interaction design through hacking. All garments can act as an interface between individuals and their immediate environment. This applies to both garments for performance and garments for everyday wear.

Like the acquisition of clothing for one off events, so too garments which are created for a specific performance or event can be rendered obsolete after the performance has taken place.

This collaboration prompted questions around the continued value of performative garments in a world which increasingly devalues objects. The challenges for the garment designer in this project were to create a modular garment which might contain within them the potential to become something else after the performances have taken place. A secondary challenge was to work with the interaction designer, Rebecca Stewart, to create a collection of garments which did not visually betray the technology embedded within them.

For the *Flutter/ Stutter* piece, pre-existing cotton t-shirts were used which were already owned by the designer, along with some cast off long-sleeved cotton t-shirts found in thrift stores, and were considered as raw material for a new manifestation of the material. The product development took place over a 4-month period, where the designer intermittently worked with the interaction designer and then each withdrew to work alone. The pieces needed to be flexible enough to make small changes if necessary, and also needed to have a solid structure. Thus, the modular elements were situated above the structure. These elements included the fabric sensor and embellishments, which acted as the ties to secure the garments on to the body.

As both artist and designer the aim was, through a deep engagement with the materials, to create something, through hacking, which was visually organic rather than technological, something which moved with the movement of those wearing them, and finally something which was inherently  modular and re-purposable, and which could potentially manifest as something else in the future. It was through the destruction of the original garments that a reconstruction of new garments took place.

## Electronics Design

The wearable computing system consists of a collection of capacitive touch sensors worn on one shoulder of each dancer and a motor with a ribbon attached placed near the neck. The sensors and actuator on each dancer are controlled by a wifi-enabled microcontroller[1]. Each of the capacitive touch sensor electrodes are a single conductive thread sewn to the underside of a fabric pleat as seen in Figure 2. The electrodes are connected to a capacitive sensing chip[2] which handles the calibration and measurement of the signals.

Figure 2. Image from a rehearsal in Sheffield, UK of the dancers interacting with the textile touch sensors embedded in the pink pleated fabric.

The actuator is a small motor with an integrated planetary gearbox. The motor's circuit is constructed from conductive fabric mounted on a patch of black leather seen in Figure 3. A fabric ribbon is connected to the motor so that it rotates and brushes against the wearer's neck, causing a tickling sensation. For this reason, the actuator is referred to as a 'tickle motor'.

The microcontrollers connected to the sensors and actuators publish messages to the network whenever a sensor is activated by a touch - by either the wearer or the other dancer. The microcontrollers also subscribe to a feed to be notified when their motor should be turned on to rotate the ribbon. This system of passing around messages is implemented using the Message Queueing Telemetry Transport (MQTT) protocol. A program called a broker[3] is run on a server connected to the same local wifi network as the microcontrollers. A separate program that acts as another client of the broker, listens to the incoming sensor messages and redirects them to the corresponding actuator feed. This program also acts as a portal for the choreographer to intercept these messages and directly send her own messages to the actuators.

Sounds of reverberant chimes with various pitches are triggered when messages are received. The sound of the chimes is the entirety of the audio accompanying the performance. The sounds triggered are mapped to corresponding lines of conductive stitching in the shoulder pleats, giving the dancers some control over the sounds made and therefore another form of physical input in the interaction to enable the call and response dimension.

[1] ESP8266 HUZZAH https://www.adafruit.com/products/2471
[2] MPR121 Breakout Board https://www.sparkfun.com/products/9695
[3] Mosquitto http://mosquitto.org/

Figure 3. Leather-mounted textile circuit of the tickle motor worn by each dancer to provide haptic feedback

This arrangement of sensors reporting to a broker and actuators responding to the same broker using MQTT is an increasingly standard architecture for networked devices commonly referred to as the 'Internet of Things' (Al-Fuqaha et at 2015). However, instead of monitoring air quality across a city or the contents of a refrigerator, our network is monitoring the actions of dancers within a performance and providing an invisibly-connected network with physically-realised endpoints.

## Discussion

Researchers in recent years have been exploring wearable technologies from the mobile health dimension, but as Susan Elizabeth Ryan has noted in her recent book *Garments of Paradise* (2014:8), few are exploring the full potential of wearable technology in performance, let alone the other related issues of identity and body data ownership in performance. She writes:

> *Wearables in the context of performance present opportunities for exploring our relationships with our bodies and how we move them… [or how] communications interfaces, and other soft and sensory technologies allow us to experience or transcend our bodies, and how the concept of theatrical performance can be expanded in virtual space (2014:8)*

This collaboration addresses the issues, challenges and problems of developing methods of making and using handmade wearable sensing and actuation devices to access physiological data and create unique interactive performances. As such, we see this as way to draw in new communities, especially within performance, into the development, evolution of, and conversation around wearable technology and etextiles production, the sustainable fashion issues, data collection ethics, and in particular how these skin-based technologies might enhance performance creation, while making them playful and challenging.

Future practical explorations include: organising more performances in the UK and the US, continuing to develop different approaches to using wearable tech and etextiles in performance contexts, as well as making more robust custom wearable tech garments, embedded with both specialist sensors and actuators, that enable the performers to intervene with each other's expression using their body data. The ultimate goal is that performers engage with their own and other's body code to create new forms of 'live data performance', where the performer is initiating the interaction using the wearable devices to aid their interaction.

The overall long term direction of this project is to refine methods of working with performers, to enable them to control how they use the physiological data from their body or the data from another performer to interact and move. This will be developed through further iterations of the devices and garments worn, to enable them to interact and respond to each other and create a new movement 'dialogue'. In this way, the performers reclaim the data collection by using the technology as another tool to them help devise movement and co-create or choreograph performance works, and eventually with choreographer's role changing more to that of performance experience designer or artistic director, while the audience's role will change to part performer / part audience/ part choreographer. This circumvents and hopes to shine new light on the ethical issues of wearable technologies by putting the control back into the hands of the users, in this case, the performers and artistic director**.** This in turn is may be considered a critical act of making and confrontation of the issues of surveillance and data control.

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# Interfacing the txalaparta: digitising a traditional instrument with the help of its players

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**Abstract.** This paper describes the process of creating software for generative music that incorporates key elements of the Basque txalaparta instrument. This is part of an ongoing research project which studies this ancient musical tradition. Traditionally, the txalaparta is played as improvisation by at least two players and in this research project we have developed a system that allows a player and a computer to play together. This paper describes the user-centered approach in the software design explaining how this influenced the solutions and issues addressed. The research was wide reaching in its user studies, and it provided us with a deeper insight on the txalaparta play and the -implicit or unexpressed- rules involved in the interaction between players.

**Keywords:** txalaparta, generative, interface, interaction, participatory design.

## Introduction

The txalaparta is a percussion tradition original from the rural areas of the Basque Country. The instrument belongs to the category of struck idiophones and consists of a variable number of wooden planks placed horizontally on two trestles, and beat vertically with relatively heavy wooden batons. Planks made out of other materials such as iron or stone are also common. The txalaparta is played by at least two players who alternate their beats to construct the bar performing through an improvisatory call-and-response pattern.

The txalaparta and the avant-garde were related during the 60s and 70s (Hurtado, 2015a), and like many contemporary musical compositions since the 50s, its play can be understood as a process defined by a series of instructions that the players use as guideline to improvise rhythms. In fact, many authors and interpreters claim that when referring to the txalaparta we are discussing the rules and the rhythm generated more than the physical instrument itself (Escribano 2012, 4; Beltran 1988, 198).

Since the late 80s, the instrument and the way it is played have undergone a normalization process, called “xylophonisation” by Euba, where its traditional percussive nature has shifted towards a melodic one with the planks being tuned (2004, 32) and the rhythm accommodated to the standard western music canon. However, the old style of playing is still learnt and used by many.

## Background

The txalaparta has not been the subject of academic research until very recently. Escribano (2012) and Gambra (2008) have explored cultural and acoustical issues while Euba (2004), and Sanchez and Beltran (1998) have focus on the musical aspect. Also, some practitioners provide an introduction to the playing and describe the instrument and the traditions around it (Beltran 2004; Beltran, 2009; Goiri, 1996) and there are references from anthropologists and musicologists at the beginning of the XX century (Azkue 1906; Lecuona 1920; Donostia 1924; Barandiaran 1934).

Figure 1. The Ugarte brothers playing txalaparta. Picture by Xabier Eskisabel

Some attempts to produce software based on the txalaparta have been developed before us. In the early 90s, Tecnotxalaparta was developed at the Laboratorio de Tratamiento de Palabra y Música in Madrid. This software was able to listen and respond to the human interpreter adjusting its tempo in real-time. The input was done with keystrokes in a keyboard and the computer output was MIDI. Tecnotxalaparta was never released. Later, Ixi audio released an application where by dragging four sticks around the interface the user was able to control an ongoing txalaparta rhythm. More recently, appeared Ttakun, a sequencer aimed at creating compositions and exercises for the txalaparta. Finally, Txalapartapp for the iOS allows one or many users to play txalaparta by touching the screen. There are also projects similar to ours but that focus on other instruments and types of music. To name some: The Continuator (Pachet 2002), ImprovGenerator (Kitane and Koike 2010), GenJam (Biles 2002), Haile (Weinberg, Driscoll and Parry 2005), Robotic Marimba Player (Weinberg and Driscoll 2007) or Shimon (Hofman and Weinberg 2011). Other relevant projects focus on popular music from Ethiopia (Herremans, Weisser, Sörensen and Conklin 2015) or Tal music from the north of India (Wright and Wessel 1998).

## Software development: Results

We tried to understand and formalise the rules of the txalaparta play and to develop software that reflects those. We aimed at producing applications that could run on a standard laptops and the result was two different pieces of software. The first one, called Autotxalaparta, is a semi automatic generative software that follows similar rules to those used by txalaparta interpreters (Hurtado 2015b, 124). It generates both parts of the txalaparta rhythm (the two players) and a graphical interface allows the user to control different parameters of the process. The Autotxalaparta can also be used to produce only one part of the rhythm thus allowing to play a real txalaparta on top. However, there is no interaction involved and the human has to follow the machine. We developed a system to sequence and automate the main parameters in the system. This allowed for more control but it did not allow, either, for real time control while playing.

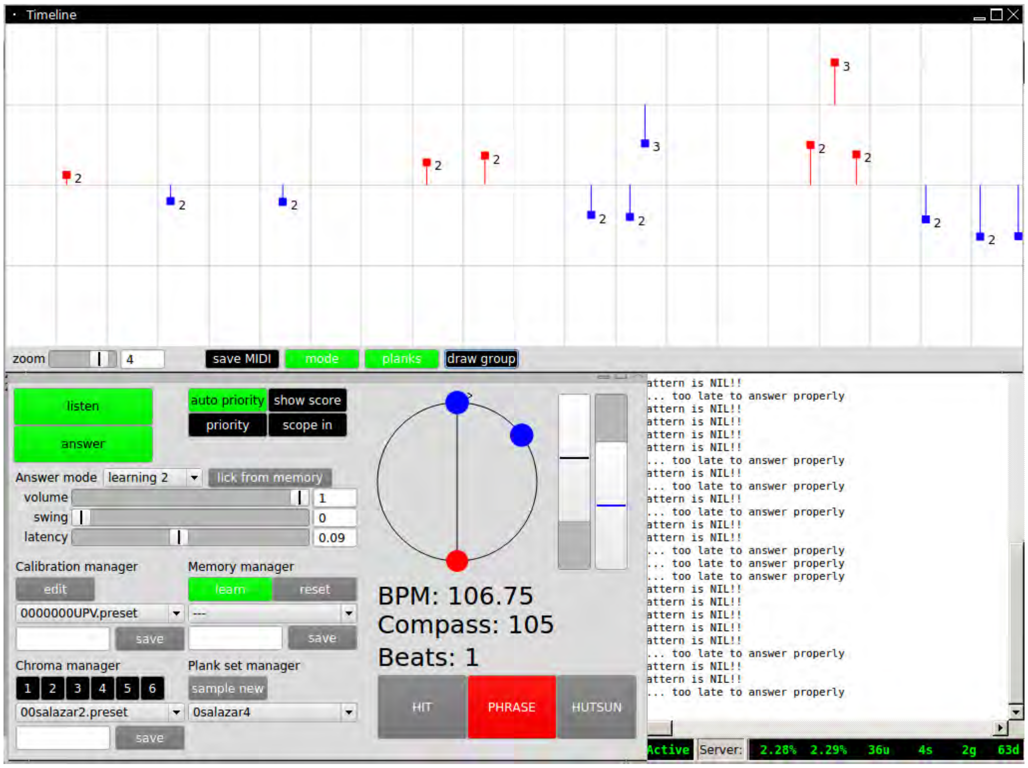


Figure 2. The Interactive txalaparta software

The second software is called Interactive Txalaparta. It listens to the human's play in a txalaparta using the microphone input and distinguishes the different phrases played, infers the tempo and provides responses that follow the human play. It also detects the number of hits on each phrase, the amplitude of each hit, the interval between hits and which plank each hit strikes. The system responds to the human using different techniques such as Markov chains and weighted random choices. The Markov chains have often been used to generate melodies (Patchet 2002), but here they are used to determine the number of hits the answer phrase should contain. Weighted random choices are used to decide which planks are played in the answer. Answers can be built in two modes, the first one builds the phrase by generating its values (amplitude, intervals, etc...), while the second one reuses information from previously played phrases, thus being more realistic. Both modes follow the player's last phrase's mean amplitude and mean intervals between hits. By doing so the system behaves close to human players, who are in constant negotiation to keep the rhythm going. Currently the Interactive Txalaparta does not propose new ideas or situations as its main effort is to adapt and follow the human consistently, still being limited in the styles of txalaparta play that can understand and produce to respond. The information with the played phrases can be saved into a text file allowing for later feeding the application with data that reflects certain playing styles or rules.

## Participatory design and feedback from players

Txalaparta players had an important role in the development as we contacted them from very early on in the process to get frequent feedback on the software, but also to learn about the latest trends on txalaparta. We looked for experienced players with an open minded attitude towards new ideas and innovations and we scheduled meetings at key stages within the process. The meetings were laid back one to one talks were we reviewed the current state of the software and tested it out while writing down ideas, suggestions and errors the player would point out. Occasionally we made changes in the code in situ, if the request or the error we needed to solve was easy to implement. We tried to get players involved in the development as much as possible and one of them actually attended up to four of those meetings at key points in the process.

Figure 3. Beñat Iturrioz playing with the Interactive Txalaparta

As a result of this user oriented approach we detected and fixed many bugs and problems in the software, but more importantly, we identified key ideas that, we believe, we would have never foreseen otherwise. For instance, during the early development of the Autotxalaparta, players expressed their interest in improvising txalaparta with the computer as second player, something we simply did not expect. Later they pointed out that they felt structures generated by the Autotxalaparta were too random and “non human”. To respond to this issue, we decided to develop a system that would adapt to the human allowing for an interactive improvisatory play: the Interactive Txalaparta. In this case the real instrument, the txalaparta, effectively becomes the interface to control the software, as the software adapts to the human play. The Interactive Txalaparta was a direct consequence of the feedback and the requests received from txalaparta players, and it might have never been envisioned otherwise.

Apart from the invaluable feedback on the development cycle we just briefly described, the meetings provided us with a very interesting insight on the txalaparta play. They shaped our understanding of the txalaparta, but more interestingly, they also shaped the understanding of txalaparta that players themselves had. The fact that players were, for the first time, improvising with a machine instead of a human, made them self-aware and conscious of many aspects of the txalaparta play, and the way players interact to each other, that were previously taken for granted. They said they found distressing, for instance, not being able to see the arms and body of the second player. This seems to be crucial for the txalaparta play as they realised they foresee the actions of the second player in the position and movement of the body and arms. In our case, because of the absence of a body while playing with a computer, they sometimes found the rhythm generated by the machine difficult to understand. This issue influenced the software development: to overcome it, we designed graphical representations of the computer's rhythm. The main graphical aids developed are a circular animation[1] that represents the events played in the current bar and a piano-roll time line. In the first one the current bar is represented as a circle with the phrases of both the human and the machine being displayed, the hits drawn as dots following clock-wise direction. Size represents amplitude, position represents timing, human produced hits are red and machine hits are blue (see circular graphic in the centre of figure 2). The second graphical aid is a piano-roll time line where the percussive events and its main characteristics, such as player, amplitude, time and plank are displayed in real

[1] Inspired by a diagram by Sanchez and Beltran (1998)

time (see top part of figure 2). Future developments should include the possibility to save the data displayed in the time line as MIDI for further analysis or to be used within a sequencer.

Players said it was very interesting to play with both programs but in their opinion the software is still quite limited stylistically, as the Interactive Txalaparta can only understand a certain type of txalaparta style and rhythms, and both programs can only generate a limited style of txalaparta. We observed that some interpreters occasionally used the software to get responses such that no human would produce. They also played around with the errors the system produced. These players said they found stimulating when the software played close to the limits of what can be considered a valid txalaparta rhythm or when it did something that no txalaparta player would ever do. We presented an early version of the programs at the Txalaparta Conference in Pamplona in March 2015 where most attendants thought the software would be useful because it allows to improvise txalaparta without a second player. Attendants were also very interested in the questions on the nature of the txalaparta play that the software raises and that have pointed out above. Finally, we would like to mention that in this ongoing research on txalaparta, we have carried out the first ever survey on it. This was an online survey with questions on the txalaparta and the changes it has undergone. It mainly focused on qualitative data and provided us very interesting data that complemented many aspects of our research, but that fall out of the scope of this paper.

## Conclusions and future work

We have produced two computer programs based on the traditional txalaparta. One of them, the Interactive Txalaparta, can be controlled by playing a real txalaparta and allows players, for the first time, to improvise txalaparta with a computer as the machine generates responses that follow the user's play while learns and adapts to it. The close involvement of txalaparta players during the development proved crucial as it allowed us to reach unforeseen results as well as to identify key ideas and concepts on the matter. This also provided us with a deeper understanding of the txalaparta play and its main characteristics. Future work should include the development of more functional and complete software that would allow to analyse further the txalaparta play. This should improve the algorithms that analyse the human play to allow for more styles of txalaparta and rhythmical techniques to be understood by the system. We will also improve the answer system to generate more complex and rich rhythms, as well as closer to the complexity of the human play. We plan to produce a cross platform version of the programs that would allow us to reach a bigger number of txalaparta players. This would provide us with a more variate and systematic feedback from the players on the software we have developed.

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# Collaborative coding interfaces on the Web

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**Abstract.** The recent developments in Web technologies, including full-stack reactive application frameworks, peer-to-peer communication and client-side audiovisual APIs have introduced the possibility of creative collaboration in a number of contexts. Such technologies have the potential to transform the way Internet users interact with code. This paper introduces a theoretical and technical methodology for developing collaborative coding interfaces as web applications, tackling the issues of interactive rendering, user-platform interaction and collaboration. A number of existing interactive programming environments are reviewed, followed by a technical description and evaluation of *CodeCircle,* a collaborative coding web platform developed at Goldsmiths, University of London.

**Keywords:** Collaboration, Web Applications, Interactive interfaces

## Introduction

In the recent years, the popular definition of the Internet has changed significantly – starting with the introduction of dynamic websites and Ajax (Dutta 2006), reactive web application frameworks such as AngularJS (Darwin 2013), and realtime communication technologies such as WebSockets (Hickson 2012), the Web has been widely accepted and treated as an application platform, not unlike traditional 'native' platforms such as Microsoft Windows and OS X. This notion has been further reinforced by the introduction of standardised Web APIs such as Web Audio (Adenot and Wilson 2015), WebGL and the File API (Ranganathan and Sicking 2015), which often match native platforms in terms of performance and potential. JavaScript and CSS have evolved from simple complements to HTML markup, to powerful and popular languages, the former being used on both client- and server-side, on mobile systems (Janczukowicz 2013) and even microcontrollers (Espruino.com 2016).

Unlike the static form of Internet content (Web 1.0), and the single user type of native application, the dynamic Web offers the opportunity of sharing and collaboratively creating documents, including directly executable code. This opportunity has been exploited in open-source software projects on platforms such as GitHub (GitHub 2016), 'pastebin' tools such as jsFiddle (Jsfiddle.net 2016), and cloud-based Web IDEs such as Cloud9 (Ciortea et al. 2010). Recently, a number of projects have also used Web Audio and Web GL to create audiovisual live coding environments, such as Gibber (Roberts and Kuchera-Morin 2012) and Livecodelab (Della Casa and John 2014). Applications like glslsandbox (Glslsandbox.com 2016) and Shadertoy (Jeremias and Quilez 2014) focus on developing small, self-contained visual pieces reminiscent of the Demoscene. In this paper, we introduce CodeCircle, which is the result of research in Web-based collaborative live coding, combining the elements of Web IDEs and rapid prototyping pastebin apps with real-time collaboration and rendering.

## Research objectives

CodeCircle is the result of our ongoing, in-depth research in digital interactivity and collaboration. Our principal aims in developing CodeCircle are as follows:

- To design and develop a web-based interface that enables real-time, collaborative, and social coding in a creative context.
- To implement an integrated code sharing and collaboration system that enables us to study the process of collaborative, creative coding.
- To devise the platform in such a way that makes it attractive and accessible to learners and professionals alike, and can be used in a variety of contexts including computing education.

This paper is mainly concerned with the first phase of this research. In the 'Existing platforms' section, we discuss the existing web-based coding environments, and compare their feature sets with the desired features of the CodeCircle platform. We then elaborate on the issues and requirements related to the main features of existing applications. In the 'Technical description' section, we describe the various design decisions and solutions implemented in CodeCircle. Finally, we discuss the potential use cases and the future development, as well as research, in the CodeCircle project.

## Existing platforms

There are numerous publicly available web based coding interfaces. However, their intended use cases, which inform their design decisions, vary significantly. Through a survey of existing web based coding interfaces, we have identified the following classes:

- Pastebin-style applications. These interfaces enable rapid prototyping of simple web code, usually allowing HTML, JavaScript and CSS code, and render using the browser as the engine. They are designed to store code experiments and examples, and are often used as supplements to programming community forums such as Stack Overflow. Pastebin applications surveyed in our research include jsFiddle, JSBin, CodePen, Codr, Liveweave, dabblet, Mozilla Thimble and CSSDeck.
- Live and creative coding and environments. Another distinct class of web-based coding platforms are creative coding applications. These are designed specifically for live coding performances, education, or building artistic works. They usually allow the user to write in one language, and either use user code to control an internal audiovisual engine (Livecodelab, Gibber) or inject the code into a pre-built web page (GLSL Sandbox, Shadertoy).
- Web IDEs. These are targeted at software companies and developers, and usually include cloud container services, rich asset systems, and complex coding tools. They always require authentication to access documents. While these applications enable development of complex client-server architectures and present the user with a very large feature set, their document representations are not easily shareable, and they require high skill levels. In our research, we reviewed several Web IDEs, including Cloud9, Koding, and Codeanywhere.

One of the principal aims of the CodeCircle platform is to combine certain features of all web coding application classes to build an environment that supports multiple approaches to writing code on the Web. While it is important for such a platform to provide the comfortable user experience of a Web IDE, combined with the ease of use and shareability of pastebin apps, it is also crucial to leverage the creative and educational potential of live coding interfaces. Finally, by emphasizing the aspect of collaboration and sharing on the platform, CodeCircle is an attempt at creating an environment for *real time social coding* – a practice which may radically change the way we interact with code and computing in general.

| | Platform type | | | Features | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Platform | Live coding | Pastebin | IDE | Live mode | Code Validation | Forking | Collaboration | Assets | Shareable |
| Gibber | x | | | | Yes | | Partial | | |
| jsFiddle | | x | | | | Yes | Partial | | Yes |
| Livecodelab | x | | | Yes | Yes | | | | |
| CodePen | | x | | Yes | | Yes | Partial | | Yes |
| GLSL sandbox | x | x | | Yes | Yes[1] | | | | Yes |
| Codr | | x | | Yes | | Yes | Yes | | Yes |
| Cloud9 | | | x | | Yes | | Yes | Yes | |
| CodeCircle | x | x | x | Yes | Yes | Yes | Yes | Yes | Yes |

Table 1. Comparison of feature sets of selected existing platforms

## Feature requirements

Building on the survey of existing platforms, we can specify a set of requirements for the CodeCircle platform which differentiate it from pre-existing platform and which will imbue it with the novel functionality required to enable us to begin addressing our research objectives. First and foremost, an integrated collaboration system is required which enables semantically synchronized real-time collaboration, applied directly to document content. This is in contrast to systems such as *TogetherJS,* which is used in a number of pastebin-style applications. Second, it is necessary to maintain a high level of interactivity, i.e. maximize the intensity of system feedback and minimize the feedback delay. Many existing platforms, such as CodePen and JSBin include an 'auto-update' function, which renders user code automatically as it changes. Others, including jsFiddle and Gibber, require user interaction to perform rendering, which increases feedback delay. Furthermore, manipulating binary assets is a core requirement for a number of audiovisual programming techniques including sampling, processing and sequencing. It is often impractical and limiting to work in an environment without the possibility of using pre-made content. Functional asset systems are currently only implemented in professional Web IDEs (Ciortea et al. 2010)(Koding.com 2016). Finally, pastebin tools such as jsFiddle have been widely adopted as the standard way of sharing code snippets on the Web. According to Goméz et al. (2013), Stack Overflow contains over 300 000 references to jsFiddle URLs. A simple shareable URL scheme and a forking function could improve the social aspect of the platform.

## CodeCircle – technical description

In this section we provide a technical description of the CodeCircle system and explain how it meets the requirements listed above.

[1] No error description

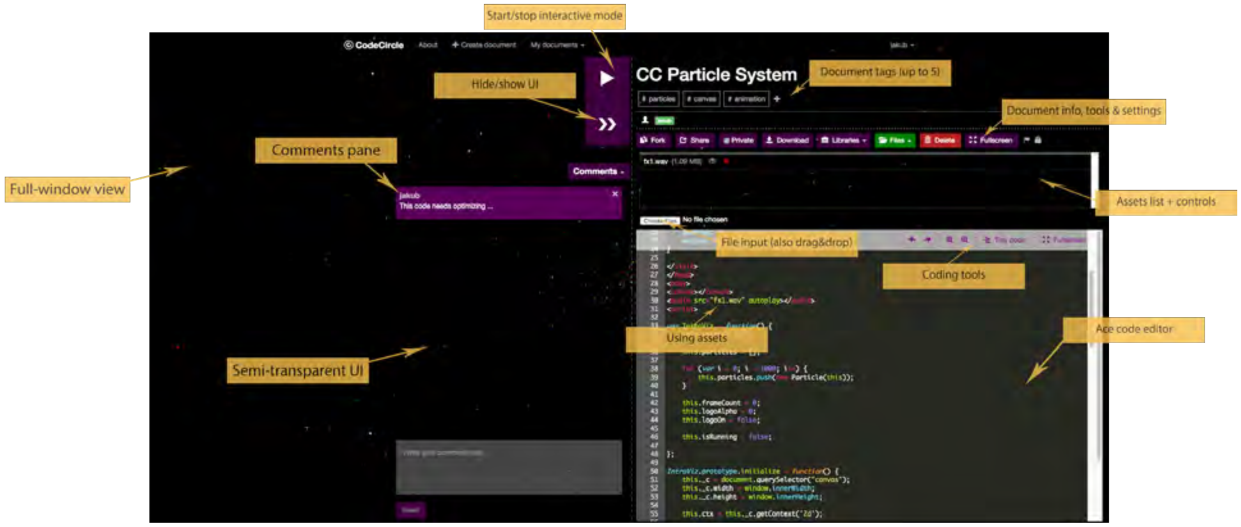


Figure 2. Screenshot of the CodeCircle UI

The user interface (UI) of CodeCircle aims to mirror the underlying rendering system structure by splitting the window into two parts – first, a dismissable semi-transparent editor panel containing document settings, controls, and the Ace code editor. Second, the viewer frame, which is positioned behind the editor panel and spans the entire window. This layout paradigm is prevalent in live coding environments that are based on a custom audiovisual engine, such as Gibber and Livecodelab. It is also extremely useful in a direct rendering environment, because it increases the intensity and immediacy of visual feedback from the application. Documents can be viewed in a viewer-only embeddable mode by appending */view* to the document URL. CodeCircle also includes a number of coding tools and features to improve the user experience. We used the beautify.js library to provide a 'Tidy code' function which automatically adjusts line indentation. By embedding the Ace editor, the UI also benefits from code highlighting, multiple cursors, and code completion. Similarly to a number of pastebin-style platforms, each document can be associated with pre-built JavaScript and CSS libraries that are automatically added to the code before rendering.

## Application structure

Real-time collaboration requires reactive content, which stays up to date without the need for refreshing the page. Solutions to this problem are part of many web frameworks, such as Angular, React.js, etc. For CodeCircle, we decided to use Meteor (Meteor.com 2016), a full-stack framework that combines a number of JavaScript libraries, and a server- and client-side engine. Meteor has a number of features that help build scalable collaborative applications rapidly. Since its server-side engine is based on node.js and MongoDB, and client engine on Blaze (Meteor.com 2016), the entire app logic is written in JavaScript. Meteor's subscribe/publish model and reactive templates are ideal for managing complex real-time interactions between collaborating users. The Meteor package library contains useful packages wrapping systems such as ShareJS, UI libraries, etc.

The CodeCircle application layout consists of two main views, and a set of auxiliary views. Each view is represented as a Meteor template. Meteor's dynamic templates system enables a highly structured approach to web application development, where individual templates can be reused in a modular fashion. Each of the main views is a template, which is composed of one or more sub-templates. In Meteor, each template is given its own set of helper functions and event handlers, which allows for even greater flexibility, and ensures that any interactivity is directly bound to its corresponding HTML structure in the application.

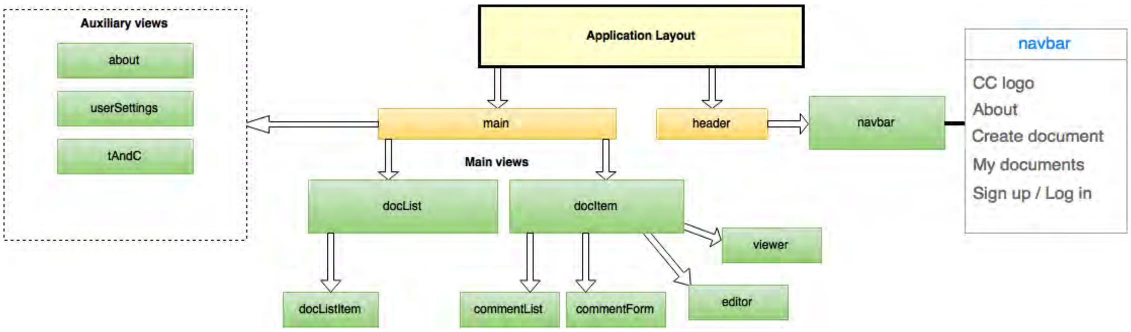


Figure 3. CodeCircle client-side template structure

## Rendering system

In its simplest incarnation, a real-time web-based web development environment consists of two elements: a code editor and a viewer frame, to which the code is rendered. These modules are easy to implement in HTML using the `<iframe>` tag for the viewer, and the `<textarea>` element for the editor. With these elements in place, a JavaScript mechanism is needed to render the contents of the `<textarea>` as the DOM (Document Object Model) of the `<iframe>`. This is the code renderer, the core element of any browser-based coding environment.

```
var editor = document.querySelector('textarea');
var viewer = document.querySelector('iframe');

editor.onkeydown = function() {
     var code           = editor.value;
     viewer.innerHTML   = code;
}
```

A simple HTML code renderer.

The above code executes an event handler whenever a key is pressed while the editor element is in focus. This solution seems perfectly good for writing basic HTML and CSS code – if the entire "webpage" is written as a single HTML file with inline CSS. On a modern browser, changes appear in the iframe element immediately. However, several problems arise when this simple system is implemented: the foremost being that when a script tag is included in the code, the browser does not execute the JavaScript inside. Furthermore, with enough code to render and a high typing frequency, the rendering system becomes overloaded, and the JavaScript thread freezes or slows down significantly. However, we can use a slightly more complex technique to render script content, too:

```
viewer.onload = function () {
     //write the new DOM
     viewer.contentDocument.open();
     viewer.contentDocument.write(code);
     viewer.contentDocument.close();
}

viewer.src = "";
```

Writing to an iframe.contentDocument stream.

With this technique, we have solved the script issue, as well as another problem arising from rendering a DOM repeatedly – when using computationally heavy APIs such as the Web Audio API, there is often a limited number of "contexts" one can create in a single window instance. However, a context needs to be created every time a new DOM is rendered, as the old contexts fall out of the new JavaScript scope. After a certain number of rendering routines[2], new contexts cannot be created anymore. The `<iframe>` element needs to simulate a page reload in order to release the existing context(s) and enable the creation of a new one. The one remaining issue is related to execution frequency. Since CodeCircle is primarily envisioned as a creative programming platform, the renderer response should be as close as possible to real time. Rendering on each keystroke results in a great performance decrease above a certain typing speed and DOM size. It is necessary to find a compromise between rapid renderer response and efficient execution. The most useful API for achieving this is requestAnimationFrame (Robinson and McCormack 2015), which aligns JavaScript execution with the browser's animation loop. The code is executed only if the browser is ready to render another frame, avoiding the ‘bottleneck’ which would increasingly prolong the time needed to continue rendering.

## Code validation

In a secure web application, it is important to ensure that only valid, secure code is being executed on the client. Apart from the obvious security and privacy rationale, code validation is also important for performance reasons – code that causes errors at runtime decreases JavaScript performance significantly, resulting in suboptimal user experience. There are a number of tools for HTML/CSS/JavaScript validation, the most popular being JSHint (Kovalyov 2010), CSSLint (Csslint.net 2016) and HTMLHint (Htmlhint.com 2016). The latter depends on the former two as plugins. All of these are written in JavaScript, and can be easily used in the browser.

In CodeCircle, we used a custom version of HTMLHint, which normally collects JSHint and CSSLint with the require() function, combining the three scripts into a single validator object. The validator script is executed in a Web Worker to improve performance. While increasing execution time, this approach also relieves the JavaScript thread, which results in a smoother typing response. Additionally, validation parameters must be set to accept many coding styles, but ensure that as little code with fatal errors passes the test as possible. An example of this is requiring semicolons – the code does not render until the user has finished typing the line.

## Assets

To solve the problems of secure asset loading, we have developed a system based on the CollectionFS Meteor package (GitHub 2016), which uses a GridFS file system in the application’s database. When the user inserts a file on the client, the file is uploaded and associated with the currently opened document. Image, audio and video assets can be previewed in a modal window. Once the renderer receives new code to render, it replaces each occurrence of the asset filename with a data URI representation of the asset, and the asset can be used in HTML `src` attributes. The server-side URL of the asset is not exposed, and the user can include assets in their code by simply specifying their filenames. Another problem arises when loading assets via an XMLHttpRequest (XHR), which is a common pattern particularly in Web Audio applications. At the time of writing of this paper, the native XHR object only supported data URIs in the Chrome browser. To enable asset usage in all browsers, we integrated an XHR shim which wraps the native object, detects data URIs, and decodes them into arraybuffers without calling the native XHR methods.

[2] In WebKit-based browsers, the maximum number of AudioContexts seems to be around 6


Figure 4. Public, locked CodeCircle document – content is visible, but only the owner can edit it.

## Collaboration and sharing

The collaboration functionality in CodeCircle draws inspiration from web applications such as Google Docs (Blau and Caspi 2009) and Overleaf (Overleaf.com 2016). Some popular pastebin platforms have implemented collaborative features with TogetherJS (Mozilla Labs 2016), a client-side library that enables real-time chat and view sharing. This approach does not integrate into the platform structures, and is not extensible or adjustable based on the particularities of the platform. Furthermore, TogetherJS shares the entire page view, which may result in decreased performance if the page DOM is complex. In CodeCircle, we have implemented a real-time collaboration system based on the ShareJS library, wrapped in the *mizzao:sharejs* package. ShareJS is designed for collaboration on text and JSON data, rather than entire web pages. The library is based on the concept of *ops,* i.e. highly specified representations of changes to a shared document. Ops enable efficient synchronisation of document views on a number of clients controlled by a server. A record of all ops applied to a document is stored in the database, containing metadata such as user ID. In CodeCircle, ShareJS is integrated in the code editor for each document, provided that the user is logged in.

CodeCircle documents can be shared either using a URL scheme inspired by community platforms such as Reddit, or by embedding generated `<iframe>` code. The document URL begins with the domain name, followed by the *'d/'* prefix and the document ID. All public documents are visible and searchable, although the owner may chose to lock a document, which results in the code editor being created as read-only. Any public document can be forked, which creates a copy of its code, and associates the original assets and the new document.

## Planned use cases and future work

The main goal of CodeCircle is to provide a *social coding* platform, combining the features of existing pastebin tools, Web IDEs and live coding applications. There are many potential use cases for the platform: the highly interactive UI style and document shareability of CodeCircle implies the possibility of using the platform as a 'demo showcase tool' similar to GLSL Sandbox. The social and collaborative aspects of the application also offer themselves to educational use – for instance, CodeCircle may be used by a lecturer to prepare examples for their class, and by students to submit and share collaboratively developed code, with a straightforward way of receiving feedback in the comments. The platform is already in use in an online creative coding course on Kadenze. In addition to showcasing and educational sharing, CodeCircle can support 'code crowdsourcing'. Because of the openness of the system, where any registered user can contribute to other users' code, users are invited to propose coding 'problems' and enable the community to contribute to the solution. The ownership of a document becomes less important as the importance of collaboration increases, and the concept of authorship is dismissed. The next step in the development of CodeCircle is to test the effect of an open collaborative system on the way users interact with code and with each other. Testing shall be performed by using CodeCircle as a teaching platform for both small and large groups of students, as well as specific user experience studies with groups of users from a variety of backgrounds. The integration of ShareJS enables detailed monitoring of the user-document interaction, and the obtained data may produce interesting insights into the dynamics of collaboration in creative coding.

## Conclusion

Technologies for collaborative programming and code sharing on the Web are a relatively novel, but very powerful addition to the Internet. In this paper, we have provided a theoretical framework for analyzing web-based coding environments. Next, we discussed functional requirements arising from their architecture, including collaborative and social aspects, code rendering, UI design and asset systems. By analyzing existing platforms and applications, we have identified solutions to some of these issues. Finally, we have provided an extensive technical description of the CodeCircle platform, which attempts to provide an environment for a fundamentally different, collaboration-driven way of developing audiovisual web programs. While the potential of the *social coding* concept can only be assessed by rigorous studies and testing on the CodeCircle platform, it is already possible to state that by combining a modern web application framework such as Meteor with an integrated collaboration system, an open sharing environment, a secure asset system and a highly interactive user experience, technical and design-related issues that arise in web-based coding platforms may be addressed effectively. The resultant web environment has a unique feature set that may provide a unique creative coding experience, as well as new modes of interaction between the community and the documents on the platform.

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# Colliding: a SuperCollider environment for synthesis-oriented live coding

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**Abstract.** One of the motivations for live coding is the freedom and flexibility that a programming language puts in the hands of the performer. At the same time, systems with explicit constraints facilitate learning and often boost creativity in unexpected ways. Some simplified languages and environments for music live coding have been developed during the last few years, most often focusing on musical events, patterns and sequences. This paper describes a constrained environment aimed at exploring the creation and modification of sound synthesis and processing networks in real time, using a subset of the SuperCollider programming language. The system has been used in educational and concert settings, two common applications of live coding that benefit from the lower cognitive load.

**Keywords**: Live coding, sound synthesis, live interfaces

## Introduction

The world of specialized music creation programming languages has been generally dominated by the Music-N paradigm pioneered by Max Mathews (1963). Programming languages like CSound or SuperCollider embrace the division of the music production task in two separate levels: a signal processing level, which is used to define instruments as networks of unit generators, and a compositional level that is used to assemble and control the instruments. An exception to this is Faust, which is exclusively concerned with signal processing. Max and Pure Data use a different type of connection for signals and events, although under a similar interaction paradigm. Similarly, Chuck has specific features for connecting unit generators and controlling them along time. The availability of languages capable of generating music in real time has fostered the development of live coding (Collins et al. 2003), which has the advantage of giving the audience the possibility to read computer music performances in a way that is comparable to improvisation with physical instruments. Live coding is also helpful in classroom environments, allowing students to grasp the mental process involved in using a programming language or command line. One feature that has inspired the live coding practice is the freedom and power that a programming language gives to the performer. On the other hand, restricted environments often result in unexpected creative outcomes. Facing the infinite possibilities offered by computers, musicians and artists commonly design their systems on the basis of constraints (Magnusson 2010). Constraints can be seen as the rules that define a game, and thus are considered by many to play an essential role in creativity (Boden 2004; Merker 2006).

Some constrained languages are available for live coding, most often with a strong focus on musical events (Magnusson 2011; McLean 2014). In the Music-N paradigm, this means not creating new instruments on stage, but improvising new control sequences for pre-defined instruments. The system presented in this paper explores the other side. In this sense, the concept of "synthesis-oriented" live coding can be opposed to "event-oriented" live coding. There is, as a matter of fact, a long tradition in challenging the distinction between composition and timbre, precisely on the basis of the possibilities offered by computers (Döbereiner 2011). Under this point of view, musical events can be seen as signals, and music can be created using exclusively signal processing networks.

With the release of version 3 (McCartney 2002), the SuperCollider language was split into two separate programs: the synthesis server (scsynth) and the language interpreter (sclang). A subset of the language is used to specify synth definitions, which the scsynth server can execute. It is not uncommon to find discussions among the SuperCollider community on creating music structures purely in the server side. Among other reasons, creating synth definitions can be less demanding with respect to dealing with the full language and the distributed architecture. Given the amount of unit generators available, focusing on the synthesis side of SuperCollider is both simple and powerful. In terms of user interface, the evolution of SuperCollider as a general purpose language led to a struggle between the need of a "proper IDE" for object-oriented programming, and the interest in the document-oriented rich text editor that was available on OSX.

In this context, Colliding was designed as a constrained interface for creating SuperCollider synth definitions. Apart from music creation and performance, the focus on synthesis provides a compelling environment for music and signal processing education settings, allowing easy experimentation with a wide variety of synthesis techniques. The idea of creating a simplified environment emerged when observing engineering students trying to create procedural programs with all the asynchronous calls required to start the server, create a synth definition and instantiate it. Loading audio buffers and network resources require asynchronous calls as well, which assume an understanding of anonymous functions. Both the classroom and the concert environments benefit from the reduced complexity and focus. In the case of music performance, the constraint is in part aesthetic, but still many different styles of music can be played. The rest of the paper describes the functionalities implemented so far and the use of the program in both education and performance.

# Related work

Constrained environments for live coding are common in classroom-oriented applications. Two well-known examples are Earsketch (Freeman et al. 2014) and Sonic Pi (Aaron and Blackwell 2013). The first is based on an Application Programming Interface (API) which can be used in Javascript or Python in a web environment. This API is complemented with a library of audio loops that can be manipulated and positioned in an audio sequencer time line through the API. The second exposes also a basic API, in this case as a Ruby domain-specific language that controls SuperCollider synths. The programming environment is designed to run on a Raspberry-Pi embedded computer. Both environments offer limited capabilities in terms of synthesis. The main idea behind live coding music environments in the classroom is to engage students into programming by doing something fun and creative.

Such environments allow experimentation with generative music, but are not so well suited for synthesis-oriented music or learning. While these systems generally focus on learning programming skills, Colliding emphasizes signal processing, requiring only basic programming concepts. In this sense, perhaps a more similar approach would be using the compiled language Faust in an interactive setting. FaustLive (Denoux et al. 2014) is a just-in-time compiler aimed at facilitating this kind of set-up, however, it does not provide an interface for coding. Faust is used live by Julius O. Smith for teaching signal processing using Emacs[1].

As the name suggests, Colliding is mainly influenced by Processing (Reas and Fry 2006) and its cousin the Arduino IDE. Both have succeeded in creating simplified development environments for activities that traditionally required specialized training. Processing was originally presented as a subset of the Java language that can be embedded in Java programs. Arduino offers a simple C API for embedded systems. Similarly, Colliding uses a subset of the SuperCollider language.

Another major influence is ixiLang (Magnusson 2011). While heavily focused on musical events, ixiLang stresses the importance of reducing complexity for music live coding. Like ixiLang, Colliding can be seen as a "SuperCollider parasite", in this case for synthesis-oriented live coding.

# Interface

## Overview

The program follows the interaction paradigm of prototyping editors like Processing. The interface (Figure 1) allows the user to create up to 8 tabs, each with a code editing window configured with a large font size. This encourages short snippets and facilitates readability. The number of tabs (and also of buffers, as described below) is not completely

[1] https://www.youtube.com/watch?v=2lEt7dsziO0

arbitrary. It is generally agreed that similar numbers of elements are related with working memory capacity (Miller 1956). It is common to find 8-channel limits in music production hardware (small mixers, old tape recorders) or software. The main actions consist in compiling the code (for error checking), running it (which results in a potentially infinite sound stream), and stopping the sound. These actions can be run through keyboard short-cuts or using a set of buttons below the code window. Another set of buttons in the top right corner exposes project-level operations (adding tabs, getting help for the currently selected text, loading and saving projects, and a panic button that stops all running processes). Text color in the code editing window is used to indicate compilation state. White means the code has been compiled, grey means it is being edited, and red means there is some error.

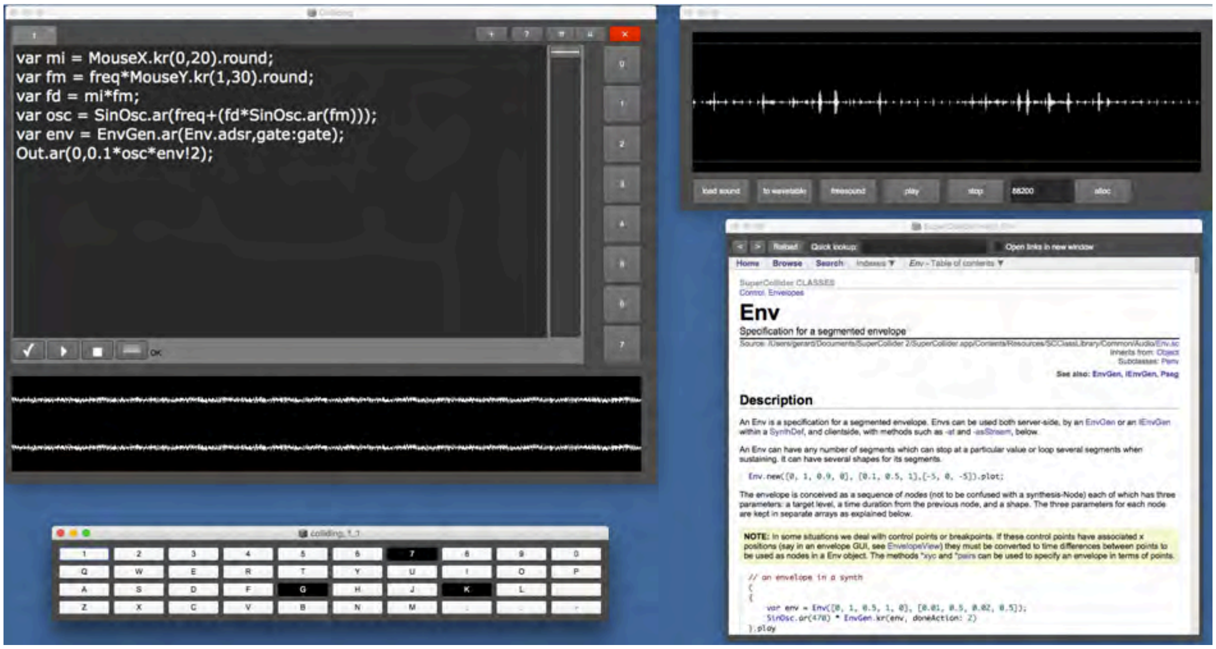


Figure 1: The Colliding interface

Colliding offers two modes of operation: "synth editing" and "advanced". The synth editing mode affords the metaphor of editing a patch in a hardware synthesizer, but it can also be used for live coding. In this case, the code is assumed to be a synth definition, and the environment provides some predefined variables and the means to trigger notes, if desired. In advanced mode, the code can be anything "playable". In SuperCollider this is achieved by compiling the code and making it the source of a NodeProxy, which allows using the interface with JITLib (Rohrhuber, de Campo, and Wieser 2005) as a back-end for live coding. This includes also event patterns, although this possibility has not been explored or specifically supported. One important difference is that in advanced mode the audio output channel is controlled by JITLib, while in synthesis editing mode it is specified explicitly. Thus in "synth editing" mode it is simpler to address multiple outputs. For synthesis oriented live coding, i.e., in SuperCollider talk, if only server code is evaluated, both modes can be used, although the advanced mode allows terser code.

A feedback panel below the code window and buttons is used for error reporting. Long stack traces can be overwhelming for beginners, and are also undesirable in live situations. When the code results in a stack trace, the system selects the relevant message and highlights the offending line (Figure 2). In order to provide such feedback without disrupting the current interpreter, it was necessary to implement compilation as a separate process, by writing the snippet to file and calling sclang to parse it. All of this happens under the hood.

All code is run in SuperCollider's internal server, which facilitates visualization of the output. The bottom end contains an oscilloscope that provides visual feedback about everything that is happening in the server.

## Synth editing

Additional features are provided in the synth editing mode. In this mode, the code is wrapped to build and instantiate a synth definition, with several pre-defined parameters. A window representing the computer keyboard allows triggering notes using the synth that has been defined in the current tab. The keyboard uses an isomorphic mapping. A slider next to the code window allows controlling the gain. This results in the following pre-defined variables. It is up to the coder to make use of them.

- key: The MIDI number corresponding to the key pressed in the computer keyboard. 4
- freq: The frequency in Hz corresponding to the key.
- gate: A gate input for envelopes.
- amp: The value defined by the slider.

It is trivial to extend this system with other widgets, for example additional sliders could be attached to the keyboard. For the moment, the system provides the minimum to leverage the input devices already available in every computer. The mouse is accessed using the traditional SuperCollider unit generators. This is a convenient setup for classroom PCs and laptop performances. It is also easy to extend the concept to MIDI controllers.

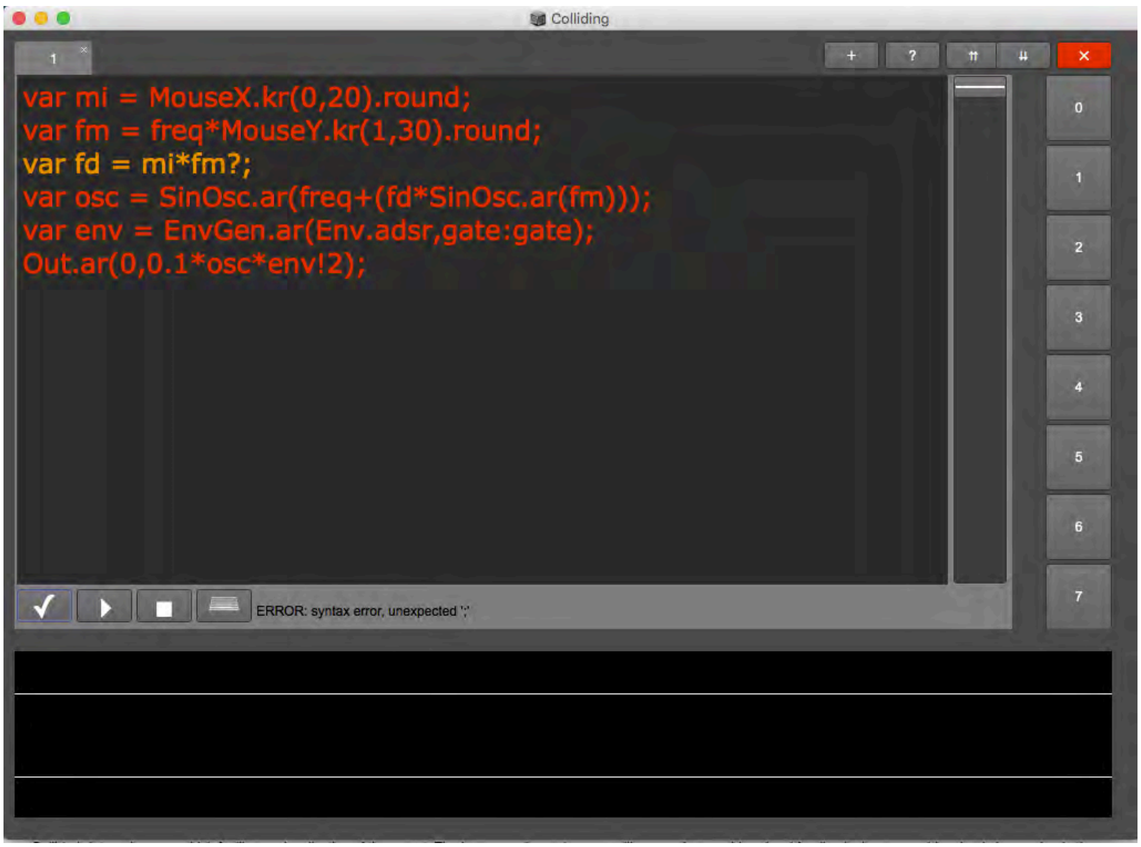


Figure 2: Error reporting

## Buffers and files

Besides synth definitions, another area that requires asynchronous calls is dealing with audio files. This is often a source of confusion in SuperCollider. Graphical interfaces are generally appreciated for browsing the file system and accommodating the time for file loading. Colliding provides 8 slots for buffer management. Buffers are simply accessed via their buffer number (0-7). A separate window is used for loading, visualizing and pre-listening each buffer. Empty buffers can be allocated for recording signals, and small buffers can be converted to wavetable format for wavetable synthesis. In addition to loading sound files from disk, the system includes an interface for the Freesound quark[2], so that the user can make basic text queries to the Freesound database (Akkermans et al. 2011), and download sounds. For the moment, the search is restricted to wav files. However, if ogg support is compiled with the SuperCollider binaries, it should be possible to access the whole Freesound database via high-quality ogg previews[3].

Finally, some basic project management facilities are provided. A project consists of the text in each tab and all the sound files corresponding to the buffer slots. This is especially useful for learning environments, but can also be useful to preserve the state of a live coding session. In the future it might be interesting to add some simple interface to version control (e.g. git) which is also usually hard for beginners.

## Initial Experiences

Colliding was developed while the author was at the Sonology department at Escola Superior de Música de Catalunya (ESMUC). While no formal evaluation was conducted, it was used in 4 overlapping semester courses between 2013 and 2015, covering basic and advanced synthesis techniques. During the previous year, the SuperCollider language and IDE were used. The difference with respect to using plain SuperCollider was dramatic. By freeing students from learning to use the SuperCollider editor and language, it was possible to focus on synthesis and processing as opposed to programming. At the same time, thanks to the large number of unit generators available and the general power of SuperCollider it was possible to explore many different algorithms and concepts, from basic subtractive and modulation techniques to physical and spectral synthesis. Colliding was used as a kind of lab notebook editor that could run in classroom PCs and student laptops. Assignments consisted in Colliding projects where different variants were explored in each tab. A small code snippet was usually seeded.

Since students were generally beginners in computer programming, a very simple grammar was adopted which worked for all assignments (as can be seen in the figures): each line, except the last one, is a variable definition and assignment, where part of the signal processing graph is represented. This suggests that, for the purpose of defining synth definitions, the language could be further simplified.

The only limitation was the project management feature, which was not always trusted by the students because of its simplicity. However in case of doubt the project structure was simple enough and text snippets could be open with a standard text editor. Some synthesis techniques that require additional processing, such as in the case of wavetable synthesis, were more difficult to accommodate. For advanced techniques, such as spectral modeling or vocoding, it was generally convenient to use "black-box" unit generators available from sc3-plugins[4].

Colliding has also been used in several live coding performances by the author. Up to 8 synthesis processes may run in parallel while one of them is being edited. The big font, oscilloscope, and the constraint to synthesis-based coding contribute to the readability of the performance. In live coding, the simplified grammar is not needed, and instead a terse syntax is more common, in line with the use of Twitter for sharing small SuperCollider programs.

## Conclusions

The SuperCollider syntax for building synthesizers allows for creating sophisticated patches with very few lines of code. Such concise descriptions often contrast with the complications one ends dealing with when trying the same things using graphical patching systems and modular synthesizer metaphors. However, learning an object-oriented language

[2] https://github.com/g-roma/Freesound.sc
[3] This depends on the version of libsndfile, which for historical reasons was fixed to an older version on OSX binaries. At the time of this writing the problem is fixed in SuperCollider 3.7 binaries, so the restriction to wav for Freesound searches will be removed.
[4] https://github.com/supercollider/sc3-plugins

enriched with functional programming constructs can easily scare tinkerers and musicians with little programming background. The Colliding environment provides a simplified interface that is particularly useful when focusing on sound synthesis and processing, as opposed to event-based music composition and performance. This focus can be seen as a design constraint that is useful in educational environments and in synthesis-oriented live coding. While the current implementation mainly stresses the concept and interface, these ideas can be further extended without leaving the SuperCollider language, by defining more helper variables and functions. Also, the system is amenable to encapsulation of synthesis processes as unit generators, a practice used by some live coders which allows growing a personal sonic palette without losing simplicity. Adding support for this kind of encapsulation will be investigated in the future. The code is available as a SuperCollider quark, and can be downloaded from the github repository[5].

## Acknowledgements

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[5] https://github.com/g-roma/Colliding

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# Challenges and New Directions for Collaborative Live Coding in the Classroom

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**Abstract.** This paper focuses on the potential of collaborative live coding in educational settings. In particular, it draws from our experience with EarSketch, a free online platform for algorithmic composition and computational music remixing that allows students to learn Computer Science Principles (CSP) by making music using either Python or JavaScript. We argue that collaborative live coding is a promising approach to learning CSP through computer music in the classroom. We draw on interviews with teachers and observations in schools. We discuss how collaboration can be better supported in educational settings when learning CSP using EarSketch, and the challenges and potential for learning music and code using a computer-supported collaborative environment.

**Keywords:** Collaboration, Live Coding, Peer-to-Peer Communities of Practice, STEAM Education.

## Introduction

Knowing how to code is an essential skill of the 21st century. National programs, such as the recent American "Computer Science (CS) for All",[1] evidence the emergent interest of providing the required resources to allow students to learn to code early on. These programs aim to broaden participation in Science, Technology, Engineering, and Math (STEM) fields, in which certain populations are underrepresented, such as women, Afro-Americans, and Latinos (Burge and Suarez 2005; Freeman et al. 2014). A successful approach is including the arts when teaching STEM subjects, also known as Science, Technology, Engineering, Art, and Math (STEAM) education. In particular, initiatives such as EarSketch (Freeman et al. 2014) have proven to engage underrepresented populations in STEM disciplines by bringing musical artistic practices with low barrier of entry into STEM.

EarSketch[2] is a free online learning platform and curriculum for algorithmic composition and computational music remixing.[3] EarSketch allows students to easily create music by combining audio samples, using either Python or JavaScript, within a Digital Audio Workstation (DAW) inspired interface. The educational platform has been deployed in a number of high schools, summer camps, and college courses. There is an existing debate of authentic learning in music education (cf. Green 2008), to which the experience with EarSketch contributes. Freeman et al. (2014) explain that part of the success of the initiative, seconded by informal conversations with teachers who deploy EarSketch and our observations in the classroom, is that working with EarSketch has an authentic[4] character: it is personally meaningful (i.e. students can create their own music using different electronic music genres, such as hip hop, dubstep, or techno), as well as professionally relevant (i.e. students learn modern programming languages, and how to operate DAWs). The

[1] http://nsf.gov/csforall (accessed February 18, 2016).
[2] http://earsketch.gatech.edu (accessed February 18, 2016).
[3] *Computational music remixing* refers here to program a different version of a song by combining existing sound samples.
[4] An *authentic* activity or practice refers here to an action or set of actions that connect to a real-world situation.

EarSketch curriculum aligns with the Advanced Placement (AP) Computer Science Principles (CSP) curriculum framework.[5] A highlighted aspect of the AP CSP curriculum framework is to support collaboration during CS learning.

This paper aims to explore the nature of collaboration using EarSketch in educational settings, and to point to future directions, with no intention to assess the musical outcome at this stage of research. *Live coding* practices are based on the use of scripting languages for real-time music improvisation (Brown 2006; Collins et al. 2007; Freeman and Van Troyer 2011; Rohrhuber et al. 2007). The potential of live coding as an educational tool with an impact on both musical and computational learning has been discussed in Freeman and Magerko (2016) using EarSketch. With live coding, the modification and execution of the code, or composing and performing, are produced as simultaneous activities in real time. As a follow-up of Freeman and Magerko (2016), this paper speculates the potential of collaborative live coding in educational environments, particularly from a performative point of view. The aim is to investigate how to better support collaborative practices using computers in the classroom. In the next section, we overview musical practices of live coding and collaboration, as well as live coding practices in CS education, that inform this work.

# Background

## Collaborative Live Coding

Collaborative live coding is an umbrella term that refers to performing live coding in group, which includes from small to larger groups. Barbosa (2003) proposed a classification space for computer-supported collaborative music based on the user's location (co-located vs remote) and group's interaction time (synchronous vs asynchronous). This research is interested in a classroom setting in which groups are located in the same space, interacting at the same time, working either on individual or shared interfaces. Next, we provide illustrative examples, as opposed to all-inclusive, of approaches to co-located collaborative live coding.

Small group collaboration using individual screens, and working as a network with a shared clock is reported by McLean (2015). A common collaborative live coding configuration is working in pairs. 2ˆn[6] is a project started in 2012 by the electronic music duo Pulso (Gerard Roma and Anna Xambó). The project uses a highly constrained environment written in SuperCollider, which is a real-time audio synthesis environment and programming language (McCartney 2002). The project is inspired by the ixi lang SuperCollider environment (Magnusson 2011). The setup consists of two laptops, each running a shared customized patch that shows two synchronized code editors, one for each of the performers (see Fig. 1).

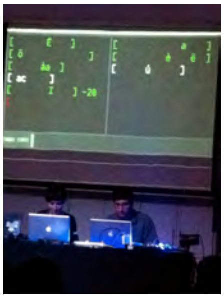

Figure 1: Pulso's 2ˆn presented in Live Coding Sessions at Niu, Barcelona (March 13, 2012)

[5] https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-computer-science-principles-curriculum-framework.pdf (accessed February 18, 2016).
[6] https://soundcloud.com/pulso-2-n (accessed February 18, 2016).

There exist a number of laptop ensembles and orchestras all over the world, of which some of them explore egalitarian approaches of the ensemble, whilst others explore more hierarchical structures.[7] Collaborative live coding in large groups, under democratic settings, is investigated by the Republic (de Campo 2014), a project that started in 2003 using laptops and their built-in speakers. The Republic is based on an available extension library written in SuperCollider. The Republic's principle is to create a symmetrical and multi-directional network, in which each player can access and modify each other's code (Rohrhuber et al. 2007). The two ensembles powerbooks_unplugged and Republic 111 use the Republic's ideas and technology. The recent advent of the Web Audio API,[8] in JavaScript, has enabled a number of projects to explore the possibilities of participatory audience with their mobile devices using their browser, and connected to a network. With a few exceptions, such as the UrMus live coding language for mobile phones used extensively by the Michigan Mobile Phone Ensemble (Essl 2010), there is little research on live coding on mobile devices, particularly participatory live coding, which seems an interesting direction to computationally support collaboration among large groups.

### Live Coding in Learning Environments

Interdisciplinary experiences between CS and music have been explored in the classroom. For example, Scratch[9] is a blocks-based programming language, which can be used to create a variety of multimedia applications, such as games. Scratch has been particularly used in music-related projects, for example, for teaching computational thinking through music in the classroom (Ruthmann et al. 2010). Accordingly, computational thinking in Scratch includes concepts such as synchronization, looping, initialization, use of variables, changing variables algorithmically, modularization, and event processing. Live coding comes into play when using infinite loops and algorithmic composition (cf. Edwards 2011). Changes can be done in real time with no disruption to the musical outcome, a key feature of live coding. The Scratch courses on computational thinking through real time music are called Performamatics (Ruthmann et al. 2010), in which the understanding of computational and musical concepts are tightly linked to the nature of a musical live coding event.

Another example is Sonic Pi,[10] an open source live coding environment for also teaching computing concepts through music, which runs on the tiny computer Raspberry Pi (Aaron and Blackwell 2013). Sonic Pi is based on imperative commands, built on top of the Ruby and SuperCollider languages. Educational collaborative exercises using Sonic Pi are reported by Aaron and Blackwell (2013). For example, students enact imperative programming by triggering sounds in turns. To our knowledge, platforms for live coding in learning environments have been designed and researched focusing on individual use. This paper is an initial step to fill the gap between collaboration as a key component in CS learning and live coding in education.

## EarSketch: Live Coding Features

EarSketch is a free browser-based DAW environment built with Web Audio API that allows students to create their own algorithmic compositions and computational music remixes while learning computing principles (Mahadevan et al. 2015). The EarSketch API is built on top of JavaScript and Python so that EarSketch can be easy to use by students. Users can work either with their own uploaded sounds, or with 4000 available music samples that were designed by Richard Devine, who is an Atlanta electronic music composer, and Young Guru, who is Jay-Z's audio engineer and tour DJ. EarSketch supports CSP through promoting creative practice and self-expression linked to computational learning; allowing for the use of computational concepts, such as layers of abstraction (e.g. the DAW timeline), loops, variables, different data types, and procedural algorithms; providing the Internet medium as both an individual and a collaborative space in which songs and scripts can be shared; and allowing for social impact of computing practices.

In the DAW view, users can play the music they created in code, and perform basic transport and mixing operations. The common workflow is to write lines of code in the code editor; execute the code by pressing the run button, which

[7] http://www.ialo.org/doku.php (accessed February 18, 2016).
[8] https://www.w3.org/TR/webaudio (accessed February 18, 2016).
[9] https://scratch.mit.edu (accessed February 18, 2016).
[10] http://sonic-pi.net (accessed February 18, 2016).

renders the tracks on the DAW view; and press the play button to listen to the results (see Fig. 2). Users are not able to edit the multi-track audio and effects content directly, instead they must edit the code to change the music. Some of the DAW features of EarSketch can be used within a live coding context (Freeman and Magerko 2016). For example, the looping playback feature in the transport controls allows for changing the code in real time with no disruption to the musical output. Loop points is another live coding feature, which allows students to set shorter ranges within the song with start and end points. Soloing and muting tracks can also be combined with the previous features to create more richness and variation of the musical outcome. However, a DAW interface, such as EarSketch, is generally designed for individual use. In the next section, we report how EarSketch is used in the classroom as part of collaborative practices, and how EarSketch teachers envision it could be improved for supporting collaboration in educational settings.

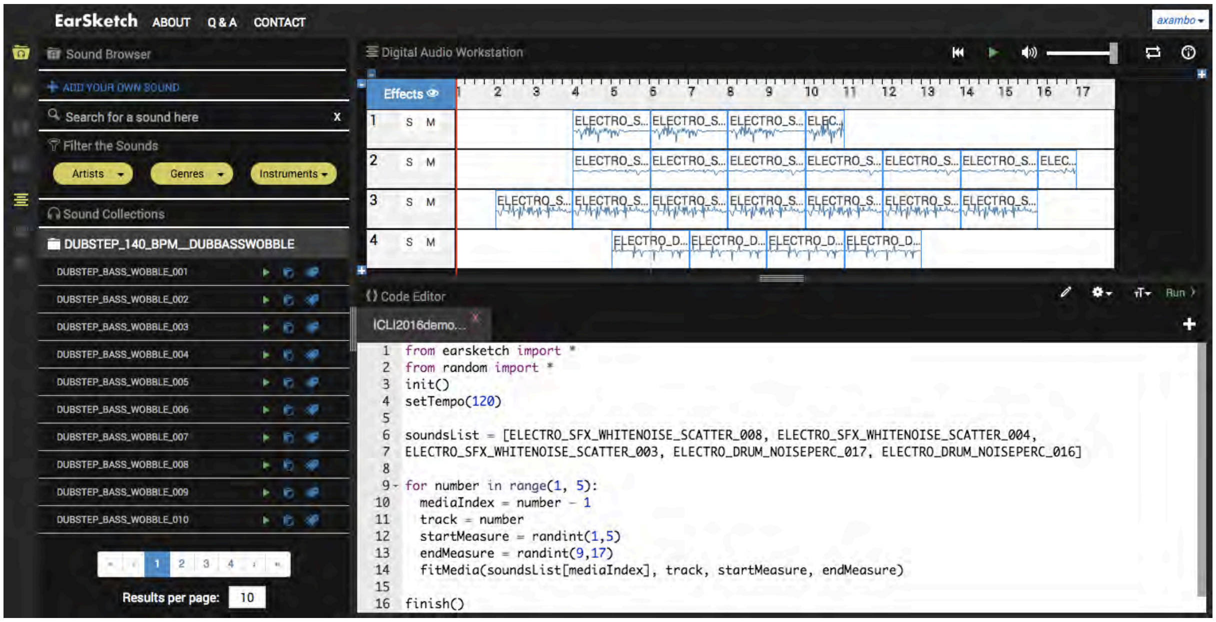


Figure 2: EarSketch with a Python script that includes a looping function and a random function

## Collaboration in the Classroom with EarSketch

Here we present relevant topics that emerged during informal conversations around EarSketch and collaboration that evidences the need of computer-supported educational environments for collaborative live coding. We had casual interviews with some teachers of EarSketch, of which some of them had teaching experience, whilst some of them had training experience. We were interested in getting a sense of current practices in the classroom and potential needs for improving communication between students, and communication between students and teacher. We also visited three schools and conducted in-the-wild and unobtrusive observations by taking notes.

We identified a number of practices for sharing code: for example, Google Docs is used for sharing the EarSketch code between students and the teacher; some students share between them the development process (e.g. techniques, composition strategies), or the musical outcome; some students share their code with other students, and Learning Management Systems are used by some students to post their code and comment on it. These examples illustrate asynchronous sharing practices occurring after completing and saving individual scripts. As potential needs for sharing code, it was highlighted that sharing a script file, like with a Google Doc, would be useful because multiple people can edit the same document at the same time and access from different computers; and some variation of Google Docs with EarSketch would be a huge improvement as Google Docs is used in other CS subjects for group projects. This points to the need of real-time collaboration support in the classroom, during the process of coding and music making. However, some issues were raised, such as to what extent sharing code can go against CSP: teachers need to make sure the work's authorship, which relates to how to grade a collaborative piece; and also sharing would require different levels of permissions.

We recognized a number of practices around collaboration in the classroom: for example, organic and informal collaboration occurs; students naturally team up; groups work in pairs; and groups of size three with at least one musician have been observed, all of which point to small, casual and interdisciplinary teams. It was also reported that students prefer to be independent and collaborative, which indicates that keeping individual terminals for each student during collaboration seems useful. Activities around collaboration include: informal presentations in which students share their content, explain what they do, and receive feedback from the teacher or other students; sessions in which everyone plays their piece as a performance and the other students give their opinions openly; gallery walks, in which the classmates visit and listen to others' work from one side of the class, and then they switch side; pair programming activities in which students alternate roles between driver and navigator; competitions of songs using a voting system; and collaborations in alignment with the AP CSP curriculum framework. In particular, the group activities that occur during the process of coding, such as in pair programming, are based on turn-taking teamwork. As potential collaborative features, we identified the need of more real-time collaboration support, including the ability to chat to each other; the ability to modify the same script from different terminals by multiple students; and an environment that supports freedom of choice during teamwork (as opposed to constrained roles).

We also identified the nature of the teaching environment and teaching practices, including: a casual environment; students talking to each other before they ask to the teacher; and the promotion of interaction with the environment almost every moment according to the AP CSP curriculum framework. As potential features for supporting teaching practices, we identified that it should be easier to see the code of each other, and to make comments from a small team (teacher, and a few peers) so that students could receive meaningful feedback. This indicates the importance to support collaboration and peer learning in a CS class within informal contexts, in particular sharing and commenting code in real time as part of the learning process. Collaborative coding as a musical performance event can promote peer-to-peer learning within real-world situations, as discussed next.

# Approaches to and Challenges of Collaborative Live Coding

In this section, we discuss potential group configurations suitable for collaborative live coding based on the notion of communities of practice; three promising approaches to real-time collaboration based on working in either pairs or larger groups using the same script; and final remarks on how we can best support collaborative live coding in the classroom.

## Peer-to-Peer Communities of Practice

In situated learning, knowledge is shared and co-constructed within a context and in a community of practice (CoP), understood as a group that shares an activity (Lave and Wenger 1991), yet this literature has typically focused on examples of beginners learning from experts. *Collaborative learning*, understood as a situation in which more than one person learn or try to learn together (Dillenbourg 1999), has been a frequently studied aspect of computer-supported collaborative work (CSCW) systems (Dillenbourg 1999). These concepts allows us to understand the action as a situated collaborative activity in which the knowledge is transferred by doing in a group and mediated by technologies. In such learning, people gradually construct a shared, convergent meaning, which is situated (Roschelle 1992; Suchman 1987), and which depends on the people involved and the particular technology used. Green (2008) identifies *group learning* through music making in informal learning practices within music education, in which students learn through watching, imitating and listening to each other. The above ideas resonate with the notion of collaborative live coding, in which students can learn from viewing and interacting with other students' practices, as opposed to only from the teacher, taking advantage of real-time collaboration features. Potential configurations and roles in the classroom can include working in interdisciplinary pairs or small groups by combining levels of expertise (e.g. beginners and experts), or domains of expertise (e.g. coders and musicians).

# Approaches to Real-Time Collaboration

## Live *Pair Programming* Approach

This approach is built upon the existing practice of pair programming in the classroom observed with EarSketch. Combining pair programming with live coding is highlighted in Freeman and Magerko (2016) as a form of collaboration where each student can add, in turns, a layer of complexity, computationally and musically, to an ongoing loop. The periodic switching roles of driver and navigator can be kept, and the changes on the EarSketch script are produced in real time in a performance setting. The screen can be projected, and so the other students can see the code and understand two approaches to computational thinking that are clearly organized in turns. In live coding, the musical outcome changes as part of a process, a process of changing by doing, which connects with process music ideas (Reich 1965), as well as with an iterative coding workflow (Freeman and Magerko 2016). Even though the clarity on who is doing what, turn-taking adds constraints to collaborative live coding because it limits the flexibility of modifying a script synchronously as in the case of pair live coding (which is explained later in this section), due to students are working with only one shared terminal. This approach can be useful in a CS class to strengthen learning of CSP through pair programming within a creative context. The selection of a set of audio samples from two people can also create interesting hybrid music styles, unless a music style is planned beforehand, or the music style is constrained by an assignment, or both students like the same type of music. This possibility of creating hybrid music genres also applies to the next two approaches.

## Multiple *Live Coding* Approach

This approach is based on the Google Docs approach of allowing for multiple editors, who can work simultaneously on the same file. With EarSketch, a planned future feature is that the script can be shared simultaneously, everyone can modify it, and the musical outcome results from a sum of individual cursors. In an educational context, this approach can be applied to teach democratic approaches to music making in real time, as well as learning to intervene in due course, similar to the cycle of listening and playing in group musical improvisation. Computational concepts can be learned using a more interactive approach than just watching a projected screen of other's code as in the case of live pair programming, where the knowledge can be spread throughout the whole class, increasing the information flow within the class. This approach can also become chaotic, but nothing prevents the teacher and the students to decide for certain roles and rules. For example, an interesting avenue to explore is a conversation with the teacher as a live coder showing a computational and musical concept, with a script that can be shared and occasionally modified by students, either by replying a teacher's question, or by writing questions or suggestions as comments that the teacher or other students can address, or by modifying code in an organized form. Another example is exploring interactive programming in group, where there can be a division of labor of creating different functions for different parts of the song and test them as they are written, in real time. As a potential challenge, it is unclear how to know when to re-excute the code in a state that has no syntax or logical errors when multiple people are editing the same code document. Another challenge is, if students want to create a symmetrical network as in the Republic's example, identifying how to know what is each other's code, as well as how to know who has modified it, assuming that it matters to know about code authorship.

## Pair *Live Coding* Approach

This approach is an instance of the multiple live coding approach, but constrained to two students. It is also based on duos as in pair programming working on a single EarSketch script, but each student has an individual terminal so both can be drivers who contribute to the script simultaneously. In an educational context, this approach can be useful for simultaneous sharing of computational and musical strategies on the same script, as well as for team solving of computational errors. This approach's flexibility for real-time group work is in detriment of knowing who is doing what beyond the pair of students, for example, when projecting their script. An interesting challenge is working with two simultaneous scripts in EarSketch, as in Pulso's 2ˆn, that would require both to be synchronized.

## Live Coding Suitable for Learnability and Collaboration

According to Ruthmann et al. (2010), a suitable environment for live coding in the classroom needs to allow for the exploration of real-time manipulation of code, in which both musical and computational understanding are important. Furthermore, the environment needs to be easy to use (e.g. EarSketch, Scratch, Sonic Pi), including domain-specific languages that are easy to understand (Aaron and Blackwell 2013). We argue here that the benefits of collaborative live coding in the classroom include that computational thinking moves from an individual to a social plane, in which problems and progress are shared as part of the learning process, in real-time and real-life situations. This approach includes existing practices observed in the classroom, such as showcasing students' work, or discussing the code in group. It also spans to potential new practices, such as performing in pairs of live coders, or manipulating in real time the code as part of a participatory, multi-directional musical piece involving the whole class. An open question is whether the sessions should be recorded to reflect on them pedagogically. Another open question is how collaborative live coding would be screencasted and understood in certain live coding educational contexts, such as Livecoding.tv,[11] a livestream platform that generally focuses on learning from watching individual live coders. Future work includes assessing the musical outcome of collaborative live coding in the classroom, as well as designing a set of exercises based on this practice.

## Conclusion and Future Work

This paper discussed the challenges and potential of collaborative live coding in the classroom. We presented existing collaborative practices in live coding, and live coding environments in education. Drawn from the literature review and empirical work, we discussed three challenging and potential approaches to collaborative live coding using EarSketch, as part of peer-to-peer communities of practice. Finally, we proposed how to best support collaborative live coding in educational settings. As future work, we plan to assess the suggested approaches to collaborative live coding in the classroom.[12]

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# Creative Thinking:
# A Brain Computer Interface of Art

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**Abstract.** The artistic expressions are universally recognized as creative. It might be considered a window on the mind since an artwork implies a blend of implicit and explicit thinking processes and results in behaviors mediated by some media or epistemic instruments. In this sense, art may be seen as creativity enacted, since the mind/brain must interact with the surroundings so to close the cognitive loop open by inspiration.
We can state that creativity is a part of every human daily activity, so that, to understand individuals' behavior, abilities, and the mechanisms of the mind, we must start from the creative process, as, in general, the search of a different (innovative) solution to a problem.
In this paper, we will treat the cognitive aspect of the creative process and we describe an example of creativity enacted by the use of a Brain Computer Interface: the mind the chair project.

**Keywords**. Creativity; Brain Computer Interface; Cognitive Science; EEG.

## Scientific Investigation On Creativity

Scientific investigation through new technological tools, such as Brain Imaging and Artificial Intelligence (A.I.), opens a wide scenario on the opportunity in studying relationships among Art, Technology and brain, and, consequently, creativity. Brain Imaging techniques allow notable improvement in the analysis of the brain "in action", that is the study of the individuals' reactions and brain mechanisms involved in motor, cognitive or perceptive tasks. Thanks to devices and methods, such as fMRI (functional Magnetic Resonance), MEG (Magnetic Electroencephalography), PET (Positron Emission Tomography), EEG (Electroencephalography), it is possible, in fact, to verify in real time the response of an individual to specific stimuli. Because of its low invasivity and high time resolution, EEG is the most used technique to investigate mechanisms such as creativity. Intuitively and experimentally, it is possible to state that Art is a creation of the brain (Cela-Conde, et al., 2004). The study of the neuronal mechanisms that underpin the artwork as well as the aesthetic experience represents the base of the experimental discipline named Neuroaesthetic, officially born in 2001. Founder and pioneer of Neuroaesthetic is Semir Zeki, known neurobiologist who, in the '90s, begun to study to the links between Art and brain, using psychological tests and electroencephalography. Zeki compares artists to a neuroscientist (Lumer and Zeki, 2011; Kawabata, Hideaki, and Zeki, 2004; Zeki and Nash, 1999) "*exploring potentiality and the ability of the brain, even if with different tools"* and, even with a different language "states" an idea discovered or intuited. However, differently from scientific knowledge, artistic ideas are not completely overt. The aesthetic experience of an artwork integrates and transforms the individual perception of reality in a lived experience with regard to the subject: the artwork disturbs, excites, and soothes the individual. Finally, Aage Brandt (2006) proposes to consider neuro-aesthetics as the study of the neuronal process of perception and mental organization of cognitive activity stimulated by the artwork, following both a cognitive and evolutionary approach.

Particularly suited for the described research, the B.C.I. (Brain Computer Interface) headsets are a simplification of the medical equipment for EEG (Allison, Wolpaw and Wolpaw, 2007), and allow to record cerebral rhythms and the direct brain-computer interaction. BCI devices are widely used in research, for the registration completely comparable to the medical EEG, but also for their low cost and high portability. They present, moreover, the advantage to keep in comfort the individual wearing them as they allow a wide movement freedom in the experimental environment. BCI devices collect several brain frequencies, grouped in rhythms: the alpha rhythm (8 Hz – 12 Hz), related to relaxation, meditation, contemplation; the beta band (12 Hz – 30 Hz), associated with active thinking, attention, problem solving (Lucchiari and Pravettoni, 2012); the delta rhythm (0.5 Hz – 4 Hz), a sleep-related rhythm also associated with arousing stimuli (Lucchiari and Pravettoni, 2010); the theta rhythm (4 Hz – 8 Hz), generally related to emotional engagement; the gamma signal (30 Hz – 40 Hz), usually related to the focused attention and cognitive interpretation of multi-sensory signals. BCIs allow investigating the mechanisms of creativity both from the point of view of the artist while creating a work, and from the point of view of the public while observing the final result.

In this framework, BCI devices are particularly useful in research, either to register the response to visual and musical stimuli and recognize the emotions valence (Banzi and Folgieri, 2012) and to reveal the mechanisms of the visual creativity (Folgieri, Lucchiari, Granato and Grechi, 2014). The objective of the studies, past and *in fieri*, is to evaluate the emotive and the cognitive response to stimuli, with the aim of understanding what are the mechanisms triggering creativity or characterizing the creative process (the insight). In some experiments, the objective is to evaluate the emotive and cognitive response to visual-perceptive stimuli (Allison and Pineda, 2003; Wiggs and Martin, 1998), based on the concept of *priming* (Banzi and Folgieri, 2012). Other studies, investigate the mechanisms of response to colors (Folgieri, Lucchiari, and Cameli, 2015), or to stereoscopy and monoscopy (Calore, Folgieri, Gadia, Marini, 2013). The obtained results show interesting correspondences among some cerebral rhythms and the creative activity.

Currently, the research focuses on the comprehension of the cognitive mechanisms at the basis of creativity, of emotional intelligence and expression, but the technological cognitive tools at disposition today show, evidently, an enormous potentiality, in giving the possibility to verify, as Vygotskij stated, how the human ontogenesis is strongly influenced by cultural (technological, in our Era) tools at disposition in the historical and social context.

## Creativity enacted: Mind the chair

Art might be seen as a window on the mind. It allows probing implicit and explicit thinking processes since artworks are able to give a tangible shape to a complex and covert brainwork. To do so artists generally use some kind of media that we call epistemic instruments. Even artists’ body may be used as an epistemic instrument and in some case either thoughts or apparently simple movements. In this sense, art may be considered as creativity enacted, since the mind/brain interacting with the surroundings try to close the cognitive loop open by intuition by translating it in a shareable matter.

This is the reason why cognitive scientists are interested in Art. In fact, they study artificial and natural intelligence, and creativity is one of the most investigated fields. Among the questions to which cognitive scientists try to answer, we wish to recall the following:

- Creativity is innate or can be acquired?

- Could we strengthen it, stimulate it?

- Is there any area of the brain where it resides?

- Is it a prerogative of natural intelligence or also of the artificial systems?

Creativity may be defined as the ability to generate novel and valuable ideas and artifacts. From a cognitive point of view, creativity is a complex cognitive, process resulting from the search of a balance between conscious and unconscious processes. Indeed, creativity may be considered a borderline state of mind, in which the thought seems to fluctuate in a fluid cognitive state. When a new idea arises to the consciousness, and then a balance is achieved, the mind turns back to a “creative-off” state and divergent thinking is replaced by canonical thinking.

Taking an external perspective, we can see creativity as the process that gives rise to these new items (ideas and artifacts) and then we can define three kinds of creativity since new ideas may derive from the combination, exploration or transformation (Boden, 2004). This perspective allows scholars not only to analyze human's productions but also to investigate if computers may show some kind of creativity and which computational mechanisms could underpin this process.

However, we are interested here in how the human brain may interact with epistemic instruments to shape intuitive ideas. We can find a theoretical foundation in the work of Piaget (1970) and Vygotskij (1925) who underlined as the interaction between subjects and objects stimulates the constitution of superior psychic processes. Nevertheless, Vygotskij expresses an interesting point of view, strongly related to the consideration of the links between creativity and means (also technological ones) at disposition. In fact, he underlines how the human ontogenesis is determined also by the contribution of the cultural instruments available in the social context.

The experience we have of the world is made up of details and information, but is also rich in complex forms that interact each other not only to shape concepts and meanings, but also to evoke emotions, memories, thoughts, which are not directly matched with some physical features of a given stimulus detected by the senses. Consequently, creativity is a basic cognitive process which mechanisms are hard-wired in our brains so to give rise to a whole experience of the world, even when we see it for the first time. Hence, these processes allow the human brain to enrich our experience, shaping the deeper motivations that guide our cognition well beyond contextual needs. This is the cognitive core of creativity. As Ramachandran and Hirstein (2011) pointed out, creativity is not magic at all but is the consequence of the way our brain works. In fact, we continually learn and use heuristic rules that guide use in our exploration of the world and these rules allow easy (sometimes, creative) generalizations.

However, this process does not give rise to an illusionary world: simply, it extends mind possibilities, opening new frontiers and unblocking landscapes and options, thanks to an “as if” experience. Furthermore, this view of the brain working through "as if" processes may be integrated with the theoretical perspective by Changeux (1994). This author argues that we should always consider the perception as a creative process. For instance, when someone observes something (e.g. an artwork) in his/her brain a sort of re-creation is “in march”, so to find a meaning but also to attribute mental states, emotions, intentions to the “source” of that object, thus mentally tracing the path from the creator to the observer.

Creativity may also be described in relation to problem-solving since it allows to think “out of the box” to find a solution. Problem-solving is a one the function of thinking and is a basic issue in cognitive psychology. It refers to the activity performed by a living organism or by an artificial intelligence device to achieve a status starting from one or more given condition. It is, so, the set of processes allowing analyze, organize and combine information to solve given problematic situations. In its work “The Act of Creation”, Arthur Koestler (1964) explains creativity through the bi-section mechanism that is “means to join unrelated, often conflicting, information in a new way”. In fact, if in our daily life we associate elements belonging to the same reference system (book-sheet, cooking-food, etc.), in the artistic, humoristic or scientific creation we realize a connection among heterogeneous reference systems, usually considered incompatible. Problem-solving and creativity are correlated cognitive processes and can be analyzed through Brain Imaging methods, and it is evident that we can measure, also quantitatively, the activation level of a brain, analyzing the electric signal produced (Zeki, 2001).

Consequently, we can state that the more and more cognitive scientists now consider the creativity as a basic field to explore in order to better understand how our brain works and hot it shape our mental processes. We argue that in this investigation we cannot rely only on traditional methods and techniques. We also need creative methods. For instance, new technologies are now available to be used outside psychological labs so to implement creative experiments. Artworks investigation might become a relevant field in a near future.

In particular, the links among Art and Technology, creativity and the study of its mechanisms are several:

- the opportunity for the preservation of the artistic heritage;
- the potentiality provided by new instruments for the artistic expression;

- the possibility to study the links among Art, brain and Technology and, jointly,
- the creative processes, allowed by the progress of Artificial Intelligence, *Brain Imaging,* and technological devices.

In this introductory paper, we will focus on the last point of the list. In the next paragraph, we will introduce why and how scholars perform scientific investigations on creativity. In the following, we present the use of technology to express creativity and an experimental example of it, concluding with our considerations.

With the aim to show how creativity is related to brain activation, we wish to introduce "Mind the Chair" (or "La sedia del Pensatore"), an interactive installation focused on a real time audio/visual representation of the activity of the brain, providing the possibility to control it. The performance allows visualizing the level of concentration of an individual, through an audio/visual answer (LED lights and sound generation/manipulation). While using a BCI headset, a person is able to understand how 'control' own brain activity and therefore to increment the level of concentration, modifying the intensity of the light or filtering the associated sounds. The interactive performance aims to give awareness about how our brain works and what 'concentration' means, therefore, how much brain energy is required to perform a specific task (for example, to increase the lighting), and how it can be difficult to keep our brain working for a certain amount of time.

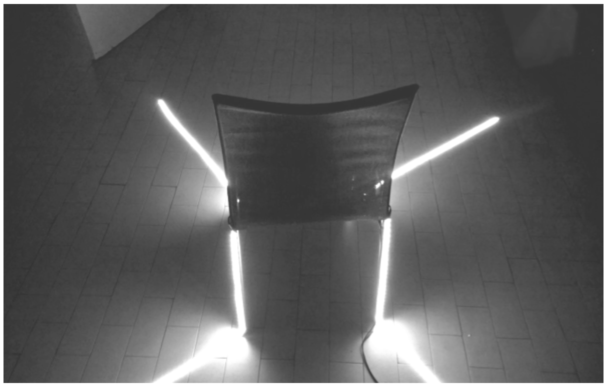

Figure 1: "Mind the chair", Francesco Soave. The performance installation in action, as exhibited in the artistic event " Terni Festival", 18-27 Sept 2015, Terni, Italy.

The concept comes from the idea of 'the chair of the thinker' where a person sits on a chair, and its own thought starting from the mind, flows through its body, along the chair and then in the surrounding space as light.

During the performance, the visitors are not given physical objects to concentrate on. They are only asked to 'concentrate' in terms of 'focusing' on something close to their attitudes. The visitor is required to not distract too much from feeling his/her brain activity, or the purpose of the installation would fail. During the performance, the word 'concentration' is, then, used as the simplest way to describe the aim of the interactive installation that is testing the power of the brain. For instance, many visitors tried to relax doing some yoga exercises, but even if they were expecting a deep fall of the lights, this didn't always happen as, in fact, whatever action you perform requires brain activity, even the act of relaxing and 'freeing' the mind.

The ability to control the brain rhythms and the concentration level, depends on, of course, by the experience of an individual: solving a simple equation can be an easy task for a mathematician, but can be a really difficult task for a non-mathematical mind. To make the installation react is, then, necessary to find a specific, personal task that makes our brain work, which, of course, can be different for different people. Also, the ability to control the brain changes depending on the psychophysical status of the person: if the user is really tired, he/she will experience difficulties in controlling the performance. Interesting enough, when the brain activity is peaking, individuals show more difficulties in losing focus and slowing down the level than actually increase it.

To realize the project a Neurosky Mindwave BCI interface and specific Java code were used to detect the brain activity through the analysis of the collected brain waves. In detail, as the installation involves concentration, Beta rhythms play a key role in identifying the level of brain activity. To make the representation consistent with the real brain activity, the interactive installation does not have a 0 level (in terms of 'lights off'): this is because our brain is working at all times and what makes the difference is the amount of work required to perform a task. Then, when the level of concentration is close to zero, a random blinking will appear, to represent the floor noise which is, in fact, a random signal existing in every kind of impulse and therefore even in the EEG brain rhythms.

## Conclusions

Cognitive Science as well as neuroscience study creativity and artistic inspiration to discover their cognitive mechanisms. At the same time, non-invasive and wearable new brain technologies (e.g. BCI devices) may be used to new artistic expressions (i.e. as epistemic instruments) allowing researchers to investigate how the brain creates and understand Art in real-time and in an ecological setting. In cognitive science, the functioning of the brain and the achievements of Art are considered together to explain our aesthetic experience. The application of the Cognitive Science approach to Art, entertainment, and educational fields also represents a promising field. In fact, the importance of a BCI-based performance like “Mind the chair” is not limited in creativity studies. We argue that the use of BCIs and similar tools, such as, for example, eye trackers, should also be useful within a pedagogical program in order to contribute improving users’ ability to focus attention on abstract cognitive tasks and in translating abstract thinking in concrete operations. Many people find great difficulties in approaching similar tasks since their attention is easily grabbed by environmental distractions and so they fail in getting important educational achievements. Furthermore, the ability to focus and maintaining attention on mental tasks may contribute to the development of multitasking abilities, now considered particularly important in different contexts. Normally, expressive arts techniques are useful in helping people to increase attention skills, but they are limited by individuals’ technical competencies (e.g. drawing) or by personality traits. BCI-based tools, such as BrainArt (Folgieri, Lucchiari, Granato and Grechi, 2014) or BCI-based performances, may instead be enjoyed by everyone, without any prerequisite both in stand-alone and in group settings. Future research will test if BCIs are concretely able to increase attention-based skills and creativity, potentially increasing the penetration of art within the realm of the neuro-cognitive approach to individual empowerment both in normal and pathological conditions.

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# Face to Face – Performers and Algorithms in Mutual Dependency

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**Abstract.** This article explores modes of interaction or 'interfacing' between dancers or musicians and algorithms, and the ways in which inter-dependence and co-performance between human and machine performers arises. Two artistic works, an interactive dance piece and a live-electronic music piece, serve as example cases for the observation and discussion of how algorithms can play a central role in composition processes as well as human-machine interactions during performance. The intended goal of using algorithms in this context is the emergence of idiosyncratic behaviours in interactive systems that reflect and combine aspects of the performance situations, the generative algorithms and the adaptation mechanisms themselves. By comparing the interaction relationships and 'interfaces' of the example works, fundamental differences of the algorithmic systems become visible, and a better understanding of the impact and effect of algorithmic systems in real-life performance can be gained.

**Keywords:** adaptive mechanisms, algorithmic behaviour, artificial evolution, interactive dance, interactive systems, live-electronic music, machine learning.

## Introduction

Human-machine interactions in live-performance represent a broad and common topic in electronic music and interactive dance practices. Less common is the use of adaptive and learning algorithms during composition, systems design, and the performance phases of such works. The use of intelligent and adaptive algorithms enhances, yet potentially also obscures the human performer's role as the source and focus of the expressive force of a piece. Because of this, both technical and conceptual challenges arise when developing strategies for establishing meaningful links and relationships between human and algorithmic agents.

For an improvisation system to respond to a performance situation in an adequate manner, the system's properties need to be adapted to the particular characteristics of the context. Such an adaptation can take at least three different forms: the system can be provided with context-specific source material to operate on, the system's sensory predisposition is specifically selected for perceiving the activity of the performance partners, or the characteristics of the system's behavioural properties are specifically chosen and adjusted to the context.

In this article, we explore the modes of interaction or 'interfacing' between humans and algorithms, and the ways in which a balance between inter-dependence and co-performance of all involved players may be reached. With the help of two exemplary pieces, we attempt to show how two types of intelligent algorithms inform compositional solutions, how principles that are derived from the technical characteristics of chosen interfaces influence behaviours (and vice-versa), and how inherited structures and action patterns can generate a conceptual interface between performers and algorithms.

At the same time, the limits of applying intelligent algorithmic systems to artistic concepts that rely heavily on human expression are exposed. The main constraint is the necessity to control a system's problem and solution space, in other words, to design and train it to consistently produce meaningful output, while remaining adaptive and responsive. An additional characteristic of working in the performing-arts context is the highly specific and idiomatic ways in which performers behave. Dancers, for example, may be repeating a choreography and musicians a given piece of music, but the variability in interpretation due to renewed expressive shaping is considerable. In open-form, improvised performance, without the presence of strictly scored movement- or sound-phrases, the field of possible variations becomes so wide as to prevent the formalisation of generalised solutions that are appropriate for algorithmic systems. Therefore, in both example works, the training and adaptation phases are closely related to the individual performer's phrasing and repertoire as well as the composition's conceptual intentions, and occur during the inception and development phases rather than the performance.

By juxtaposing the central characteristics of each piece, we show the consistent relationships and their 'conceptual interfaces', observe differences in the structure and concept of each piece, and the manner how the generative, algorithmic systems are deployed.

## Background

Much of the fascination and potential of generative systems arises from interactive settings and in particular from real-time performance (Lewis 2000). In such settings, the procedural nature of a work is exposed and becomes integrated into a larger web of relationships between algorithm, performer, audience and environment. Through their impact on the characteristics of these relationships, generative methods may substantially alter the creation processes in interactive, technologically mediated dance and music performances (Jones, Brown, and d'Inverno 2012).

In terms of generative open-endedness, automated forms of real-time adaptation are important since they influence the diversity of a generative system's behaviours (Galanter 2009) and may be considered to exhibit a high level of meta-creativity (Eigenfeldt et al. 2013). However, in order for generative, algorithmic systems to become a productive part of creation processes, it is essential that their unpredictability be balanced by reproducible outcomes. While consistency is essential for understanding generative behaviour, it is only through unpredictable behaviours that generative, algorithmic systems can provoke creative discoveries (Beilharz and Ferguson 2007).

Open-form and improvisational practices both in music and dance provide the opportunity for algorithms to act as artificial performers and to engage in a playful and exploratory manner with their human counterparts. These improvisation situations constitute examples of "synergistic hybrid human-computer systems" in which a generative system assumes the role of a colleague (Lubart 2005). But these algorithms can only usefully contribute to a performance, if they are sensitive to context and environment rather than merely autonomous and independent (Bown and Martin 2012).

## Example Works

Two artistic projects shall serve as real-life use-cases in order to observe and discuss how algorithms can play a central role in composition processes as well as human-machine interactions during performance. The two examples come from the complementary fields of interactive dance and open-form music with live-electronics. The concepts and premises of each work are different, yet both exhibit an overlapping, blended space (Fauconnier and Turner 2003) between performer and algorithmic system. A comparative analysis of these examples can generate a better understanding of the role and import of adaptive algorithms in human-machine interactions in general and in performing arts with algorithmic systems in particular.

### Phantom Limb: Virtual Body Structures for Interactive Dance

The interactive dance performance "Phantom Limb" was realised in collaboration with composer Pablo Palacio and choreographer Muriel Romero. The performance employs a generative approach to allow a dancer to alter and extend her bodily presence and movement possibilities. This approach is based on the simulation of artificial body structures whose morphological and behavioural properties are tightly interrelated with the dancer's body and movements. The virtual body structures take on the role of extensions of the dancer's body that are capable of responding to her activities through a combination of reactive and pro-active behaviours.

The morphology of both the dancer and the body structures are represented by the simulation. The morphology consists of a mass-spring system (MSS) that is organised into a branching tree-like structure. The simulation models spring tension forces according to Hooke's law and simulates directional restitution forces that push springs towards relative rest directions. In addition, the simulation implements an Artificial Neural Network (ANN). This network can possess recurrent connections and signals propagate with time delays. The activity of the ANN affects the properties of the MSS and vice versa. This functionality is realised via the implementation of sensing and actuation elements. Sensing elements read the property of a spring and modify the activity of a neural node. Actuation elements change the property of a spring based on the activity of a neural node. For a thorough discussion of the simulation principles please refer to (Palacio and Bisig 2014).

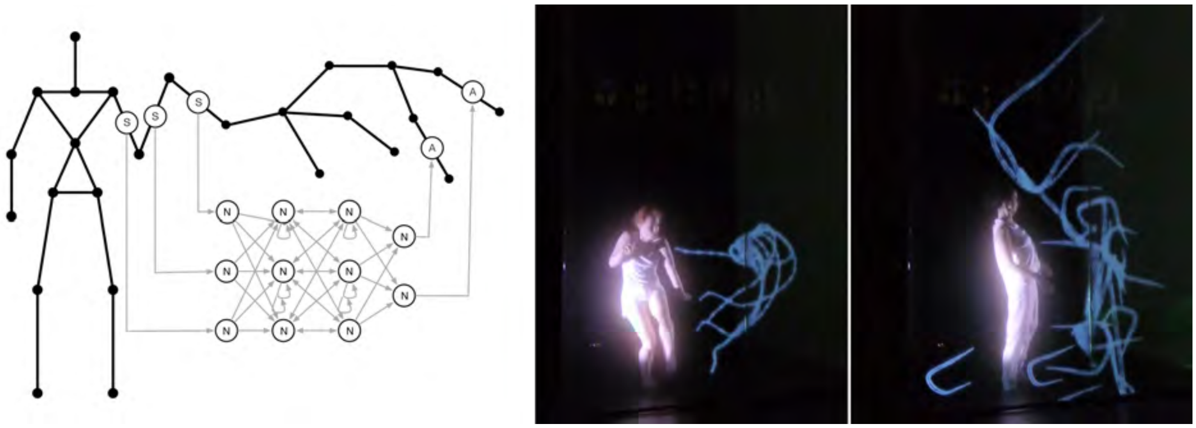

Figure 1: Phantom Limb: Simulation and Presence of a Body Structure. Left Side: Schematic depiction of a morphological and neural coupling between a skeletal representation of a dancer and a virtual body structure (black circles: mass points, black lines: springs, circular outlines: neurons (N), sensors (S), actuators (A), grey lines: neural connections). Right Side: Video projection of body structures on a transparent screen that hangs in front of a dancer.

Behavioural coupling between dancers and virtual body structures is based on their common abstraction and operational use as MSS and ANN (see left side of Figure 1). The MSS representing the dancer's body is acquired by a Kinect-based skeleton tracking mechanism. This skeletal MSS is extended with a simple ANN that serves as a proprioceptive sensing mechanism which translates the dancer's body postures into neural activity patterns. By connecting elements of the dancer's skeletal structure with those of a virtual body, the latter becomes a physically coupled mechanical system that propagates the dancer's movements. A neural coupling is established by axonal connections between the proprioceptive sensing elements located on the dancer's skeletal joints and the ANN of a body structure. This allows the dancer's movements to affect the neural activity in the ANN, which in turn initiates and modulates the active behaviours of the body structure.

For most body structures, the MSS was designed by hand whereas the ANN was generated automatically by a process of artificial evolutionary adaptation. This adaptation process took place during the development phases of the piece and served to create a repertory of behaviours that are related to specific movements of a particular dancer. Adaptation is based on a genetic algorithm that affects neurons, sensors and actuators in the model. The fitness function evaluates the quality of behavioural synchronisation between dancer and artificial body structure and can be manually overwritten in order to favour certain traits.

The visual rendering highlights the morphology of the body structure by rendering it as three dimensional tube-like structures that represent the branching topology of the underlying MSS (see right side of Figure 1). This rendering is projected on a transparent screen that hangs in front of the dancer and places the resulting image at a position and scale that aligns with the dancer's own body position and size. This settings fulfils two purposes: the correspondence between the dancer's body and movement and the virtual body structures is clearly visible for the dancer, and the audience perceives the appearance of the dancer and that of the virtual body structures in a visual superposition.

The sonification of the body structures complements the visualisation and foregrounds the sensorimotor coupling between the dancer and the artificial body structures. It does so by rendering audible the internal structural relations and dynamic processes that underlie the simulated behaviour. The sonification employs a combination of different sound synthesis and mapping techniques. Additive synthesis renders movements of the body joints audible as coordinated glissandi. Alternately, the shape of the body structures is used to control an extended dynamic stochastic concatenative synthesis model (Luque 2009). A third approach maps activity bursts within the ANN to the parameters of a synthetic percussion model, thereby generating polyrhythmic musical structures. For an in-depth discussion of the sonification principles please refer again to (Palacio and Bisig 2014).

## Double Vortex: Supervised Learning in Live-Electronics

The investigation into the potential of machine learning (ML) algorithms as generative tools in electronic music is carried out with the piece "Double Vortex" for trombone and live-electronics. The interaction of the instrumentalist with the algorithmic system reflects varying degrees of inter-dependence. The connections range from purely analogous linkages to interactive and quasi-independent decision taking by the ML algorithms. The core question in the compositional process is that of agency and inter-subjective interaction, or simply the interplay between trombone player and algorithmic system. The intent is to generate a conversational interaction model that may also exhibit abstract autonomous behaviours, which are not necessarily perceptually connected to the sounds or actions performed by the musician.

Live-electronic sound processing and motion sensing represent the compositional domain that problematises the relationship between musician, instrument, movement, sound, and the algorithmic system. For the audience the declaration and subsequent recognition and reading of these techniques during performance generates expectations: they want to see and recognise the linkages and dependencies that are 'at play'. A way of playing with these expectations through the composition is by letting the system sometimes fulfil them and sometimes propose alternate modalities of interplay, the most abstract of which are autonomous, algorithmically generated musical decisions. Thus, the technology sits at the conceptual nexus between the instrumentalist's actions and the natural or electronically extended sounds.

Different ways of relating musical playing techniques and movement characteristics are explored either perceptually, or with the aid of movement and orientation sensing. The juxtaposition of movement- and sound-instructions for the musician lead to sections of the piece where simultaneous playing and moving of body and instrument produce a perceptual shift between eye and ear (see right half of Figure 2). With this strategy, complex movement patterns are overlaid to musical elements and influence the instrumental sound through a physiological impact, affecting the breath and destabilising the air-column by disturbing the player's posture.

To clarify the technical system a brief description of the systems structure of Double Vortex follows (see also left half of Figure 2). For an in-depth description of the technical tools used in this piece, please refer to (Schacher, Miyama, and Bisig 2015).

The machine learning tool is configured with three pipelines that simultaneously observe the trombone player's movements (see left half of Figure 2). The two flavours of supervised ML algorithms, Dynamic Time Warping (DTW) from the Gesture Recognition Toolkit GRT (Gillian and Paradiso 2014) and the Gesture Variation Follower (GFV) (Caramiaux et al. 2014), need to be trained, i.e., provided with templates of the movement patterns to look for. The configuration of sensors on the instrument, along with the use of patterns that are specific to the performer, demands that training be done by the instrumentalist himself, in circumstances as close to the performance as possible. This points to the fact that training should eventually become an integral part of the performance, since training by demonstration can be done in real-time with the appropriate algorithms.

For this work, and in relation to the trombonist's movement repertoire, six archetypal movement sequences are trained that can be recognised easily during performance. They are achieved with more or less ease during playing, either fully formed in the proper tempo or as elements of other gestures. It turns out that training the system with very precise movement patterns leads to a well trained ML system, but also to a narrow window of recognition. Providing a more broadly varying set of templates renders recognition more tolerant and lowers the threshold for obtaining meaningful results.

The output of these algorithms is used to control live-electronics processing for capturing and a subsequently deconstructed rendering of the sound materials performed by the trombone player himself. In order to achieve this, the boundaries of the algorithm's capabilities are explored. In addition, the differences in reaction time between the two types of algorithms are leveraged. GFV, on the one hand, is relatively fragile but provides a continuous answer about the position within a template. DTW on the other hand is quite robust, but only provides an answer after recognising a segment. In this system the two algorithms cooperate. The former takes the decisions for capturing sounds and the latter triggers a response using these deconstructed sounds-elements.

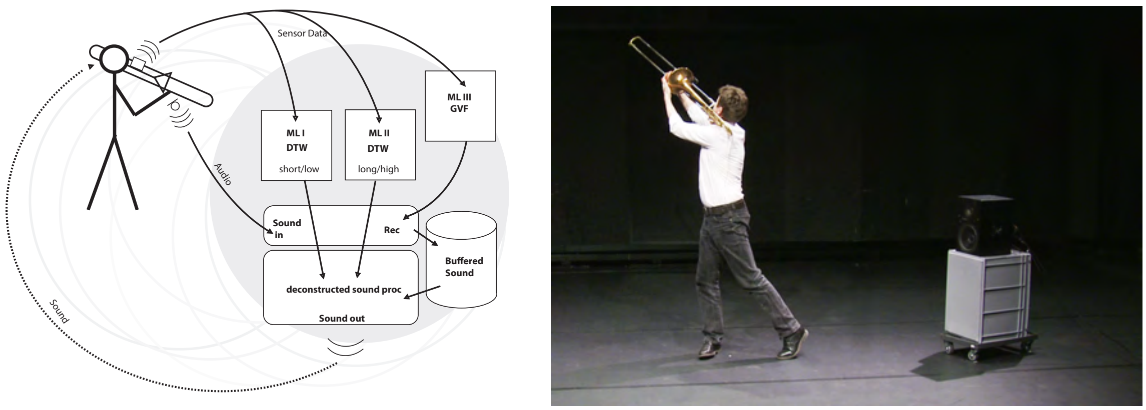


Figure 2: Double Vortex: Left: Relationships between trombone player and software agent. Of the three machine learning pipelines (ML), the first two (DTW) control sound generation, the third pipeline (GVF) controls the capture of audio. A central element is the sound feedback given to the musician. Right: Stage configuration with the moving performer and a single speaker.

## Conceptual Interfacing

The two artistic examples presented here provide an opportunity to reflect on common characteristics in order to better understand the role and impact in the live-performance context of algorithmic systems endowed with some form of autonomy. In addition to the technical modes of linking the performers to the machine and vice-versa, conceptual couplings become visible that represent the central 'interfaces' for both works. The following overview juxtaposes the two tiers of interfacing: on the one hand the **technical** linkage and on the other hand the **conceptual** role of the algorithmic system in relation to the human performer.

| Interfaces | | Phantom Limb | Double Vortex |
|---|---|---|---|
| **technical** | sensing input | camera/skeleton tracking | motion (IMU), microphone |
| | media output | image, sound | sound |
| **conceptual** | semantic | behavioural coupling w/algorithm | behavioural coupling w/algorithm |
| | inheritance | morphology | sound material |
| | adaptation | evolutionary adaptation | machine learning |

Table 1: Comparing interfacing relationships between the two works.

In both cases the **technical interfacing** between system and dancer/musician is informed by the necessities of stage-worthiness and portability.

*Phantom Limb* employs camera-based tracking to update the dancer's representation as an MSS and to generate new sensory inputs for the ANN. The stationary camera provides an absolute spatial reference that allows to position the dancer's body in relation to the virtual body structures.

*Double Vortex* connects the performer with the system with the aid of a motion-sensing inertial system, that provides data about the absolute orientation of the instrument in space. This information enables the ML system to observe the performer, and controls by traditional mapping aspects of processing of the instrumentalist's sound.

A microphone on the bell of the instrument is the source of all sound treated by the live-electronics, and also generates an acoustic feedback path between the instrument and loudspeaker.

In *Phantom Limb*, the creation of synthetic audio and video is based on a sonification and visualisation approach and fulfils the functional requirements of highlighting the kinaesthetic correspondences between dancer and body structures.

In *Double Vortex* the algorithmic system as well as the traditional live-electronics processing produce their results as sound. This is played back on a single speaker situated next to the performer, thus endowing the system with the character of an independent 'object' if not 'subject' that is present on stage.

The **conceptual interface** exists in the manner that performers and algorithmic systems relate to each-other in the domains of perception, measurement, and particularly behaviour.

The *semantic* relationship describes how significance or meaning is generated by the presence of both human performer and algorithmic system.

The design of the simulation in *Phantom Limb* is informed by concepts from the field of embodied artificial intelligence (Pfeifer and Bongard 2006). Phantom Limb connects to the notion that fundamental aspects of agency as well as cognitive capabilities are grounded by mutual inter-dependencies between a system's physical, morphological, perceptual and neural characteristics (Sørensenn and Ziemke 2007). This approach enables the integration of an interactive system with embodied improvisation techniques in dance and emphasises the relationship between bodily predispositions and kinaesthetic imagination and creativity.

*Double Vortex* is designed to endow the algorithmic system with a semblance of autonomy. This perceived autonomy challenges the notion of control by the musician and creates a slight ambiguity with regard to authorship and the origins of the perceived sounds. At the same time it demands of the musician to act and interact with the system during the performance, thereby enforcing a shared focus between inner and outer perception (Marcel 2003).

The *inheritance* relationship describes how behaviours and structures are inherited from one side to the other.

In *Phantom Limb*, the visual and acoustic rendering of a body structure possesses little similarity with the dancer's appearance. Rather, inheritance originates from a correlation of simulation-based abstractions. A direct form of inheritance is established through a mechanical coupling between dancer and artificial body structure. A less direct form of inheritance is created by giving the ANN a sensitivity to particular types of dance movements. This increases a dancer's influence on the behaviours of an artificial body structure.

In *Double Vortex* both sides operate in the movement as well as sound domain. By linking the technical observation to movement and not sound, a gestural rather than sonic link is established between musician and algorithm. Since the resulting responses of the system occur in the sonic domain, by reusing, deconstructing, and therefore abstracting the instrumentalists sound contribution, a first type of inheritance is established. As a consequence, the reaction to the decoupled sound-events that originate from the system puts the human player into an inter-dependence, thereby generating a 'dialogical' and truly interactive situation.

The *adaptation relationship* describes how the presence and actions of one side influence the behaviour and output of the other.

The evolutionary adaptation in *Phantom Limb* serves to provide the ANN with sensitivity to particular dance movements. This results in a continuous mapping between input data, simulation behaviour and audiovisual rendering rather than static relationships between input categories and musical events. The criteria specified loosely by the evolutionary fitness function enable a large solution space. This enables the automated adaptation process to come up with a wide variety of potentially interesting solutions, later to be narrowed down according to additional quality criteria.

The technique used in *Double Vortex* to create adaptive responses from both sides is to deliberately blur the precision of pattern-recognition and to modulate the sensitivity of the algorithmic responses in such a way as to generate a self-reinforcing adaptive loop between performer and system. In addition, the juxtaposition of decisions by the musician with semi-autonomous musical decisions by the algorithmic system creates a balance. Both agents need to perceive the other in order to meaningfully react. The performer does this by listening to the algorithmic sound responses, the machine does it by watching the player’s movements.

## Discussion and Conclusion

By juxtaposing the two case studies several arguments can be developed which may inform a common heuristic for integrating human performers and algorithmic systems into shared improvisation contexts.

A core concern when using generative algorithms in an interactive setting is the issue of comprehensibility of a perceivable, albeit complex, correlation between human and machine activities that becomes visible both from the performer and the audience perspectives. Three elements affect this: human and machine possess comparable perceptual capabilities, human and machine exhibit a shared musical and/or visual presence, and human–machine interaction is at least partially reproducible.

The machine possesses perceptual capabilities that enable it to read and respond to aspects of the performing partner’s presence and activities, which in turn are readily observable by the human player. In both *Phantom Limb* and *Double Vortex*, the machine’s perceptual capabilities are connected to the performer’s own kinaesthetic body awareness.

The visual and/or sonic presence of both interactive systems is sufficiently related to the presence of the human performers for comparing them within a perceptual as well as aesthetic domain. In *Phantom Limb*, this shared presence is apparent in the visual overlap between the dancer and the simulated bodies but also exists in the metaphorical domain as a sonic translation of kinaesthetic activities. In *Double Vortex*, the shared presence arises from the combination of the physicality of both the human musician and the loudspeaker. The speaker-object acts as a physical representation or ‘place-holder’ for the interactive system whose musical co-presence is based on live-input and transformation of the instrumental sounds performed during the piece.

In both cases, the interaction between human performer and algorithmic system only becomes traceable and comprehensible once clear relationships between their respective behaviours are established. While the characteristics of these relationships are discovered, developed and reinforced through the use of potentially open-ended adaptive mechanisms, these mechanisms themselves are no longer operational during performance. They occur during the composition, design and rehearsal phases. In Phantom Limb the evolutionary adaptation relates to idiomatic movement phrases of a single performer, whereas in Double Vortex the training of the machine learning serves to capture gesture templates that are recurrent or demanded of the musician during performance. This approach preserves the capability of generative systems to create surprising interactive relationships, but at the same time stabilises the relationships in order to make them reproducible.

Employing machine learning and evolutionary adaptation facilitates the integration of generative, algorithmic approaches with compositional and choreographic techniques. While it is still possible and fruitful to integrate musical or movement concepts directly and explicitly on an algorithmic level, the generative system can be primed with particular performance ideas through an iterative process of exposition to representative elements of the performance. By doing so, the generative system is treated as an artificial performance partner throughout the creation and rehearsal phases of a new work. This establishes a more fluid and immediate mode of exchange between algorithmic design decisions, choreographic and compositional goals, and experimentation and experience in performance.

A core concept that is shared by both case studies relates to the automated adaptation mechanisms. They are used to transfer some of the stylistic or subjective qualities of a particular performer and performance situation to the interactive system. This transfer reduces the generic aspects of human machine interaction in favour of a relationship that conveys elements of an inter-personal exchange. Thus the interactive system becomes sensitive towards higher-level expressive qualities that are unique to a performance situation. This enables the emergence of idiosyncratic behaviours in the interactive system that reflect and combine aspects of the performance situation, the generative algorithms and the adaptation mechanism itself.

In closing, we wish to emphasise the complexity of the relationships generated when creating work in this manner. These relationships are by no means limited to the performer and the algorithmic system. Rather, the performer's presence is preceded by the composer's and choreographer's intentions and efforts, and is completed by the audience's partaking in the performance. A particular aspect of the distributed authorship between human and algorithmic performers is the inherently unstable relationship and the necessity to continuously negotiate the position of each player in this game. After all, the effectiveness of these strategies can only provide an aesthetic gain to a person who manages to perceive all the intertwined and relational elements of a technological performance as one.

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# Pod: A Multi-Sensory Sound Interface

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**Abstract.** This paper describes the development and presentation of Pod (2009-present), a multi-sensory sound installation involving sight, sound and touch. Pod consists of large inflatables with speakers inside emitting low-frequency sounds - sounds that the audience are encouraged to touch through the medium of the vibrating skin of the inflatable. A consideration of the use and management of multiple sensory modalities, techniques for combining audio and visual into a cohesive work and the concept of the interface as an exploratory boundary between audience and sound are presented.

**Keywords:** Sound installation, tactile, multimodality, multisensory, audience engagement, interface metaphors.

## Introduction

This paper describes a sound interface, not - as the term is commonly used - a controller for musical parameters such as pitch and volume, but a boundary between the audience and sound; a tactile membrane which converts audible frequencies into tangible vibration. The work described herein is Pod (2009-present), a sound installation which has been presented publicly several times since its debut, at venues such as Oxford's Light Night and the Barbican in London (fig. 1). The piece is an ongoing collaboration between artists Alison Ballard and Mike Blow, and grew from a desire to encapsulate sound in such a way that it was given form and substance.

Aesthetically Pod consists of low-frequency sounds emanating from inside large inflatable spheres (the 'Pods'). The first incarnation, at Shunt under London Bridge station in 2009, used 6 climb-in balloons each with an inflated diameter of around 2m. Each balloon contained a pair of speakers in a cardboard resonator tube fed from an external amplifier and a MAX/MSP patch, which provided low frequency sine waves of around 75Hz. Since 2013 the piece has continuously evolved and is now presented as two 1.8m PVC spheres which are much more robust and allow for outdoor siting. The audience are encouraged to touch and hug the inflatables to feel the sound vibrations with hand and body. The piece is simple in concept but elicits a range of responses and behaviours from visitors and is very much a live sound interface of a tactile and experiential kind. As well as being a sound-touch translator it is also cross-modal work where the colour, shape and sound are all designed to mutually reinforce the audience experience (see discussion).

Figure 1. Pod at the Barbican, London (Mike Blow)

## Context

Pod currently consists of two 2-meter inflatable spheres emitting low frequency pulsing sound. The public are invited to touch and hug the spheres, which resonate with the frequencies played inside. Due to its use of inflatables this work has overtones of play, like Jeff Koons' balloon animals (the majority of which were actually steel, e.g. Balloon Dog 1994 - 2000) or Florentijn Hofman's giant Rubber Duck (2009 - 2013) - and indeed the piece can be seen as sonic playground, multimedia artwork or physics demonstration depending on the context in which it is shown. Both Mark Bain's Sonusphere project (2003) and Kurt Perschke's Red Ball Project (2001 -) use large inflatable spheres, Bain's piece being especially relevant as it used the sphere to present sounds coming through the earth beneath the building in which it was situated. However both pieces have at their core an engagement with space and are have architectural motivations, a distinct difference to Pod. Although careful siting is a factor in our installations, the piece has grown out of the idea of the visceral experience of sound rather than trying to comment on the space in which it is sited. It seems to turn the attention inward rather than outward and in this respect it shares more ground with the experiential and meditative motivations of the Luminaria by Architects of the Air (1990 -). With speakers inside, Pod is a tactile listening experience; the low frequency sound and vibrating skin of the spheres encourage the audience to listen to the sound through their bodies as well as their ears. The resonance of the body's internal cavities and the possibilities of corporal listening have been the focus of Bernhard Leitner's Sound Chair (1976) – deriving partly from Leitner's belief that sound affects our physical and mental wellbeing (Licht 2007 p. 42 ) - and Kaffe Matthews' Sonic Armchair (1997) and Sonic Bed (2005), all with embedded loudspeakers. Works that exploit or make apparent the vibrational quality of sound and its interaction with materials are at the core of the sound art canon, Alvin Lucier's work and David Tudor's Rainforest IV (1973) being obvious examples. Notable also is Laura Maes' Oorwonde (2011), a multisensory experience that aims to create the experience of an 'aural operation' using speakers and vibrational transducers embedded in a steel hospital trolley. Pod focuses on the whole-body experience of sound, but arguably in a more visual and playful way than these examples. Nevertheless, the idea of a new way to focus on audio (meditative and restful, and often with the eyes closed) seems to be common to most of the corporeal listening works and Matthews' sound bed incorporates the same ideas of a collective sound experience, being big enough for several people to lie side by side.

# Technical

As mentioned in the introduction the first incarnation of the work used climb-in balloons, which are simply larger and slightly tougher versions of party balloons with a 10cm neck hole. The sound equipment consisted of two 6" woofers facing each other inside a cardboard tube which helped combine and resonate the frequencies from the speakers. The speakers were fed with a sine waves at slightly different pitches to produce slow pulsing beat frequencies. All of these technical decisions were strategies to try and achieve the appearance of very low frequency sound within the limitations of relatively small speakers and restricted entry to the balloons.

In 2013 the piece was commissioned for the Whitley Arts Festival in Reading and as the site was to be outside the fragile climb-in balloons were replaced by two PVC inflatables which, if punctured, just deflate slowly rather than exploding. The internal equipment also evolved, using MP3 players and T-Class 12V amps powering standard installation speakers all being run off a 12V leisure battery. We also fitted a low-wattage omnidirectional LED light to give a subtle glow. As this equipment was inside the Pods they were fully autonomous and able to run for many hours outside without attention.

A desire to be able to adjust volumes on the fly and for more interest in the sounds has led to the current version, which retains the speakers and amp but broadcasts the sounds to the Pods over a proprietary performance radio system. In this way the sounds can be created live from a Pure Data patch and consist of a long drone loop of a low-frequency pulse of around 75Hz with random frequencies chosen by the software of between 100 and 300 Hz superimposed upon the drone, changing every 10-12 seconds. The result of this is that the tactile element of the piece is retained but the sonic element has more movement and interest as the fundamental (lower) and harmonic (higher) frequencies randomly develop dissonant and consonant intervals, a range of beat frequencies and harmonic tension and resolution. The situation is made more variable by the fact there are always two Pods installed and the interactions in the frequencies are not just created by the bass and harmony sounds of one alone but exist in the space between them and between each of their randomly-chosen pitches.

# Discussion

## Experience not Control

Pod is presented not as a way of controlling sounds (the piece does not react to the actions of visitors) but as a human-sound interface. The experience of being able to feel sound physically at relatively low volume is one which many people seem to find engaging (it is notable that it is very possible to talk at normal levels right next to a Pod as the volumes and frequencies used do not interfere with normal speech). The interface has obvious affordances due to its size and material and visitors often spend quite a long time listening to, touching, hugging and even lying against the Pods (fig. 2). We have had instances of people sitting at the base of them and 'soundbathing' and one visitor, in an installation in a hall with a sprung floor, lay between them to experience the vibrations through his whole body. Our intention is not educational as such, although of course there is an element of revealing that sound is in its very essence movement and vibration to people who perhaps had not previously considered this, but more as a way to give the audience a new experience - a combined sensory event of sight, sound and touch, a tangible version of Michel Chion's synchresis (1994 p. 63). The piece creates a situation where people are encouraged to spend time and focus their perception, which we agree with Viktor Shklovsky is "an aesthetic end in itself and must be prolonged" (1917).

Figure 2. A visitor interacting with the Pods (Alison Ballard)

We try not to impose any readings onto the work apart from the name which perhaps implies something containing an unknown life or technology. In addition the sounds used are abstract and non-referential. This engineered gap in the audiences' knowledge conforms to Umberto Eco's idea of the 'open work' - a purposeful 'non-explanation' which encourages the audience to form their own readings of the Pods at the intersection of the work itself and their immediate (perceptual) and prior (remembered) experiences. Eco suggests that:

> The search for suggestiveness is a deliberate move to “open” the work to the free response of the addressee. An artistic work that suggests is also one that can be performed with the full emotional and imaginative resources of the interpreter. (Eco 1989 p. 9)

## Cross Modal Correspondences and Sound-Object Binding

Pod explores the perceptual relationship between the seen and heard; it has been found through experience that low-frequency drones match the shape and colour of the inflatables better than high-pitched or narrative sounds, and that there is an optimum volume of sound to match the size of the object. While this is clearly subjective, ubiquitous cross-modal correspondences (as distinct from synaesthetic mappings which are unique to one person) have been a focus of my own work in recent years and there is some research from other areas to back the idea up. Psychologist Charles Spence notes that “people consistently match high-pitched sounds with small, bright objects that are located high up in space” (Spence 2011), revealing common correspondences between pitch, size, physical location and brightness. Certain colours are often thought of as being associated with particular types of sounds; bright colours for high pitch and dark for low; in ‘Concerning the Spiritual in Art’, Kandinsky uses colour and timbre almost interchangeably, pairing red with “a sound of trumpets, strong, harsh and ringing” (Kandinsky 1977, p.40) and blue with flutes, cellos and double bass (ibid.

p.38), and futurist Carlo Carrà talks of painting "Reds, rrrrreds, the rrrrrreddest rrrrrrreds that shouuuuuuut" (Carrà 1913 p.54). It is difficult to say if these effects are universal or cross cultures, but there is some evidence for intuitive sound-shape mappings. Ramachandran and Hubbard's 'Bouba Kiki' experiment (a restaging of an original experiment by Köhler (1992. p224)) asked participants to match two shapes, one rounded and one spiky, with the words 'bouba' and 'kiki'. 95% of respondents chose the rounded shape as Bouba and the Spiky one as Kiki, lending credence to the idea of sound-shape correspondences as a basis for language and suggesting "that there may be natural constraints on the ways in which sounds are mapped on to objects" (Ramachandran and Hubbard 2001, 2003).

Deriving from the idea of crossmodal correspondences, an important consideration in the piece is that the look, feel and sound of the Pods work coherently to create an enhanced multisensory experience. In practical terms this means that:

- the shape of the pods should be matched to a 'round' sound, in our judgement one that is continuous, fairly soft and changes slowly without spikes or sudden transients (there is also of course the common musical usage of 'round' which roughly equates to sound rich in low-mid frequencies and without much treble). Sounds of electrical hums and buzzes were tried in the pods and rejected as the sounds were far too dynamic to appear as a unified whole with the shape, an observation which recalls the Buba Kiki experiment described above. When auditioning sounds, the rule of thumb is that if we become aware of the speaker - that is, if the Pod loses its sensory unity and starts to feel merely like an audio clip within an inflatable - the sound is dismissed. Although this may appear an esoteric test, it is usually clear what works and what doesn't, and Alison and I tend to agree without much discussion on which sounds are successful.
- the sound of the Pods needs to suit their colour and soft glow. Kandinsky equated low sounds with blues, and from experimentation low pulsing sounds seem to work most effectively with the shape and colour of the inflatables.
- the volume of the pods matches the volume of the sounds. A subtle observation but it has proved important to match the size of the physical and audible elements of the work. The volume of a sound is not simply a measure of loudness, but of physical volume occupied by the soundwaves. A sound's physical size increases with volume; with more energy it spreads further and fills more space. This would indicate that the volume of a sound in a multimodal work should be carefully controlled to match the size of the object it is presented with if the desire is to create the best possible match. Rolf Julius, a master of work exploring audiovisual relationships, shows just how seriously he took this topic in this quote:

  > My problem with the glass plate onto which I had sifted gray cement pigments: the glass was $1m^2$ in size and the cement color a little too dark for the gray sounds I had prepared for the piece [...] But what about the size of the surface, how do color surface and sound surface relate to each other? And how dense were the musical molecules? I had the feeling my music would just barely be enough for an 0.8m2 plate. So I had to make corrections, I had no choice but to purchase a smaller plate of glass (Julius 1995).

Another important aspect of the work is that the visual and sonic aspects enhance each other to create something that is greater than the sum of their parts. An interesting exercise when experiencing a multisensory work is to imagine it with only one sense at a time and note what is lost compared to the complete work. In this case, a low hum or a glowing blue ball on their own carry much less interest than when the two are combined, at which point the piece seems to become imbued with new readings not attainable by either element alone. It can be argued that the point of a multimedia piece is not the senses themselves but the space between them that is created by their interaction, the phenomenon Michel Chion calls 'added value' (Chion 1994 p. 5).

Finally the audience needs to be convinced that the sound and object are part of the same entity. In addition to the quality of the sound matching the object as described above, the two need to be perceptually bound. Sound-object binding is a vital part of any multisensory work and in this case spatial proximity (the speakers being physically inside the object) is used to join the sonic and visual elements in the perception of the audience (for a detailed treatment of sound-object binding, including other strategies and the use of cross-modal correspondences in audiovisual work, see Blow 2014).

### Pod as an Interface

Pod is obviously not the normal type of interface or control surface we are used to, with defined and repeatable mappings between actions and results, and it doesn't allow us to directly change the nature of what is happening inside. What it does do is conform to some of the basic functions of an interface. Like Tony Smith's Die (1968) and every game controller, it is ergonomic, being built to the scale of a grown human - as Smith has said, neither smaller ('an ornament') or larger ('a monument'). Pod meets us at our own scale and invites us to engage. As Juhani Pallasmaa says "A work of art functions as another person, with whom one unconsciously converses" (p. 66). This is probably rarely as literal as in the case of Pod, with its affordances of touch and hugging initiating a tactile conversation. The sense of touch is key to the work and rewards the sensitivity of the fingertips and the resonance of the chest with a haptic rendition of sound, which grows and fades in time with the sonic pulsing of the soundtrack. The material is important, the welcoming bounciness, relative warmth and resonance of the skin lending the work an apparent vitality and life; for all that it does not respond electronically to the actions of visitors (a deliberate strategy to stop audiences getting caught up in a 'button pushing' mentality), Pod is a live interface that accords new experiences in response to varying pressures from the hands and body, and sounds quite different if you press your ear against the skin.

A few visitor reactions from recent trials with schools at the Science Museum in London:

> ‘[I like that] it’s blue, really big, soft, squashy, nice to hug!’ (Student, 8-9)
>
> ‘It vibrates so the sound bounces off!’ (Student, 8-9)
>
> ‘That’s how deaf people hear, right? By feeling it’ (Child 9)
>
> ‘It makes you relax’ (Student, 9-10)
>
> ‘I could sleep on it!’ (Adult)

### The Interface as Metaphor

Finally this example leads us to consider the idea of an interface which tries to represent the same information in a number of ways. Explored in computer science, where users' prior knowledge of the affordances of desktops and folders is leveraged to facilitate intuitive interaction with the underlying digital system, Pod raises the idea of sensory correspondences between elements of an interface as an aid to interaction - of using one modality as a metaphor for another. Indeed this exact idea has been tried in Apple's Sonic Finder (Gaver 1989) and a colleague who regularly used it remarked that when it disappeared in an OSX update, "everything felt slippery".

Of course aligning the look, interaction technique, and sound of an interface in order to produce a stronger experience is often at odds with the idea of a reusable 'abstract' control surface which can be mapped and remapped onto any musical parameters. However when transposed to compositional and live music interfaces the thought leads one to ask which control techniques or visual forms intuitively map to particular sounds, and whether any added value in terms of playability and understanding of sound or performance might be created by exploiting these associations.

## Conclusion and Further Work

This paper has described the evolution and presentation of the work Pod by Alison Ballard and Mike Blow. The work was presented in Oxford and Reading earlier this year and is still in active development. It has recently received a commission by the Science Museum in London which has promoted the educational aspects of the work. It has also won Arts Council funding to develop a spatially extended version with more inflatables for public display outdoors. For such a simple piece Pod seems able to capture and hold the visitor's attention with great success and we believe this is due to the fact that the shape, colour, feel and sound of the piece work together to create an intriguing and very physical multisensory experience. It is also an interface with sound which requires absolutely no prior knowledge to use, with obvious affordances and playful associations. Pod is perhaps as close to hugging sound as it is possible to get.

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# Bridging the gap between performers and the audience using networked smartphones: the *a.bel* system

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**Abstract.** The *a.bel* project aims to provide artists with a way to easily interact with their audience, making use of their participation to effectively craft unique performances. This paper gives an overview of the *a.bel* system and details the development of a suite of tools (as well as its integration into mobile applications) with which multimedia artists can easily create and distribute interactive content unto mobile devices.

**Keywords:** music, interaction, interactive art, collaborative system, smartphones, audience participation

## Introduction

The use of smartphones has been steadily increasing during the last decade and 2015 marked the year when most Western European countries surpassed 50% smartphone penetration among the total population (Google 2016). These devices combine a growing cluster of sensors, networking technologies and high quality multimedia capabilities. Yet, we still mostly use these devices as personal computing devices, using them to communicate as we did with 2G mobile phones (i.e. voice calls and SMS), to play or work individually (e.g. reading the news, playing single user games, listening to music, editing documents), and to access services through the web (e.g. social networks, internet browsing, video calls). We believe that smartphones can also be used to foster real-time interaction between users sharing the same physical location, and thus we propose a solution to explore the large scale use of smartphones in a music concert setting to bridge the gap between performers and the audience.

## Background

### Digital orchestras

Even though the use of laptops and mobile phones in networked live musical performance systems is not new, these devices' role has mostly remained as that of an instrument dedicated to performer use. Stanford and Princeton universities, for example, have both implemented networked systems for live performance using laptop computers, which became the staple for most laptop-orchestra implementations (Trueman and Cook 2006; Wang et al. 2009). Each of the laptops is connected to a common network, communicating with a central computer server, and is operated by a performer to execute a given musical piece. Mobile phones also have been used in a similar way, taking the place of laptops in similarly organized mobile phone orchestras (Wang, Essl, and Penttinen 2008; Oh, Herrera, and Bryan 2010). Elements interact with each other to create a performance where the individual composer/performer is responsible for the establishment of the rules, much like a composer would go about creating a musical piece for a conventional orchestra.

### Audience participation using portable devices

Golan Levin's 2001 *Dialtones (A Telesymphony)* made use of the audience's cellphone ringtones as an instrument (Levin 2001), namely by uploading ringtones to the cellphones and calling each one at a given time. This approach is closely related to the one we propose, as it makes the audience a part of the performance, even if in a rather passive role. Since 2012 the British band Coldplay has been using a device called Xylobands to “engage audiences and make them part of the show” (Xylobands 2016). A similar technology is used by PixMob to create “interactive, immersive and unforgettable crowd experiences” (PixMob 2016). These are some examples of the growing willingness of popular music acts to adopt novel ways to increase interaction with their audience. In fact, the responsiveness, precision, reliability, and timing requirements of a musical performance provide an interesting and demanding testing environment for both novel interfaces and computer networks in the context of musical interaction.

# a.bel

It is nowadays increasingly safe to assume that a significant part of the audience in a concert setting will be carrying a smartphone in their pocket. The *bridging the gap between performers and the audience using networked smartphones* project, henceforth referenced in this document by its working name *a.bel*, aims to provide a solution to the use of networked smartphones to promote interaction in musical concerts, proposing a framework that enables the bidirectional interaction between performers and audience, in a *performer-system-audience* interactive system (Bongers 2000). Some examples of the creative potential of this novel framework are: the distribution of sound emanating from the audience, enabling the creation of large diffuse sound fields, sound paths and musical responses that emerge from the audience; the distribution of video signals amongst the devices, using their screens as a small part of a larger screen; the network control over some musical parameters of each device (e.g. current harmony or timbre), thus facilitating the musical integration of each person’s contribution. All of this as part of “a situation [...] where the audience and performer meet, each influencing the other, as if conversing, while maintaining the quality of the performance at a high level.” (Bongers 2000, 49). The potential of this system, however, is not limited to music or concert settings: the same framework could also contribute to the development of location-based and time-sensitive networked intelligent systems using smartphones, such as location-based multi-user games.

Since the main objective of this project was to allow multimedia artists, in particular musical composers, to make use of audience members’ mobile devices as part of their performance, two main issues were addressed:

- The development of a multi-platform (iOS and Android) mobile application that provides, to the artists and front-end developers, an easy way to develop, test and distribute content built with a standard development environment for interactive media; and to the user, a transparent way to participate in live performance settings.
- The development of a solution to connect hundreds of mobile devices to a network in a concert environment that is reliable, cost-effective, and easy to deploy and operate.

This paper focuses on the first issue and describes the implementation of the *a.bel* app, available for iOS and Android, with the network implementation details going beyond its particular scope.

## Proposed Framework

The *a.bel* framework can be separated in 3 distinct operative blocks (as illustrated in figure 1). The main application consists of the performance material, developed by the composer using Pure Data (Puckette 1997), and the networking management application, which uses the implemented network infrastructure to send data to the mobile application. The data is sent from the Main Application to the Mobile Application, where it triggers a specific event or creates and controls an opportunity for user interaction. The return of the audience interaction is thus solely based on their sonic and visual contribution, as the communication from mobile devices to the server is not currently implemented. This intrinsic limitation of the framework proved to be, however, a very interesting challenge for the composers, as they were forced to build self-contained musical/sonic instruments for the audience, even if their behaviour can be altered via the network. This way, each audience member has a local feedback, and thus increased awareness, of his or her contribution.

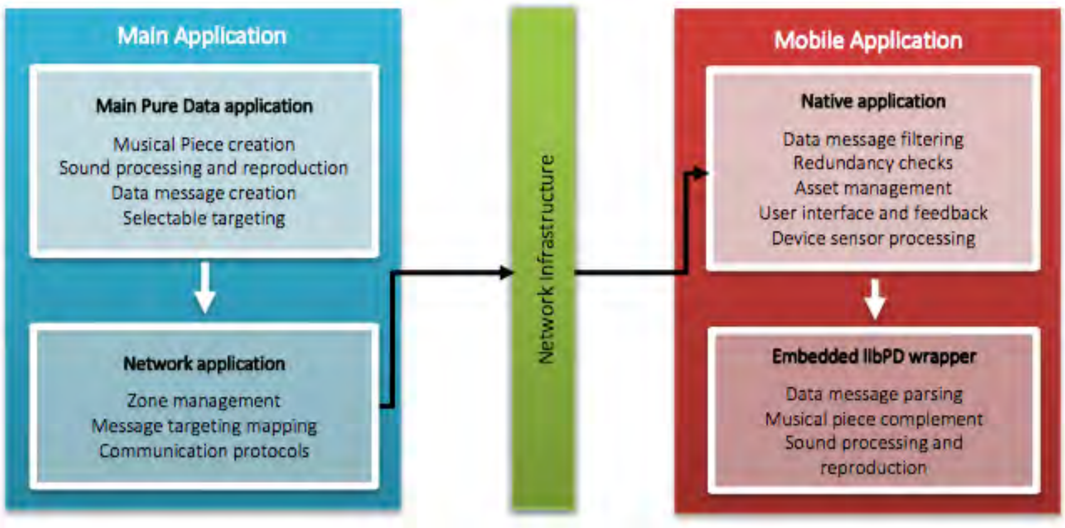


Figure 1. Global system structure

Audience-side assets for the mobile application can also be developed using Pure Data, as the mobile applications carry the libPD wrapper library (Brinkmann et al. 2011), and are distributed using simple QR-code scanning. Schiemer's Pocket Gamelan (Schiemer and Havryliv 2005) implements a tool allowing for musical performance on mobile phones using Pure Data as well, although it makes use of PD2j2me in order to convert Pure Data patches into java code, allowing developed assets to run on the phones. By using libPD, we bypass the need of this conversion, making it so the mobile applications can load and run the PD patches directly. A toolset of external objects was developed, in order to give composers easy access to the system's data communication, to the functionalities of the audience members' devices (sensor data or user interface feedback, such as touching or waving the device), and all other system functionalities. The application was designed to operate seamlessly, with the embedded patches taking care of all audiovisual content associated with the performance, using the information gathered both from composer/performance provided data (through network communication) and from the device's own sensors to promote interactivity.[1] We decided early on that, in order to take the device out of its ordinary role as a personal device destined for individual use, the screen should be completely filled by a single, patch-controllable colour when in performance mode, showing no user interface elements other than an optional text message. This decision proved to be an effective way of transfiguring the very personal device as a musical instrument during the performance, and audience members were often seen waving the devices in the air, sometimes performing *impromptu* group choreographies. These interactions might be achieved by means of OSC controller mobile applications, but these aren't, by themselves, tools for musical expression or collaboration tools, but merely a way of controlling remote systems.

## Pure Data library

LibPD is based on Pd-Vanilla (Brinkmann et al. 2011), which means that it only features a limited set of objects that lack functionalities that were critical to achieve our goals. Whilst some of these needs were already covered via third-party objects, the need to have fine control over some of the network settings and an easy to use platform for the development of mobile assets led us to the development of a suite of Pure Data objects. This toolkit is embedded in the mobile *a.bel* app, being also available for development using Mac OsX, Windows and Linux. Table 1 gives an overview of the created toolkit.

[1] Examples of user control of musical features using the *a.bel* app can be seen at http://vimeo.com/142726571 and http://vimeo.com/142726073.

| Category | Description | Function |
|---|---|---|
| Data communication | One-way data transmission using Wi-Fi and/or *data over sound* | 8-bit value transmission, performance control messages |
| Device input | Device sensor reading based on user input | Accelerometer, touch, swipe |
| Device output | Device visual output | Screen colour change, text messages on-screen output |
| Auxiliary | Process standardization and system-specific functionalities | Scale remapping, data message targeting |

*Table 1. a.bel* toolkit components

## Data communication

To cope with the particular features of the network model, a particular communication protocol between main and mobile application was developed. Our first approach was to use a Wi-Fi network, which proved a reliable way of connecting hundreds of devices with low latency but required a considerable network infrastructure to guarantee the system's stability. At the time of this writing, we have developed and are currently testing an additional solution based on ultrasound communication.

When using Wi-Fi, data is sent and received through a series of up to 40 data slots. These data slots correspond to a series of user-definable variables, which are responsible for storing the data values to be sent via network to the mobile devices. The data communication objects accept 8-bit integer values, which are grouped, converted and sent over network in the form of a string block, and read back by the application upon reception. This string is composed of 2 different characters for each data slot value, the first corresponding to the data slot index (for correct parsing and output in the embedded patch) and the second corresponding to that slot's sent value.

When using ultrasound communication, data is sent using amplitude modulation of a given frequency and received by demodulating on the client side. This frequency can be chosen by the composer, but it has to take into account the frequency range of both the emitting loudspeakers and the receiving smartphones. This mode of communication only allows for two 8-bit integer values and is noticeably slower and less reliable than Wi-Fi. It has, however, the potential of enabling the control over a bigger number of devices and of unlocking local communication between devices. It can use the concert venue's existing sound reinforcement infrastructure and can be used for real-time localization of devices, using time difference of arrival techniques, something we plan to implement in the near future.

## Input methods

The touchscreen is the most ubiquitous sensor in modern smartphones. It allows for multiple input types, from simple touch-coordinate reading to complex gesture recognition. For the *a.bel* tool set, 2 interaction modes are considered:

1. **touch:** touch/tap event coordinates are made available in a normalised form as screen dimension percentages (e.g. a tap at centre screen corresponds to a 50 / 50 coordinate);

2. **swipe:** 4 different swipe gestures are made available (up, down, left, right) as action triggers (trigger upon gesture detection);

Another very common sensor in smartphones is the accelerometer. The developed object gives the composer access to raw acceleration values, as well as calculated roll and tilt values, overall acceleration magnitude and a device shake action trigger.

### Output methods

A colour object provides simple background colour change functionality, allowing for individual manipulation of the Red, Green and Blue components of the colour. A text object allows the artist to pass a text message from the patch to the application, showing it on-screen. These objects can be used together to show, e.g. a splash screen showing relevant information at the onset of each piece.

### Auxiliary components

In addition to the main objects, some additional auxiliary objects were created, so as to provide standardization of some processes and system-specific functionalities. These objects are not as relevant as the aforementioned ones and will not be discussed in this paper. The toolkit download[2] includes standard Pure Data help files to demonstrate the functionality of all of the objects.

## Testing the system

*a.bel - nova música interactiva* was the event which served the purpose of both presenting and testing the proposed system. It took place on October 26th, 2015 at Casa da Música's Sala Suggia, the main concert hall at Porto, Portugal. It featured pieces by Carlos Guedes, José Alberto Gomes, Neil Leonard and Rui Penha, using acoustic instruments, electroacoustic devices and the *a.bel* system.[3]

One of the pieces — *cellular*, for soprano saxophone, vibraphone and live electroacoustics, in addition to the audience members' smartphones — was composed by one of the authors (Rui Penha). The piece started with only the audience's smartphones waking up from black screens to different shades of evolving greens while producing various synthesized animal and water sounds, producing a diffuse rainforest soundscape. The fact that each smartphone produced an unique, isolated and easily locatable sound — and, in the case of the water drops, changed colour while doing so — made the contribution of each smartphone very easy to pinpoint. This section helped the audience to be aware of the individual impact of their smartphone to the whole experience and to build a serene starting point to the subsequent shift towards a more frenetic interactive experience.

The second section of the piece introduced user interaction to accompany fast-paced articulations of the saxophone and vibraphone. Audience members could interact with the musicians and with each other by using two musical gestures:

- by waving the smartphone in the air to produce slowly evolving drones[4];
- by tapping the screen to produce short notes from a given harmonic series, which were then automatically repeated with variable delays[5];

The harmony, timing and delay behaviours of these gestures were automatically synchronized with the output from the musicians on stage via the a.bel system.

More than 700 people attended the event and logs show that roughly 70% were able to connect their smartphone to the system and successfully made use of it. The remaining 30% include people that did not carry a smartphone to the concert, users of other operating systems (e.g. Windows Phone or Blackberry), users of incompatible Android versions (below version 4.0), users of incompatible iOS versions (below version 6.0) and a small number of users that could not connect to the system for other reasons, mainly due to incompatible Android ROMs. During the event no disruptions were observed, either in the network data streaming or from the audience engagement.

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[2] To be made freely available in time for the conference.
[3] An integral video of the concert can be seen at http://youtu.be/X_YeO3Qi3H4.
[4] An example of this interaction mode can be seen at https://vimeo.com/142726571.
[5] An example of this interaction mode can be seen at https://vimeo.com/142726073.

## Conclusions and future work

We have described the initial development of *a.bel*, a system for the development of interactive performer-system-audience experiences, and we have shown how it can be used to bridge the gap between performers and audiences in musical concerts. The audience response at the systems' première event was very enthusiastic.[6] The system was proven to work as intended and, given the observed results, has shown room for concrete improvement, scalability and further development.

With the emphasis being placed on the ability to reliably connect hundreds of smartphones and trigger behaviours with very low latency, it was early on decided to postpone to a later stage the capability of sending data from the smartphones to the network. The cycle that starts with the information being sent from the stage to the smartphones is, thus, completed solely by an audiovisual return that is partially dependent on the audience's willingness to interact. Whilst we still intend to enable the upload of data from the smartphones to the network in the future, we believe that the exclusively local audiovisual feedback — akin to the one of a traditional musical instrument — is in fact a characteristic that helps end users to be more aware of their own contribution than what would be possible if, e.g., the data generated by their interaction was to be mingled with hundreds of other sources and used to drive an audiovisual feedback coming from stage.

We have only begun to scratch the surface of how this system can be used to enable audience participation in musical concerts. One issue that we need to address is the fact that the audience has no rehearsal time with the musicians before the concert, which can limit the quality of the more complex interactions. A solution that we plan to test is to have the concert divided into two sections: an informal rehearsal of all intended interaction modes followed by the main performance. Another issue is the fact that most concert venues were designed with the audience facing the stage and, consequently, the audience members do not see each other easily. At the *a.bel* concert, this meant that audience members occupying the front rows were somewhat excluded from the collective experience. Inspired by Golan Levin's *Dialtones (A Telesymphony)* (Levin 2001), we displayed the view from the stage over the audience on a big projection above the stage, but this solution encouraged some of the audience members' to find ways to identify themselves on the projection, leading to a momentary detachment from the performance. We aim to explore a disposition of the audience around the musicians, thus with audience members facing each other, akin to the disposition used by Iannis Xenakis in *Terretektorth* (Xenakis 1966). Finally, we aim to explore ways to promote the direct musical interaction between audience members, namely by composing pieces that rely solely on the audience.

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# Postdigital Efficiency in Interaction Design

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**Abstract.** The analysis discussed here of the making of Punchdrunk's productions *The Drowned Man* explores the influence of an immanent perspective on interaction design, where participants are primarily modelled in terms of their agency, rather than according to reductive demographic principles that enforce a transcendent perspective where participants are represented as fixed categories describing instrumentalised perspectives on identity. This aspect of the immanent perspective on interface design, which might also be termed postidentitarian, draws on the posthuman discourse and calls for a definition of efficiency that is based on extended and idiosyncratic agency, supported by detailed articulation of actions, and for the development of interactive systems that have enhanced capacity to parse and facilitate emergent interaction.

**Keywords:** Interface design, interaction design, postdigital design.

## Introduction

A post-Cartesian, embodied definition of the 'user' or participant in interaction design as a cognitive component to be included in the materialities of computational technology repurposes a historical precedent. The term was initially employed to describe persons working with computing, or calculation (United States Congress 1890, 247), often performing repetitive mathematical operations to exacting standards. Early electronic computation was intended to enhance the exactitude of such operations and simultaneously relieving human workers, prone to boredom and inexactitude, of tasks that could be automated.

Within the transcendent digital mythos of intelligent systems that dominated the conception of technology in the latter part of the 20th century, the guiding ideology of efficiency, defined as the avoidance of wasting materials, time or energy, positions the user-participant as an inferior subject, imperfect and subject to the imperative of learning how to operate within systems in which their participation is already reductively modelled, or, less imperfectly, as compliant with a set of objectives closely defined by the system narrative. The conceptual reliance and incorporation of human agents in digital systems is established in computer science as the study and implementation of human-based computation, e.g. natural human computation or swarming platforms, both of which take a transcendent perspective on human participants; in the first example by instrumentalising pre-existing human behaviours (Estrada and Lawhead 2014), and in the second instance through outsourcing problem solution to crowds or swarms of human participants, regarded as collective intelligence in relation to specific problems (Rosenberg 2015). While superficially attractive as approaches to augmentation of digital computation via the inclusion of compartmentalised human computation, limitations are recognised and subject to critique, including the observation that participation in crowdsourcing platforms for generating solutions to specific problems can fall rapidly after an initial spike in interest, with the majority of activity being performed by small subgroups (often associated with the designers of the platform) driven by special interests who remain engaged throughout (Jafarinaimi et al. 2014). The efficiency of human-based computation – and participation – within a transcendent design paradigm thus warrants questioning.

In contrast to the transcendent perspective on efficiency of human-based computation in interaction design according to the aforementioned models, the analysis discussed here, based on an ethnographic study of the interaction design and making culture of the 'immersive' theatre company Punchdrunk, suggests an 'efficiency' that is also based on distributed agency and human participation, but which regards the moment of interaction and its design within an immanent perspective, or "method designing" (Interview with PD company 03 2014). In interaction designed within an immanent perspective, the efficient interaction is based on optimised experience potential as a function of the dynamic and situated articulation of the interaction and response capacity of participants in the moving instance.

## The interface: affording and regulating

The focus of the study of the interactive productions by theatre company Punchdrunk, with which the author worked as a researcher/designer 2010-2014, was to investigate Punchdrunk's interaction design and how it was experienced by participants, using ethnographic methods.  The interaction design of Punchdrunk, which stretches across physical and digital interfaces, often with blended reality narratives, aims to envelop the audience participant physically and psychologically, while casting them as 'cameras' or editors of their own experience (Ersoy 2013). The physical theatre sets constructed by the company are generally realised in large disused buildings, with the last major productions (*Sleep No More* and *The Drowned Man*) comprising 100 and 170 fully realised, interactive installation rooms, respectively. Their digital (and multimedia) blended reality projects in recent years include *Silverlight* and *The Borough,* which are based on the diffusion of the boundary between the story world and physical world for one participant at a time. In the case of *Silverlight*, the story interface was carried by a game app for smartphone, and, in the case of *The Borough*, audio guides.

In Punchdrunk's methodology, both single-participant projects like *The Borough*, and large-scale productions like *SNM* and *TDM* conceptualise audiences as material to the completion of interaction. The main focus of this research was the large-scale physical productions, as robust, three-dimensional, interactive storyworlds, populated on a regular night by up to 600 participating audience members plus a cast of 35 performers and an additional backstage and stagehand crew of 55. The scale of these productions has contributed to producing a pragmatic and artistic approach to modelling participants that is applicable to interaction design as a broader discipline. In interviews with company members, the flows and forces created by audiences are often discussed in terms resembling fluid dynamics (Interview with PD company 01 2014). Audiences (who number 400-600 per performance in the large shows) operate within the interactive system as co-opted agents in a 'mirror choreography', the larger flows of which being shaped and timed by the architecture and detail of the set and the coordinated movements of the cast across the space. Black Masks, acting narratively within the set in the double capacity of stagehands and moderators of audience interaction, mediate between the authorable part of the productions (set and cast), and the emergent part (participating audience members).

Conceiving of the audience as material to the completion of interaction suggests that the interaction design of the company could be considered as part of the proposed ”psychotechnics” of cognitive capitalism (Parikka 2012, 73), although Punchdrunk's work is differentiated by key acentric features, including the conceptual modelling of participants as agents, independent of their identity-as-category. In place of identity, Punchdrunk models audience members in terms reflecting the distributed agency of the posthuman discourse (Hayles 2002; Braidotti 2013) and Deleuzes's ”postidentitarian philosophy of difference” (Cull 2012, 17). Participation is anonymous, with audience members being masked and asked not to speak while navigating a deliberately disorientating experience, the aim of which is to destabilise quotidian identity. Questions of identity and subject-event relationship thus emerged as central to this analysis, with a bifurcation forming around whether the designed interaction occurs within an immanent or a transcendent perspective. The immanent subject-event relationship in interaction design can be defined as close range and emergent, with the particular qualities and topographies of the moment of interaction being critical to its unfolding. Bearing upon this unfolding are the possibilities within both interface and participant, many of which by necessity having to remain unarticulated, that lend the moment of interaction qualities that simultaneously intrigue and frustrate. Surplus experience potential emerges in interviews as key to the attraction of the interfaces designed and built by Punchdrunk. Together with the scope of the sets, surplus experience potential is given physical form by a depth of detail that offers apparently inexhaustible affordances. This allows the audience to suspend disbelief, and participants who claimed to be 'cynical' about alternative forms of theatre and performance felt supported and reassured by the level of detail:

> It felt like…it was a high, yeah, because of the detail of the sets. It made me feel like I had more trust in them to give me a good experience. So, you know, I was really impressed by…the different sets, the thick sands, the desert set was really cool, and the attention to detail in the rooms (Interview with PD audience 02 2014).

The richness of detail counters the narrative of optimisation via reduction of resolution, and generates, together with the deprioritisation of identity, conditions of possibility for participants that are characterised by their undefined extension. To achieve a sufficient level of detail across the sets to engender this response, one part of the production team designs and builds the sets and the detail, while the other creates the choreography and performances in tandem. The design team, within which the author participated for the build of *The House Where Winter Lives* and *The Drowned Man,* subdivides architecture and detail, with the former division primarily focusing on the shaping of the physical space, and the latter on the creation and layering of texture and 'dressing' of the set with tactile and interactive detail. The performance and choreography team rehearse on other premises until the performance space is sufficiently formed for on-site rehearsals. From that point, actors/dancers, as well as set and detail designers, devise and develop the production on-site.

Attention to minute detail is key to both teams, with iterations continuing throughout the run to both set and acting in response to observations made during live performances. Distributed agency characterises the development of detail, with individual actors and designers in direct contact with the interface and audience participants being at liberty to respond and adjust to materials and situations that are presented during the creation and running of the production, thus building the layers of meaning that support audience participation and exploration:

> Because the details are so…the wrong detail could shatter everything, and the right detail could… You know, the wrong word is like playing the wrong note in the key, it just doesn't… But then the right way can be so suggestive, just draw you into that world in such a powerful way. It's just…all about details and accumulation of many, many, many, many details; and many, many small decisions, and the decisions that haven't been made, as well, the decisions not to do something; that would be the expected thing to do. The notes that we aren't playing, or beats that we aren't playing, those are really important decisions (Interview with PD company 01 2014).

Layered detail is here identified as key to the psychological immersion of participants, which is followed through in the performance of an often overlooked, but important part of Punchdrunk's interaction design. The Black Masks, who would normally be regarded as stagehands, are important components of the responsive capacity of the interface in a regulating role, that has been formulated to support the overarching narrative of distributed cognition. They are dressed and masked in black, and stay hidden within the already dark set until intervention or guidance is needed, giving audience members who encounter them the impression of diffused agency, with the 'set' extending and blending with their own agency:

> I definitely felt like most of the decisions, like the control was kind of in somebody else's hands, and I had a diminished control […] Like being a spectator and an actor all at once […] the stuff you do have to decide on is completely personal, but where your body is isn't […] I wanted to be in the machine, in the software, I wanted to work with the algorithm, however you want to put it. I wanted to function, I didn't want to be the glitch that was in the bar, I wanted to function along with the rest of the machine that was going on, that was also a narrative (Interview with PD audience 02 2014).

The psychological immersion experienced by this participant was enhanced by the sense of distributed agency and the diffusion of personal boundaries within the set that occurred through the regulation of their actions by Black Masks. This response conforms with the sublime experience that results from the impact of entrapment and the experience of entanglement in the artwork-as-trap (Chow 2012, 47), discussed in some detail below. The postidentitarian difference suggested by Cull as informative of immanence is here exemplified by the extended agency of the interface, blending with the agency of the participant. Although emergent in unscripted situations, this particular form of merging-with and regulation-of audience actions is based on responsive articulation, much like set design and acting are, with emphasis placed on haptic interaction. Words are not used; the Black Masks are silent, and invisible apart from if and when their interventions are necessary. Their training incorporates techniques with which they can blend in with, and influence the embodied narratives of individual audience members, without pulling them out of psychological immersion:

> So you don't walk with the usual gait. Very slow and sort of within keeping with the show […] you want to blend in, so if you start, you can't run […] it's very calm, almost like someone's about to brush past you. And then you can…what we normally do, is going up behind them, hands on their shoulders and grip, and just gently pull back,

and you get them to move […]. And there was another thing where, if you wanted to walk with someone, you could sort of run…so, put your arm down, just put your arm down by your side. You would do that and just lead them, keep that elbow contact, so all your forearm is touching […]. You're keeping them quite close to you, and you would be able to steer them as well, with that forearm contact (Interview with PD company 02 2014).

A postdigital efficiency that draws on the posthuman discourse needs to open the 'Wizard of Oz' curtain in interaction design that obscures the human processes that are required to complete interactions and produce immanent responses (Dow et al. 2007, Dixon et al. 2012), whether they occur under the control of the designed experience or are outsourced to user-participants. Participant computation, currently often outsourced as an externality, comprising not just cognitive labour but also drawing on the social and cultural narratives that bear upon the cognitive processes of participants, needs to be incorporated and accommodated within the factors regarded as material to interactive systems; particularly as they allow for an alternative 'optimisation' or extension of experience potential. To this end, participants are better modelled in terms of their agency, i.e. their extended capacity. Modelling participants as data objects will, by virtue of the differential nature of the human condition, be reductive, with the process of reduction being informed by representational hierachies. In an alternative view, the interaction may be regarded as an instantaneous articulation of the entanglement of system and participant narratives extending beyond the instance of interaction, thus potentiating the experience of emergence. Achieved not through the impossible articulation of all possibilities but through the design of interactions that narratively hold the complexity of possibility in their detail, the excess experience potential that results from this approach to interaction design generates a different form of efficiency, the effects of which can be seen in the unusual degree of commitment to the experience that is demonstrated by Punchdrunk audiences.

## Embodied responses by participants

| **Audience responses: action descriptors** | **Percentage of total** |
|---|---|
| Descriptors of cognitive processes (e.g. understand, learn, figure out, discover, find out, think, believe, suppose, guess) | 31.8 |
| Descriptors of embodied exploration (e.g. walk, move, wander, lead, run, chase, see, look, gaze, watch, feel, sense, experience) | 26.7 |
| Descriptors of synthesised/processed actions (e.g. talk, describe, articulate, pretend, dance, create, work, challenge, question, build, design, control, adapt, decide, contact, approach) | 23.8 |

Table 1. Action descriptors extracted from interviews by the author with participants (n=12) in Punchdrunk's *The Drowned Man* 2013-2014. Subcategories of extracted action descriptors were grouped into three overarching categories; descriptors of primarily cognitive processes, descriptors of embodied exploratory activities, and descriptors of processed and synthesised actions in response to the interactive environment.

The prevailing sense of intrigue, driven by the impossibility of exhausting all possible avenues in a given moment of interaction, that draw large numbers of audiences throughout production runs lasting 1-5 years (with many audience members returning dozens of times), evidences the 'efficiency' of narrative complexity and the careful balance of satisfaction and frustration in Punchdrunk's interaction design. The combined effect of complexity, satisfaction and frustration can be compared with Chow's concept of the artwork as a trap in which the captivated audience fulfils the trap's design (Chow 2012, 43). Thus ensnared, the audience is subject to the sublime experience from the compund experience of impact of entrapment and fear of annihilation, or dissolution of self, within the trap (Chow 2012, 47). Within the 'traps' presented by Punchdrunk productions, participants respond with action strategies that are primarily associated with understanding and exploration through cognitive and embodied extension, closely followed by processed and synthesised responses to the situations they experience (table 1).

This analysis was based on discourse analysis of interviews with participants in the production and experience of Punchdrunk's interactive systems. Action descriptors were extracted to identify key features experienced as important, and descriptors with similar or closely associated meaning were grouped in subcategories. Subcategories of action words were organised in larger groups, forming three overarching categories that describe different types of actions. The largest group of action descriptors were those associated with processes of a primarily cognitive nature; e.g. problem solving and reflection. The second largest group of action words described embodied explorative actions, involving perception and physical movement. The third largest group was formed by descriptors of actions that were expressions of process or synthesis in response to the given circumstances. The three groups were relatively close in size, with the cognitive actions forming just under 1/3 of action descriptors, and the other two forming just over and just under 1/4 of action descriptors (table 1). Taken together, the three groups describe a general tendency to gather and process information for responsive expression, which, against the background of excess experience potential generating what was described as trust and the suspension of disbelief, suggests that significant and persistent voluntary participant engagement as a postdigital 'efficiency' metric in interface design can be regarded as a product of the facilitation of emergent behaviours.

## Conclusion

The expression of actions in relation to affordances offering cognitive challenge, affordances for sensory and embodied experience and opportunities for creative expression in response to the situation in this study (live participation in Punchdrunk's *The Drowned Man*) was fairly balanced and together formed over 80% of action descriptors. As participants in this study all framed their experience in positive to extremely positive terms, these groups of action descriptors (seeking to understand; embodied and sensory exploration; responsive or adaptive expression) may be proposed as key emergent behaviours in successful immersive interaction design. Participants, conceptualised as essential parts of the interaction in Punchdrunk's interaction design, perform as such in their capacity to search for, compose, synthesise and respond to information embedded within the interface, and could be viewed as 'computers' (as per the 19$^{th}$ century profession) within the system. However, in line with progress made in the field of computation and artificial intelligence, and moving beyond the subordination of the human as a lesser component in the transcendent digital mythos, the role of the postdigital human 'computer' (or participant in interactive systems) should not be conceptualised according to their ability to conform to exactitude and generalisable standards, but in terms of their agency. In its inception, the automated computer was intended to relieve human operators of relatively menial tasks that demanded monotonous and exact replication; postdigital interaction design needs to define a trajectory that deviates from this intellectual heritage, and not seek to impose fixity when defining human participants in interactive systems through the way that they are modelled: it should facilitate emergent behaviours.

A postdigital efficiency, based on persistent and voluntary emergent participant engagement, needs to incorporate the participant computation that is otherwise outsourced as an externality, at best conceived of as optimal when minimal (as per the traditional usability or user experience paradigms), and at worst disregarded. The idiosyncratic social and cultural narratives that bear upon the cognitive operations of participants can be regarded as valuable to the cognitive labour of participant computation, by virtue of contributing to the extension of experience potential. Here, the immanent, close-range and emergent design perspective ("method designing") is essential, and the preservation of situational specificity, including designing for the impossibility of exhausting all possibilities. An alternative, then, to an inherently totalising perspective on the participant in interactive systems is the turning away from their definition based on fixities, including identity, and reductive definitions of efficiency that are formed with a view of agency as problematic, and instead designing interactions that are openly inclusive of differential participant agency, regarded as essential to the extension of experience potential.

## Additional Information

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# Tuning the Interface for Relational Listening

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**Abstract.** This paper re-visits my creative and research experiences with the creation of sound-driven interfaces for navigation and performance, as part of a personal quest for space and identity. Involving geographical migration, its sonic experience and the connections mediated with internet technologies, the experience of listening and performing within dislocation refers not only to the development of technological systems, but also to the exploration of new forms of interacting with the self and others through listening and sounding in distant locations, inviting participants to the discovery of 'in-between' sonic spaces for being.

Derived from the need for a shared conceptual and technical framework, the project 'Sound Matters Framework' has explored, with other sound artists and researchers, practices of interrogation and relational playback for the creative interplay of field recordings and speech. The framework has evolved into the idea of creating *interfaces for relational listening*. What characteristics might be involved in such imagined *interfaces* and what *relational listening* means within contemporary contexts of dislocation, are the questions that I am formulating on this paper within the broader field of live interfaces.

**Keywords:** Migration, Sound space, Sense of Place, Relational Listening, Interfaces, Performing.

## From navigation to Networked Performance

My creative research work has explored people's perspectives on listening to local and distant acoustic spaces, reflecting on identities and sense of place (Doreen, 2001). Specifically, within my experience of urban mobility and geographical migration, I have searched for new forms for interaction and reflected on what seems to be, in my personal experience, a collapse of known cultural *interfaces*. For instance, my perception and ways of navigating chaotically cities such as my native Bogotá in the 80's and 90's, with unstructured public transport, were radically changed when I first used underground public transportation in Barcelona. Wolfgang Schivelbusch refers to this phenomenon as the annihilation of the "traditional space time continuum which characterized the old transport technology" (1986, 36), brought about by the introduction of railway systems in Europe in the nineteenth century. While newer transportation became my *interface* to interact with the urban space, in a parallel manner, I was creating art[1] with multimedia interactive technologies using the metaphors and experience of the underground public transport network. This opened for me the possibilities of creating a virtual interface that might disrupt geographical, cultural and technological borders. Years later, I explored how *listening* to the commuting routine can reclaim the annihilation space time continuum, and expand the sense of space throughout sonic memory and history. Derived from an ethnographic work on London Underground's commuters' listening experiences and the memories left during their daily routine journeys, I created an Internet-based Interactive Sonic Environment[2]. The interactive structure incorporates architectonical and symbolic spaces, mainly derived from the sonic experience (Alarcon, 2007). I created a sound driven multimedia score that became a user interface (Figure 1). Subsequently, and as an expansion of this work, I created the Internet-based environment 'Sounding Underground' (Alarcon, 2009), an interface[3] that links urban soundscapes via commuters' journeys from the cities of London, Mexico and Paris. Each metro has its own screen-based interface, and the interfaces are interlinked in a sonic network that allows online visitors to experience *relationships* between the different sound environments. These environments encompass a structural continuity given by the narrative of underground public transportation spaces

[1] https://vimeo.com/51626952
[2] https://vimeo.com/105343930
[3] http://soundingunderground.org

(entrance, tickets, corridors, platform and carriage) and are enriched by its overlapping in time and place where, by the navigation on the screen, different micro-narratives unfold[4]. Also, sonic spaces such as doors, trains arriving, steps, and amplified voice, emerge from the commonality of listening experiences in the three cities (Figure 2). The interfaces invited participants to listen to interrelations between sonically distant spaces, and within sounds of specific cultures:

> Wow, what an amazing soundscape. It is the accent of the world condensed into a synthesized experience making human of what I had always thought of as a mechanistic and rather alien environment. And in a stream of consciousness I find myself cushioned by the almost white-noise effect of the tube surrounded and reassured by the voices. But the voices aren't affected or forced or conveying any particular message. (Leslie)

> In particular, I was touched by the Mexico underground which is foreign to me - wonderful to hear the Spanish voices, the music, it sounded "lighter" somehow than the Paris and London counterpart. (Sylvie)

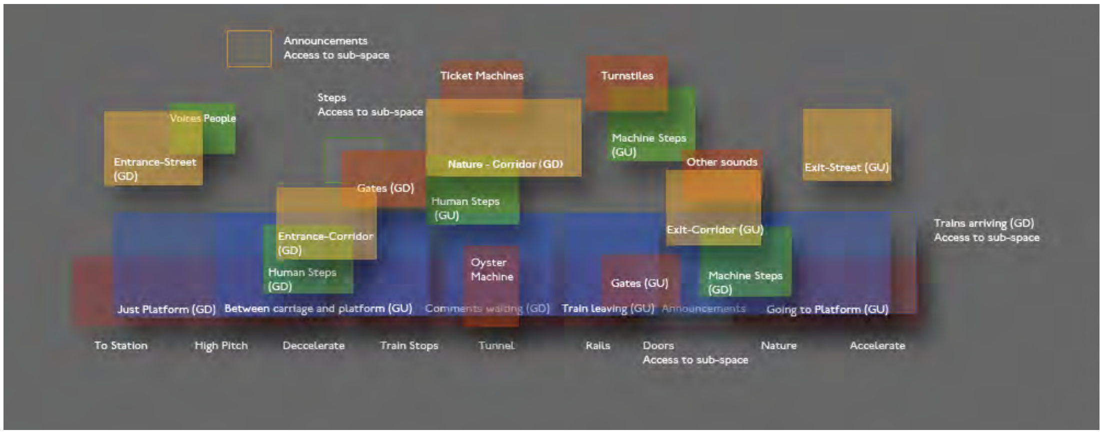


Figure 1. Multimedia Score Interactive London Underground


Figure 2. Entrance México. Sounding Underground

[4] https://vimeo.com/28416673

In 2008, the desire to make a more interactive interface developed into performance, so I created the co-located networked performance 'Listening and Remembering' (Alarcon, 2011), a system for commuters to improvise in a networked manner[5]. I invited groups of four commuters to play with their voices while listening to a journey created with all the excerpts of sound selected by them during their metro journeys. Performers were surrounded by five loudspeakers, and on their screen-interfaces they had columns with the names of the other performers. Each time they wanted to share a memory triggered by the sound, they could voice it and record it through a microphone. This memory appeared on the interface of all participants who were able to trigger it. Each triggered memory was amplified through the loudspeaker located next to the person who was the author of the memory. The graphic interface was created in Max MSP[6] and helped to create a network of interrelations between performers (Figure 3). Narratives in the flow were emerging, and performers experienced sonic spaces such as "a 'real space' (as if they were in the metro), a personal 'memory space' (the memories they shared with their voices), and a 'performance space' (where the metro is perceived as a background space to develop any kind of sonic intervention)." (Alarcón 2011, 24).

With these virtual *interfaces* I wanted to encourage hybrid listening experiences interrelating individual and collective memories of acoustic space, and also performing in a networked manner with non-trained performers using speech and voice.

Figure 3. Improvisation Listening and Remembering. Paris MSH.

Later on, I experienced listening to my own migration through Pauline Oliveros' Deep Listening practice (Oliveros, 2005). This practice invites us to train our global and focal attention of the sonic space using the whole body, expanding our perception of sound as it travels in time and space, and establishing unexpected *relations* between us and the space. Since 2012, I have been evolving the experience on co-located networked performances into Internet-based telematic sonic performances, developing improvisations such as *Letters and Bridges*[7], between Mexico and Leicester, with migrants from all over the world, and *Migratory Dreams*[8], with Colombians living in London and Bogotá (Alarcón, 2014; 2015) (Figure 4). For these I have used high quality bidirectional audio software[9], spoken word, and interfaces created in Max MSP and PD for performers to trigger pre-recorded sounds to establish relations between local, distant and imagined spaces while improvising.

By strengthening the perception of time and space using networking technologies in the distance, I have been exploring sonic 'in-between' spaces to express feelings associated to migration. Mariana Ortega understands 'in-between' spaces as negotiations between internal and external spaces performed by a person in exile (2004, 27), reflecting one's existential spatiality. These negotiations also take place through what Franziska Schroeder calls Networked Listening (Schroeder, 2013). She suggests that in networked sonic performance the body is performing as if it was "in an in-between state" (224). For her there is a de-centering of performers' attention, "resisting one's self-preoccupation in order to allow for the essential unselfing, a state of moving from oneself to the other" (223):

[5] https://vimeo.com/29055488
[6] The interface was created in collaboration with Peter Batchelor.
[7] https://vimeo.com/79626844
[8] https://vimeo.com/79622556
[9] Bi-directional technologies that I have used in telematics sonic performances are Jacktrip, Soundjack and TubePlug.

> It's interesting because I can feel more than the place and the person… the place is in my mind, imagination or something, I have the connection with the person…I can feel very warm inside of the place of Sally, I don't know if I can feel also Charlie [Sally's Dog], but I can feel a sense of home there. (César Damián, performer Letters and Bridges)

I suggest that in this networked listening artistic practice, an alternative, individual sense of spatiality emerges when listening and making relations within the dislocation. I am interested in creating interfaces to access more deeply those "in-between" spaces, which expands one's perceived existential spatiality.

Figure 4. Migratory Dreams Telematic Sonic Performance. Bogotá – London.

## Relational Listening

In 2015, I engaged in the 'Sound Matters Framework' research project, together with Cathy Lane, to address a need felt for shared conceptual and technical frameworks to creatively interplay with large collections of sound, specifically from field recordings and speech, and their trajectories in time and space. The proposed framework (Figure 5) focused on the processes of *Interrogation* – including the processes of creating meta-data, annotation, search and retrieval, and *Relational Playback* – i.e. the technical option of bringing different sound sources simultaneously into a listening environment, in order to enjoy and to create contextual and sonic relationships between them.

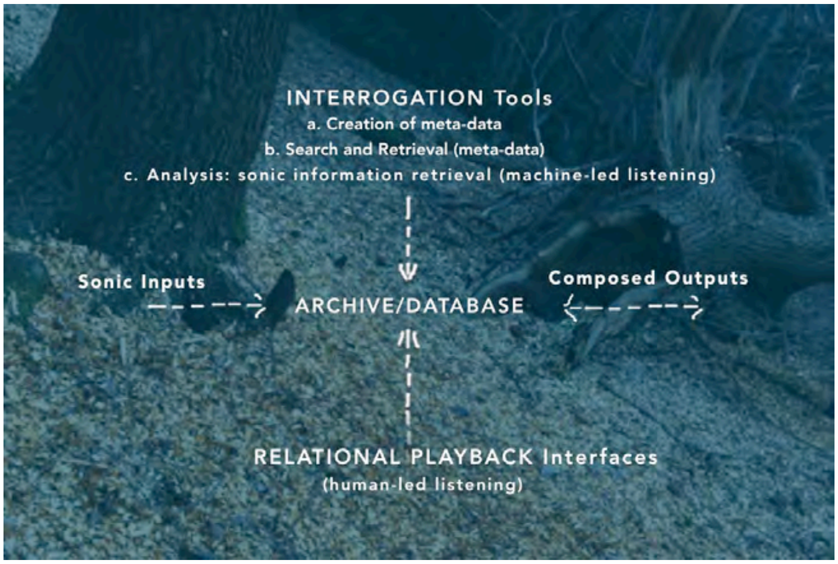


Figure 5. Sound Matters Framework

A needed link with *archives* having existing repositories, to access the sound material, can be seen in the framework. We gathered twenty researchers and artists working with field recordings and speech and asked them to reflect on the proposed framework[10] via interviews and a co-design workshop. We reflected on the nature of archives, the creation of algorithms for relational playback, and experienced some technological developments[11] including Open Source technologies that facilitate the mentioned processes[12].

The *Relational Playback* process was highlighted by interviewees as the most important process in creation and research with sound. This process is generally perceived as fluid, random, experimental, improvisational, compositional, performative and transformative. For the scholar Holly Ingleton, *relational playback* is the most fundamental process in her work, and she is interested in 'jamming' the reality of archives, focusing on the relationships between people and archival artifacts, possibly through mediated interfaces such as telematic technologies. These, she suggested, could bridge divides for making connections, and for 'undoing' traditional processes of the interrogation of data. On the other hand, anthropologist Rupert Cox refers to relational playback as a key process for ethnographic research. In his fieldwork he uses recordings to play to research participants; this practice opens the path of his research in unknown directions, as participants create relationships using their memory of the events. This takes the researcher into a new exploratory journey. Cathy Lane's major installations such as Memory Machine (Lane and Parry, 2005) and BEAM[13] exemplify her approach to memory and composition; for her, relational playback is where aesthetics can be developed and achieved by listening and developing sensibilities to the material, which is the only process that a computer cannot learn.

In the Sound Matters co-design workshop participants were asked to imagine scenarios that would enable creative interplay with large quantities of sound. Three options were proposed by them to establish relationships between sonic materials: mixing them at random according to sonic parameters; performing associative search using physical objects as triggers; and using interactive interfaces (e.g. conductive paint) that work with specific parameters of place, derived from associative tagging. Research into technological options to experiment with these processes brought into the framework open source applications and modular platforms such as Jamoma[14]. We envisioned Jamoma as helping the assemblage of functions to interplay with parameters of sound in a diversity of interfaces: screen-based, physical, interactive (Figure 6).

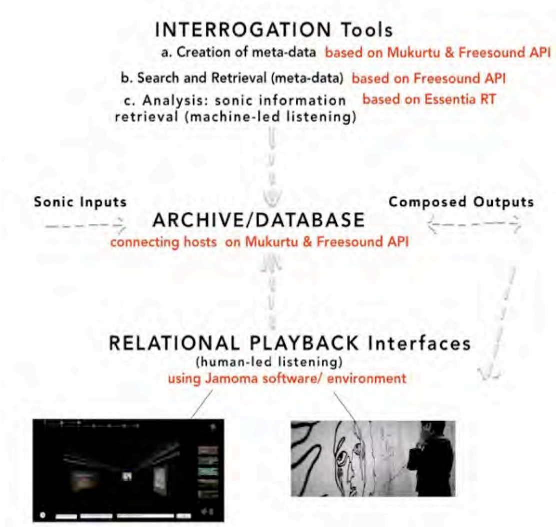


Figure 6. Framework incorporating open source technologies (images from Interfaces 'Sounding Underground' by Ximena Alarcón and 'Touch me not' by José Rizal: Audio book app, created using Bare Conductive (Touch Board, Ink)

[10] Published stories can be read and heard on http://soundmattersframework.wordpress.com and a wiki of the project is available on https://wiki.research.data.ac.uk/Sound_Matters_Framework
[11] Applications developed with Freesound API, and Essentia Library, and also BBC speech to text new recognition system.
[12] https://vimeo.com/133219234
[13] https://cathylane.co.uk/projects/beam/
[14] http://jamoma.org/

Going further into *relationality* we suggested highlighting *listening* rather than 'playback' in the process that intertwines human listening and the exploration of technologically mediated interfaces. *Relational Listening* has been defined by Lawrence English (2015) as a concept emerging from the possibility to "listen to a listener's listening" (3). This perspective resonates with Shroeder's proposed 'un-selfing' in the practice of networked listening, and with Oliveros' Deep Listening in the expansion of the sound field when practicing global and focal listening and attention to inner and outer sonic environments. English highlights the technological input, suggesting that *relational listening* experiments with what he calls 'two horizons of listening': the first driven by a psychological and experiential listening within time and space, and the second related to technological devices, such as the microphone that amplifies, transmits and serves the listener's listening. He proposes relational listening as the ability positioned 'in-between' the 'internal psychological' and the 'external technological' listening (4).

Nourished by my own and other researchers' and artists' approaches when exploring space and time with sound material directly linked to place and memory, what characteristics might be involved in such imagined *interfaces,* and what does *relationality* mean within contemporary *listening* contexts of dislocation?

I suggest that *interfaces for relational listening* should explore real-time interconnections between sounds in shared and networked sonic spaces, allowing the incorporation of individual navigation and vocal expression, and random encounters between sonic materials and people's memories, provoking global (inclusive) and focal (exclusive) listening attentional modes. These shared sonic spaces could build on the strong relational nature of sonic 'in-betweeness', pursuing dislocation in time and space, supported by networks, though maintaining referential paths to their original locations.

In this manner, the options of returning to these sonic locations, either individually and collectively, could make possible the questioning, unmaking, and making of memory in contemporary contexts. As occurs with human migratory contexts, listening to native sound spaces after being immersed in-between spaces augments the awareness of the self and others, challenging fixed cultural boundaries and beliefs, opening paths for social transformation.

## Conclusion

An evolution of a creative process involving navigation and networked performance interfaces derived from the search for sense of place, within the experience of migration, has been described. This serves as an experiential reference to the connections born out of dislocation and opens the field to explore relationships 'in-between' sonic spaces. In my specific works, access to these sonic spaces are reinforced by practices such as Oliveros' Deep Listening, and Networked Listening as described by Schroeder.

A shared sound framework proposed with Cathy Lane, and discussed with other sound creators and researchers, opens the field for thinking of the concept of *relational listening*, initially elaborated by Lawrence English, which helps bring the role of technology into the process of creating relationships with sounds, expanding the listener's listening. In this context, I have introduced the concept of *interfaces for relational listening* as live interfaces in shared sonic environments, which might open spaces for listening that rely on the relational nature of sonic 'in-betweeness'.

Within the contemporary rapid mobility of people between geographies, and the accumulation of sonic information about places and memories of place on hard drives and databases, *interfaces for relational listening* could become key tools for 'tuning' in our contemporary sense of place, questioning it, establishing connections, and offering sonic spaces for being.

## Additional Information

**Acknowledgements.** Ideas formulated for this paper have been tested in presentations with students at the London College of Communication, and Conferences such as Performing Migrations 2014, Sound Images and Data 2015, The Irish Sound, Science and Technology Association Conference ISSTA 2015, Erasmus Residency in the Bergen Center for Electronic Arts (BEK) 2016, and Creative Research into Sound Arts Practice (CRiSAP) Soirée 2016.

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# The Augmented Acousmonium as Interface

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**Abstract.** This article discusses the Sway Array project, an audio-robotic performance revolving around an interactive electromechanical acousmonium. The performance is examined from its technical aspects namely the design of the robotic loudspeaker array, the software components developed for its operation and the audio interactions.

**Keywords:** physical computing, robotics, acousmonium, arduino, supercollider, openFrameworks.

## Introduction

> Motion can be one of the most exciting and expressive tools in the physical computing toolbox. By now, most people are desensitized to motion onscreen, whether it's a monitor or a movie screen. We respond to it, but only as filtered through our conscious mind. When you see an object that has its own physical move, however, it triggers a more visceral reaction. (O'Sullivan and Igoe 2004)

The *Sway Array* project[1] is rooted in an interest for physical movement and its interaction with sound. At the centre of the work, a matrix of nine robotic-speakers (see figure 1) interacts with sounds and movements of a performer. Each speaker is about 2.5 meters high and also generates sonic actions. Their individual positioning is coupled with different audio processes through a chain of interactions involving the body and performative technology.

The first section of the article discusses the electromechanical parts of the loudspeaker array before addressing its software components. Physical and audio interactions are presented and the article ends with a short experimentation report.

## Physical components and protocols

The physical matrix is based on the principle of the Leslie speaker while extending its vocabulary of movements. Traditionally associated with Hammond organs, the Leslie speaker is a rotary speaker whose first applications date back to the 1940s. Named after its inventor Donald Leslie (1911-2004), this speaker can create a tremolo through the doppler effect caused by the rotation (Henricksen 1981).

For the project, the rotating speaker is augmented with components enabling movement on the vertical axis (see figure 2). The set includes two DC gearmotors, two rotary encoders and a microcontroller for closed-loop positioning on the two axes of movement. The encoders are attached to rotating parts and are pulled into motion by a pulley system. Limit switches are used to calibrate the device at startup and a total of 4096 rotational positions and about 1000 positions in elevation are possible to achieve.

[1] https://vimeo.com/143676764

Figure 1. An interactive robotic loudspeaker array of 9 units.

Figure 2. A closer look at a single unit's physical parts.

One piece of aluminum and one steel part were the only components that had to be designed specifically for this project. The stands were designed using aluminum extrusions[2] and all mechanical parts (gears, motors, couplers, pulleys, pillow blocks, etc.) are pre-manufactured aluminum assemblies distributed by Servocity[3]. A steel counterweight attached to the back of each speaker was custom built to counterbalance the weight of the horn and allow the use of a smaller and quieter motor for vertical movement. Finally, a "C" shape aluminum frame was also custom built to secure the different parts and hold the bearings of the vertical articulation. At the center of this "C" shaped part, a slip ring of 10 conductors transmits power to the rotating speaker, avoiding the problem of entanglement of wires.

[2] Aluminum extrusions usually come in a set of parts that can be assembled in complex structures, much like meccano models. The extrusion kit used in the project was developed by the KATIM team (www.katim.biz) based near Montreal, Canada.
[3] Servocity (www.servocity.com) as complete line of mechanical parts designed for hobbyists. Sourcing manufactured parts is essential to keep the cost of a physical project at a minimum as custom designed parts can often be 20 times or more expensive than manufactured ones.

Each speaker unit is equipped with a power supply and a motor controller[4] for managing the polarity and voltage supplied to the motors. An Arduino ethernet[5] and a teensy[6] card complete the set and enable two-way communication between the speakers and a central computer. The central computer continuously sends positioning targets at a rate of 10 times per second and receives the real positioning of every unit at the same temporal resolution. The communication between the central computer and the speakers is built on two communication protocols. First, the positioning targets are sent by Open Sound Control (OSC)[7] from the mainframe to the arduino ethernet to whom are assigned static IP addresses. Then the data is sent from the Arduino boards to the teensies over the serial port. The data as to the real position of the speakers goes the opposite way, starting from the teensy to the arduino over the serial port before returning to the central computer over OSC.

Although it is possible to have the motor control routines done on the arduino board, the teensy proved a more effective solution because it allows better reception of pulses sent by the rotary encoders. The processor speed on the teensy and the high number of inputs enabling interrupt routines[8] have made of this microcontroller board a better choice than the arduino. That said, the efficiency with which the arduino ethernet board allows IP communication[9] has ensured that this component is also essential to the project.

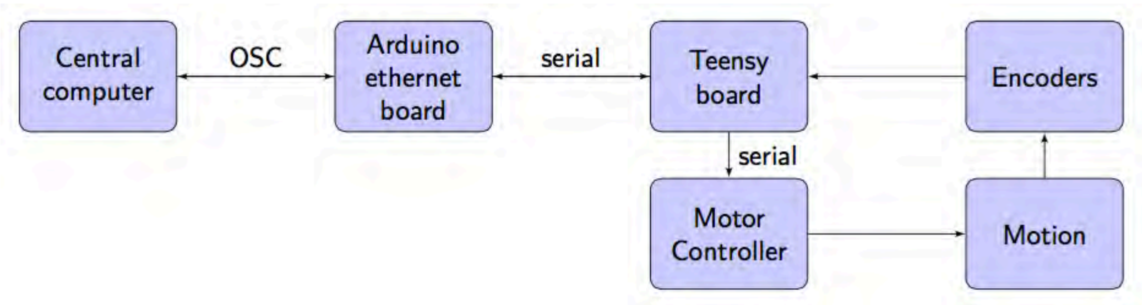


Figure 3. This chart summarizes all the physical components and communication protocols involved in the project.

## Software components

The communication between the central computer and the speakers passes through a simulation program coded in openFrameworks.[10] This program allows composition of movements without the physical device and facilitates the management of positions with the use of a virtual speaker. Initially, target positions in elevation and rotation are determined for a virtual loudspeaker. A positioning delay is applied to the real speakers as a function of the distance between them and the virtual speaker. Figure 4 illustrates this process where the master virtual speaker is white and

[4] The Sabertooth dual 12A motor driver was preferred for its pricing and ability to be controlled digitally over the serial port with a simple protocol. The controller can achieve 127 different speeds in the two directions.
[5] The arduino ethernet is a microcontroller board that comes with a build-in ethernet port facilitating IP communication with the microcontroller. This board is particularly handy when distance between the microcontroller and the computer becomes an issue or when IP like castings (multicast, broadcast, etc.) are desired.
[6] The teensy is a microcontroller board compatible with the arduino IDE. It's processor is faster than most arduinos and has interrupts on every pins.
[7] Open Sound Control is a protocol for transmitting data conceived for real time applications. It is mostly used in network contexts.
[8] An interrupt service routine (ISR) is a function that has a higher priority than the main loop. It gets triggered by a pulse received on the port it's attached to.
[9] One can do standard OSC communication with contributed libraries such as ArdOSC (https://github.com/recotana/ArdOSC)
[10] openFrameworks (www.openframeworks.cc) is a C++ toolkit for creative coding.

the real speakers are yellow. Movements are initiated on the virtual speaker and echoed on the real speakers with a delay calculated in number of frames per second times the distance from the virtual speaker.[11]

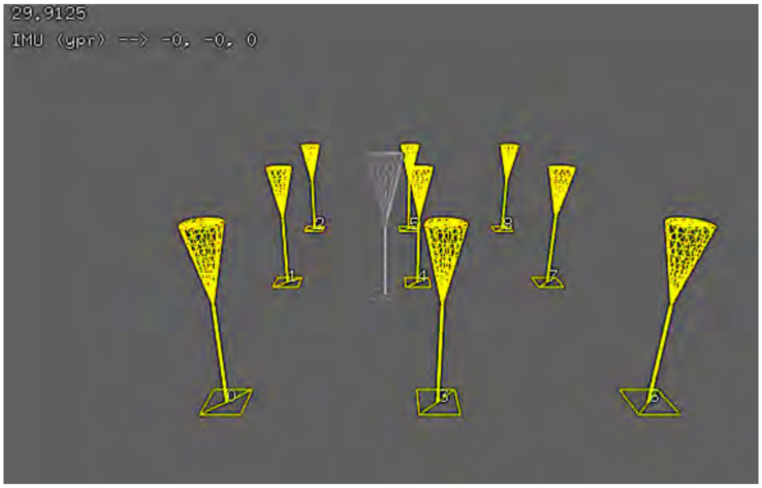


Figure 4. Image from the simulation program. The virtual speaker is in white and leads the other speakers in yellow for physical movement. Virtual speaker is mobile and can itself be positioned anywhere within the matrix limits.

An inertial measurement unit (IMU) placed on the head of the performer recovers ancillary movements (see figure 5). The orientation data collected by the IMU is sent wireless to the mainframe via the use of an XBee antenna[12]. This data is then used to control the virtual speaker so that head movements are eventually echoed on the physical device.

Figure 5. An IMU sends the orientation of the head which is echoed on the loudspeaker array.
Performer: Sarah Albu.

Audio interactions and composition of physical movements are made in SuperCollider (Wilson, Cottle, and Collins 2011). In this audio programming environment, management of location data (head positioning via IMU, desired positioning via the simulator and real positioning via microcontrollers) is associated with different audio processes. Thus,

[11] https://vimeo.com/121821246
[12] Digi International’s XBee is a radio module that facilitates wireless serial communication.

interactions between the physical movement of the performer and those of the loudspeaker array are expanded to sound.

During the introduction (6 min 15 sec)[13], a series of head movements are initiated by the performer. These movements are then echoed on the robotic matrix and the vertical positioning of each speaker is sent back to control a low pass filter. Later in the performance (10 min 45 sec), this data is associated with a live transposition of the voice. In the last section (12 min 45 sec), an audio granulation process is associated with each speaker based on the following mapping:

- Elevation of speaker: rate of grains and number of grains per second.
- Rotation of speaker: grain length (azimuth spread over two complete rotations).
- Distance from the virtual speaker in the simulator: Grain trigger delay.

## Summary chart

The following chart summarizes the data flow. Upstream an IMU is sending data as to the positioning of the performer's head. This data is received and handled in SuperCollider before being sent to the simulator by OSC. Positioning targets are then sent back from the simulator to SuperCollider and transmitted directly to the arduino ethernet of each speaker in OSC. Targets are then passed to the teensies over the serial port. Control commands are sent to a motor controller over another serial port available on the teensy. Real positions are routed back to the central computer using the reverse chain of protocols 10 times per second. Finally, when the data returns to SuperCollider, it is mapped to parameters of audio processes thus completing the chain of interactions.

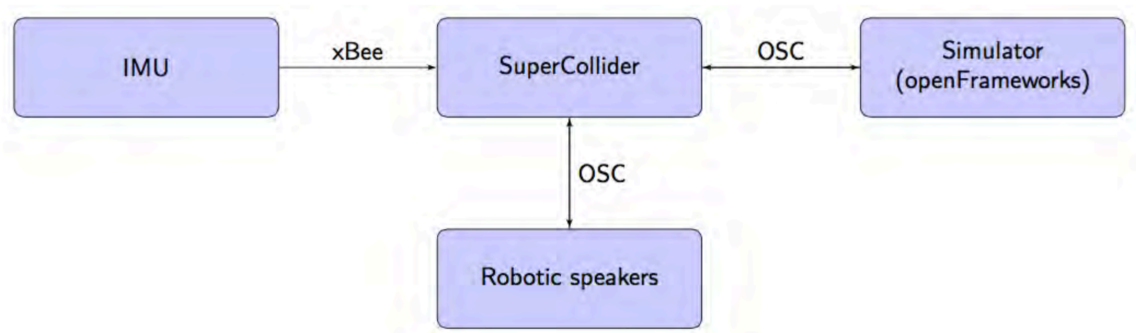


Figure 6. Data flow diagram

## Conclusion

The loudspeaker array allows composition of physical movements but its use is also oriented towards symbolic content. In a way, this strange augmented acousmonium becomes a character in itself. Its visual appearance creates images that can evoke different natural phenomena. Allusions to mass phenomena such as bird flocking, fish schools, swaying wheat and telescope arrays are almost inherent to its visual aspect. The interactions between the performer's head and the matrix also gives the loudspeakers an anthropomorphic quality which adds a referential layer to its use. Further research surrounding the symbolic resonance of the loudspeaker array needs to be done during the next creative cycle of the project.

Finally, the speakers have a certain inertia and consequently significant speed limitation in terms of movement. Research needs to be done regarding this aspect in order to upgrade the motorization. Stronger and faster motors need to be sourced. This will be a particular challenge since a compromise between pricing, speed and motor/gear noise

[13] https://vimeo.com/143676764 and https://vimeo.com/130647157

needs to be found. This speed limitation particularly favors large sonic gestures over short sounds when it comes to designing the audio interactions and composition. In this way, this augmented acousmonium can also be seen as a musical interface in itself, with its specificities and limitations, offering a singular perspective on sound creation.

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# Motion Origami

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**Abstract**. The Motion Origami project explores live performance strategies focused on gesture based control of sound. The sound processing involves granular sound synthesis in a Max/MSP patch. Motion Origami is designed for a live performance scenario as an interactive music instrument. Motion Origami makes use of the live performance audio input or of the pre-recorded sound material. This live interface prototype explores a gesture-based music composition and music performance techniques. The sound transformations are driven by the hand gestures, while the use of motion tracking device lets the user build up a specific experience and virtuosity.

**Keywords**: Leap Motion sensor, gesture recognition, motion tracking, music expression, granular synthesis, Max/MSP

## Introduction

The name of the Motion Origami project[1] is inspired by the Japanese art tradition of origami folding. The actual process of paper folding is reflected in a specific compositional strategy, which uses captured hand gestures. In other words the performing artist, the musician, is able to 'fold' sounds with his own hand gestures into new sound objects. The simple 'folds' therefore result into complex soundscapes during the performance.

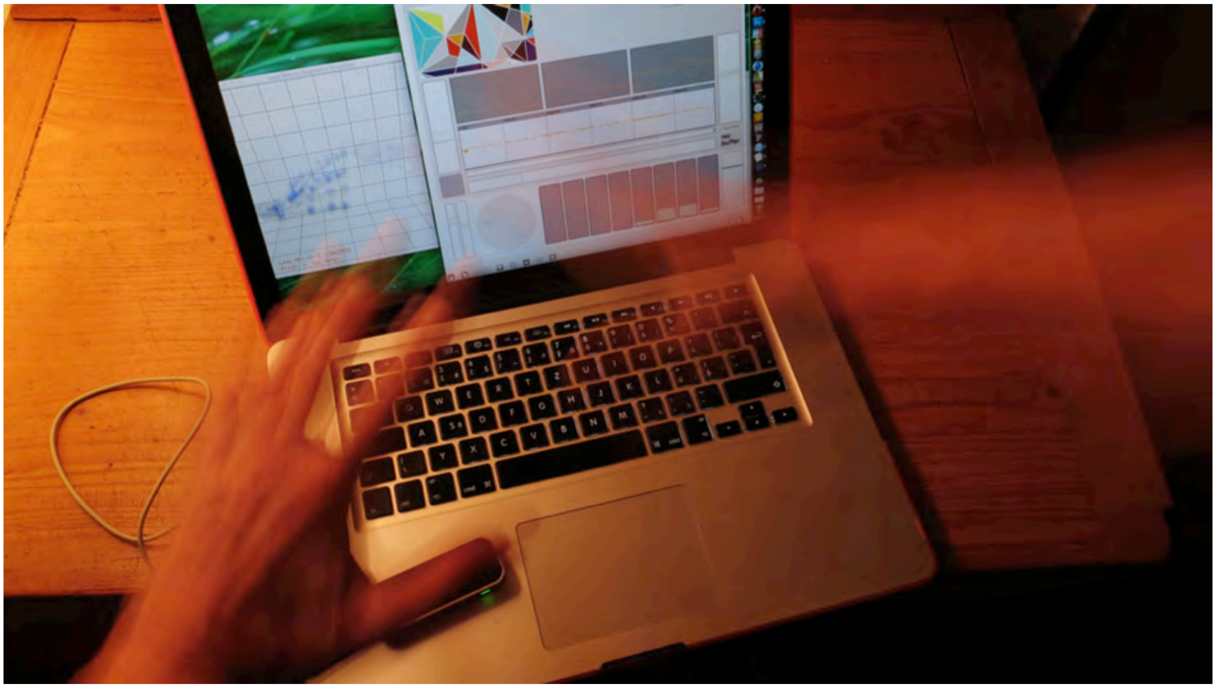

Figure 1. Motion Origami – MAX/MSP patch with the Leap Motion

[1] Motion Origami; the project presentation can be accessed online at http://www.danielbartos.com/motion-origami

This paper describes an original Max/MSP patch, which uses the *Smooth Overlapping Granular Synthesis* object *sogs*~[2] as it's main sound transforming element. The novelty of this approach is not in the production of a new code or a particular specific design, but in making a creative use of the existing and advanced audio processing tools in the sound and music performance. The project shows how a live interface prototype can be turned into an original compositional tool. As such, the Motion Origami project represents a recipe on how to approach a design of an experimental music instrument and shows an approach similar to the rapid prototyping technique applied to the realm of the advanced Max/MSP audio processing domain.

## Leap Motion

The Leap Motion[3] sensor was designed for touch-less tracking of hand gestures and their movements. The sensor in conjunction with the Leap Motion SDK becomes a sophisticated controller and delivers complex information monitoring the hand movements in real-time. Hand gestures are captured with a high precision accuracy along with the individual finger positions, rotations and finger tips accelerations.

The Leap Motion sensor was introduced to the market in the mid 2013 and swiftly found its place among other devices designed for body movements and gesture tracking – as for example the Kinect[4] and the Wii controller[5]. Such devices work usually with general body tracking and can be repurposed. The Leap Motion on the contrary is designed to capture the hand gestures and movements only. In fact the Leap Motion sensor could be thought of as a special interactive space[6] of predefined volume of air. Common music applications of the Leap Motion sensor are primarily based on the imitations of physical interfaces of existing musical instruments. This is true especially for the following projects: Air-Keyes, Crystal Piano, Air Harp, etc. (Han 2014). The main reason for that is, that the virtual keyboard represents an ideal setup for testing of the system latency (Silva 2013), as the low latency response is one of the most important elements for any real-time music performance application. The latency of the Leap Motion, as advertised by the manufacturer, is anywhere from 5ms to 20ms, but this particular figure obviously depends on the whole system configuration and components used. Another category in the existing applications of the Leap Motion sensor is represented by various hybrid instruments. A specific selection of such projects is described in the paper Lessons Learned in Exploring Leap Motion™ (Han, Gold 2014).

## The Motion Origami Body & Sound Interaction

The theme of physical interaction and sound processing is thoroughly investigated in the paper called Sound Design as Human Matter Interaction (Wei 2013), whereas the most important keyword becomes the term *material computation*[7]. In the extended sense we can think of the Leap Motion sensor as if it is constituting an interactive space on its own, where the calculations and interaction take place. The gesture recognition in conjunction with a music performance is

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[2] MAX/MSP object *sogs*~ (Smooth Overlap Granular Synthesis) by Norbert Schnell, IRCAM – Centre Pompidou; more information can be accessed online at http://forumnet.ircam.fr/product/max-sound-box
[3] Leap Motion, complete sensor and SDK specification can be accessed online at http://leapmotion.com
[4] Microsoft Kinect is a sensor using depth map to create 3D space representation. Developed by Microsoft for a game console Microsoft© Xbox 360. Kinect specification can be accessed online at www.microsoft.com/en-us/kinectforwindows
[5] Wii Remote is part of Nintendo© Wii Console developed by Nintendo© Company, Ltd. Wii specification can be accessed online at www.nintendo.com/wii
[6] Interactive space of 8 cubic feet, equivalent of 0,22 $m^3$ respectively, as stated by the manufacturer; more information can be accessed online at http://leapmotion.com
[7] *„Realtime, continuously responsive environments for the design of technical systems for human-computer interaction design …* “. Ibid, p. 2010.

also being explored by the IRCAM's ISMM research team[8]. While the physical body & sound interaction concept is present for example in the projects of Marco Donnarumma, who uses set of repurposed bio-sensors[9].

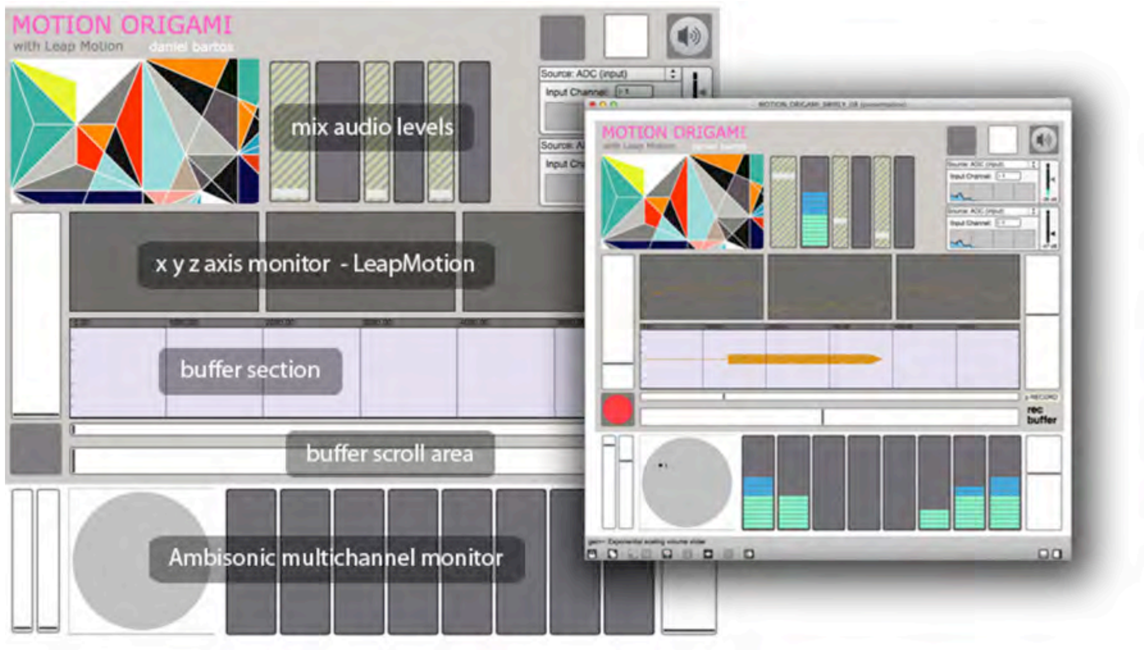


Figure 2: Motion Origami – the individual patch sections explained

In the case of the Motion Origami Max/MSP patch, the performer's physical gesture interaction is the primary source of the resulting sound transformations. The performer creates new sound objects with the captured hand gestures. The hand gestures in the Motion Origami patch are recognised in the interactive space above the sensor and are turned into a control mechanism coded in the Max/MSP patch. A single recognised hand gesture initialises the audio buffer with the incoming audio. The buffer acts as a starting point for the granular synthesis soundscape building. The hand gestures control the granular synthesis engine parameters, along with the timing of the buffer initialization with a new audio material during the live performance as well. The hand gestures control the wet & dry ratio of the audio signal input and also the multichannel audio distribution via the Ambisonics engine[10].

## Motion Origami Patch Implementation

The Motion Origami patch is programmed in Max/MSP[11]. Data from the Leap Motion sensor are captured by the *SwirlyLeap* object[12]. The updated version of the patch uses the current and well documented IRCAM's *leapmotion*

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[8] IRCAM – ISMM team {SOUND MUSIC MOVEMENT} INTERACTION; more information can be accessed online at http://ismm.ircam.fr
[9] Marco Donnarumma; project presentations can be accessed online at: www.marcodonnarumma.com
[10] Ambisonics Tools from the Institute for Computer Music and Sound Technology ICST, Zurich University of the Arts can be accessed online at: https://www.zhdk.ch/index.php?id=icst_ambisonicsexternals
[11] Max/MSP visual programming environment by Cycling74, more information can be accessed online at http://www.cycling74.com

object[13]. The *Smooth Overlapping Granular Synthesis* object *sogs~*[14] was chosen because it offers a simple and creative control over the audio captured into the audio buffer and can be used for a specific navigation and exploration of the audio buffer. The *sogs~* object also mimics the paper folding technique in the sense, that the original paper surface is substituted with a 2D plain made of two individual parameters: the grain position and the grain size. The data from the Leap Motion sensor are mapped to drive the *sogs~* object with those two selected parameters: the performer than navigates the space of the audio buffer defined by the grain size and the grain position parameters respectively.

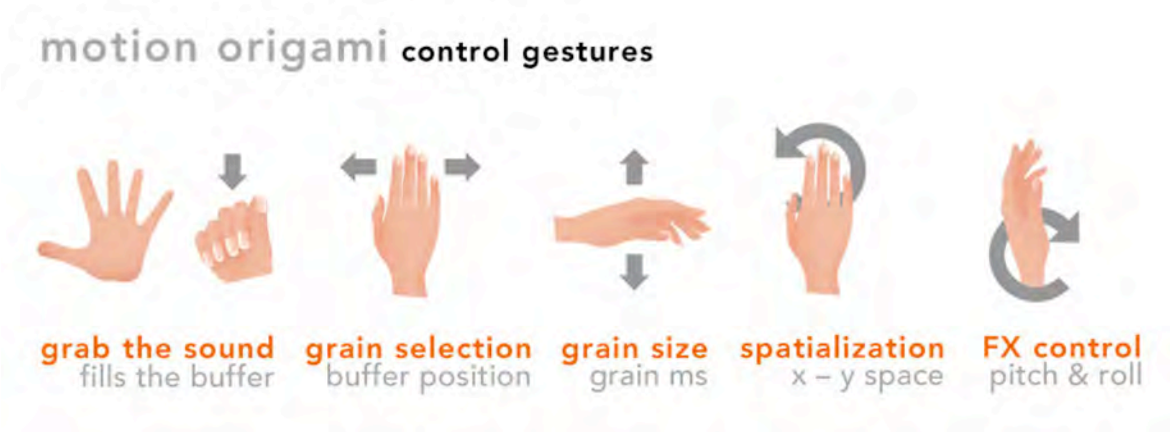


Figure 3. Motion Origami – the recognised gestures illustrated

The wet & dry mix ratio, which is also mapped to hand gestures, offers detailed control over the sound merging and accents the actual 'sound folds'. These 'sound folds' can build up a certain level of complexity thanks to the fact, that the live audio source is coupled with the audio material stored in the buffer. Although the audio is modified in the granulation process, it shares the same spectral and tonal characteristics with the original sound source. This in turn creates elaborated sound transformations, which can be though of as the introduced 'sound folding' process. The patch recognises a specific gesture, which is required to start the initialisation of the audio buffer. In this way the audio buffer is filled with a new audio material. The buffer initialisation starts with a gesture of a closed hand. This gesture can be paraphrased as 'grab the sound' gesture. In this very moment, the buffer is filled with the live sound input and becomes available to *sogs~* object. Subsequent hand gestures control various aspects of the granular synthesis engine: horizontal hand swipe controls grain position selection, vertical hand movement controls time length of a grain. Moreover the overall palm position above the sensor in the *x - y* plane defines the sound source position in the multichannel Ambisonics space and adds a multichannel spatialisation layer to the performance. The other Leap Motion recognised variables as yaw, pitch a roll are alternatively mapped to extended FX processing (reverb, distortion, etc.), depending on the performance scenario.

[12] Swirly Leap Max/MSP access the Leap Motion API, written by Tom Ritchford from New Yorku. Project can be accessed online at https://github.com/rec/swirly-leap

[13] Well documented Max/MSP object leapmotion by IRCAM, more information can be accessed online at http://ismm.ircam.fr/leapmotion/

[14] Max/MSP object sogs~ (Smooth Overlap Granular Synthesis) by Norbert Schnell, IRCAM – Centre Pompidou, more information can be accessed at http://forumnet.ircam.fr/product/max-sound-box

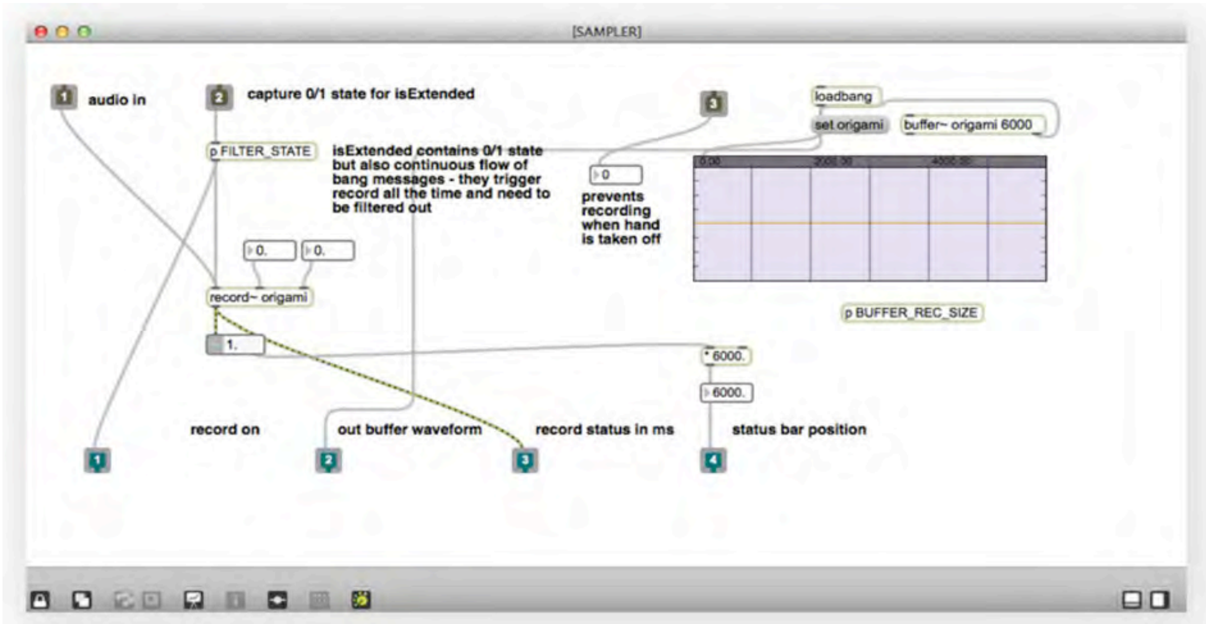


Figure 4: Motion Origami – a detail of the subpatch controlling the audio buffer initialisation

## Conclusions & Performance

The most inviting application of the Motion Origami patch[15] is a vocal performance or simply a music instrument, which leaves enough space for the interaction with the sensor itself. The beauty of the live performance approach lies the fact, that the performer can interact with his/her captured music material and add multiple layers of expression by solely using the hand gestures. New layer of improvisation can be introduced, while new themes and phrases emerge. The performer than interacts with a new music material, which is based on the sound qualities of the original music instrument or the vocal performance. The performer can control the following parameters in the Motion Origami live interface: time based selection of a phrase sampled into the buffer; grain size and it's position in the buffer; wet & dry mix ratio and Ambisonics sound source space position (if applicable).

Using gestures in music composition and performance proves to be very intuitive. The sensor alone has to be 'learned' to be operated properly and this fact delivers a specific virtuosity over time. The Leap Motion sensor with the Motion Origami patch opens up a new exciting field of music composition and sound processing coupled with immediate gestural interaction. The biggest challenge in the gesture based performance is the recognition of the quantized gestures (Potter 2013). While parametric control of the various patch elements doesn't present any technical problem tracking-wise, the recognition of the quantized and unique gestures proved difficult through out the development phase of the patch. For example, while playing on a virtual keyboard, one can limit the key strokes to a specific scale and limit the mis-triggered notes this way. But when it comes to evoking a specific functionality (sampling initialization, sound bank toggle, etc.) the gestures have to be recognized with exceptionally high precision as those decisions create an integral part of the performance itself. This aspect of the live performance gives us a specific constrains and we have to consider them in the live performance scenarios, when using the Leap Motion sensor. The quality of the tracking depends also on the present light conditions and the overall sensor setup. For example, a direct light reaching the sensors's surface can introduce inconsistency in the tracking.

[15] Motion Origami, the project presentation can be accessed online at http://www.danielbartos.com/motion-origami

Overall, the Leap Motion is very suitable for various intuitive music composition and performance scenarios. Occasional errors in tracking can be overcome with a good patch design and the restricted use of the quantized gestures – leaving out the quantized gestures to be services by traditional hardware controllers. Having said that, the Leap Motion sensor excels in the intuitive gesture interaction performance and the gesture based music composition strategies.

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[16] Michal Rataj – music composer and researcher at HAMU (Music Academy in Prague). More information can be accessed online at http://michalrataj.com

[17] Matthew Ostrowski – expert on sensors and multimedia programming based at Harvestworks NYC, offered valuable insights into Leap Motion programming. More information can be accessed online at http://www.ostrowski.info and http://www.harvestworks.org

# Taptop: Using the Laptop Chassis as a Musical Controller

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**Abstract:** This paper presents Taptop, a new gesture control application designed for controlling drum machines, samplers and other software virtual instruments running on laptop computers. Without requiring external electronic hardware, Taptop turns the chassis of the laptop into a velocity sensitive control surface for triggering samples by combining data collected from the built-in webcam and microphone to produce MIDI messages. The user taps on the unused space either side of their laptop mouse trackpad which is divided into a number of virtual 'drum pads'. Each virtual pad causes a different MIDI note to be output when tapped, with the velocity of that note determined by the force of the tap. This control solution aims to provide a more affordable and portable alternative to the hardware MIDI controller, and increase the potential of the computer as a standalone performance instrument.

**Keywords:** Gesture Control, Drum Pads, Velocity Sensitive, Live Performance, Musical Interface

## Introduction

Software drum machines and samplers are an important part of the workflow of many electronic music producers. Yet, despite the prominent role of these instruments in the modern music studio, the options for controlling them remain restricted to a limited number of methods. This is an issue not only associated with software drum machines and samplers, but other virtual instruments too. While significant advances continue to be made in developing more powerful and flexible virtual instruments, the ways in which musicians interact with those instruments has remained largely the same since the inception of the Digital Audio Workstation (DAW) Theberge (1997). When composing with a virtual instrument, a musician will often arrange sequences of notes via their DAW piano roll. This method of control obscures the musician's interaction with their instrument behind software, in contrast to an acoustic instrument where the physical gestures that produce the sound are immediately apparent to the audience (Dobrian 2001). Well thought out mapping of physical gestures to musical parameters could therefore provide a more expressive method of control for software instruments, and help to reintroduce some of the performance element that is often lost when making music with a computer (Bown, Bell, and Parkinson 2014).

For the purposes of musical interaction, it is important that a gesture control system provides the musician with the opportunity to develop a repertoire and a degree of musicality over time through practice, as would be the case with a more traditional instrument. When asked what instrument they play, few computer musicians would respond with 'I play the computer'. This is largely due to the fact that the majority of human-computer interaction interfaces leave little room for progression or virtuosity (Wessel and Wright 2002). The familiar method of controlling a computer through a keyboard and mouse or trackpad may be intuitive, but it is also incredibly restrictive as a musical interface (Pavlovic, Huang, and Sharma 1997). Such devices are unable to capture velocity information and hence limit musical expression. However, the keyboard and mouse are not the only sensors available to us on a modern laptop, indeed Fiebrink et al have investigated the use of various built-in sensors including microphones, accelerometers, and webcams among others for controlling music (Fiebrink, Wang, and Cook 2007). Hong and Yeo used acoustic feedback between the computer speaker and its own microphone to drive audio DSP for experimental audio-visual performance (Hong and Yeo 2013).

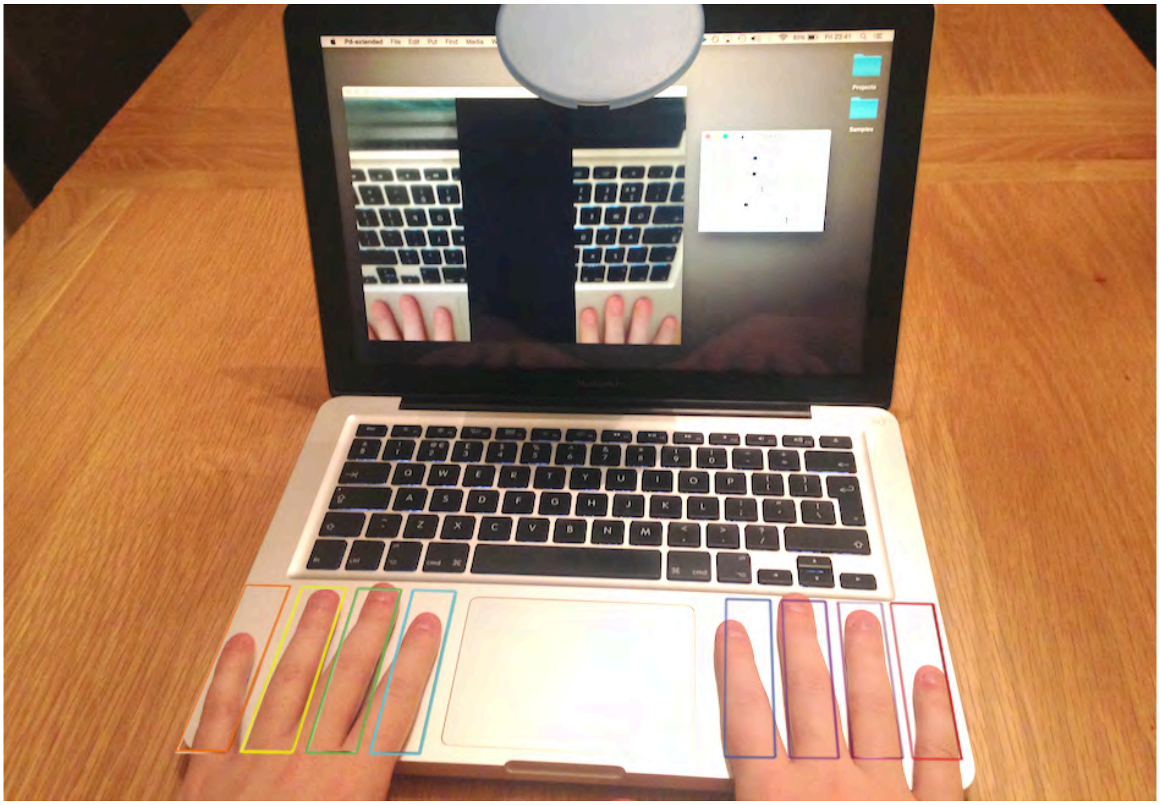

Figure 1. Taptop in use. An angled mirror allows the system to detect the user's hand motion in the drum pad area using the built in webcam. The user has a choice of dividing the laptop chassis into 2, 4 or 8 drum pads, selected via a series of buttons on the GUI. The drum pads increase in width as fewer pads are selected, so that the entirety of the laptop chassis width is always being utilised. The angle of the mirror attachment is adjustable so that it can be used with a variety of laptop models.

External MIDI controllers go some way in enhancing the musical performance capabilities of the computer, but these are often expensive devices and constitute another piece of equipment for a musician to transport or accommodate in their studio (Gillian and Nicholls 2012). A system that provides the same functionality as a MIDI controller without the requirement for external electronic hardware would therefore possess significant advantages. To this end, we have developed Taptop, a gesture control software application that uses the laptop's own microphone and camera to detect the user's actions. Using these built-in sensors, we allow unused space on the laptop chassis itself to be used as a well established interface for controlling virtual drum machines and samplers, namely a bank of drum pads. Drum pads are an intuitive interface that anyone can use to trigger samples, but they also allow a performer to develop their skills sufficiently enough over time to be considered an expert (Zamborlin et al. 2014); the electronic musician Jeremy Ellis being a good example (Ellis 2011).

The concept of using microphones to turn a generic surface into an interface for controlling digital audio is not new. A number of systems have already been successfully implemented using this idea, the most widely known probably being 'Mogees' (Zamborlin 2016). Mogees are small devices containing a contact microphone which, when connected to a smartphone or computer, allow the user to drive a synthesis engine in accompanying software simply by hitting or rubbing a surface. A single microphone allows the system to capture timbre and transient information but some other approaches have used multiple transducers to allow position information to be captured as well. For example Bisby et al. (2014) developed an instrument using an array of piezos to achieve accurate localisation of sound sources on a surface, while Novello and Raijekoff (2015) utilised a pair of contact microphones to locate the gestures of the user on a surface, mapping the position of movement to the pitch of the instrument.

## System Overview

Taptop was implemented in the Pure Data graphical programming language, making extensive use of the image and video processing objects that comprise the GEM library. Instead of physical drum pads, the user taps in the unused space either side of their laptop mouse trackpad which is divided into a number of horizontally arranged virtual pads, represented by coloured boxes in figure 1. The laptop webcam field of view is positioned over this area by means of a mirror attachment; the only external accessory required to use Taptop. To assist the user in positioning the mirror attachment, the webcam stream is displayed in a window overlaid with a black rectangle that indicates where the mouse trackpad should be located.

Taptop controls virtual instruments via MIDI. In order to trigger a MIDI note, two criteria must be met. This process is described in the flow chart in figure 2. Firstly, the audible tap of the user's finger on the chassis of the laptop must be detected through analysis of the laptop microphone signal. The level of this tap corresponds to the velocity of any MIDI note subsequently triggered. Secondly, movement must be found to be occurring in at least one of the virtual drum pads by a motion detection algorithm applied to the webcam signal. Each of these drum pads corresponds to a different MIDI note number. When a tap is detected in the microphone signal, MIDI note on messages are sent to the virtual instrument being controlled with note numbers determined by the movement occurring in the drum pads.

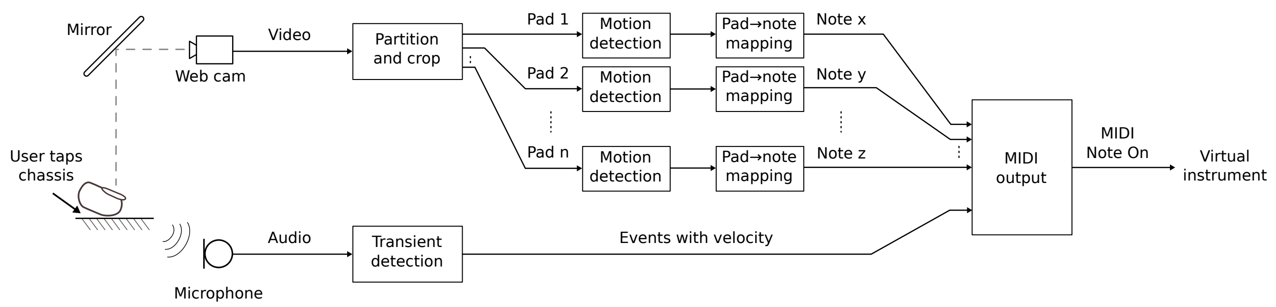


Figure 2. Dataflow in the system. Taptop translates data from the laptop webcam and microphone to produce MIDI messages which are then used to control a virtual instrument.

## Detecting Movement

Taptop crops the laptop webcam signal into a number of regions, each representing a virtual drum pad. It is the movement of the user's fingers in these regions that determine which note numbers are encoded into the MIDI note on messages that are sent. Movement is detected by comparing the current and previous frames of each region to determine which pixels have significantly changed. The video stream is converted from an RGB to an RGBA colourspace so that pixels that demonstrate a change in these subsequent frames can be stored in the empty alpha channel. If the number of pixels stored in the alpha channel is above a set threshold, the system assumes that movement is occurring in that drum pad.

## Detecting Transients

To detect the audible tap of the user's finger on the laptop chassis, we used a method based on the 'Bonk' Pure Data object (Puckette 1997). Bonk is a transient detector that has the ability to determine which instrument was responsible for a particular attack by comparing spectral changes to a set of stored templates. Taps on the laptop chassis were recorded at a variety of velocities, then stored as templates so that Bonk could be taught to ignore other audio being picked up by the microphone. This helped address the possible issue of feedback in the system, where playing back drum samples through loudspeakers could cause the application to trigger itself. While some drum hits may have a similar envelope to the templates, the spectral differences between the two should cause them to be ignored by Bonk in most cases.

## User Testing

A series of user tests were carried out in order to determine the success of Taptop as a musical interface. Ten participants were selected who each had backgrounds in electronic music production. This was to ensure that those taking part in the tests would have the relevant knowledge to provide informed opinions on the performance and features of the application. Two lines of investigation were employed; a focus group to establish if the concept was popular among music producers, followed by more detailed beta testing to ascertain how producers utilised Taptop over an extended period of time. The focus group and beta test involved five participants each.

### Methodology

In the focus group, participants were first given an introduction to the concept behind Taptop and the current issues in virtual instrument control that it was designed to address. They were then instructed on how to use the application before being given ten minutes alone to try it out for themselves controlling a virtual instrument. The tests were carried out under controlled conditions in a room where the level of lighting could be adjusted. This meant that the performance of Taptop could be evaluated in bright, dark, and optimal lighting to reflect the different environments that it may be used in. After the tests were completed, the participants each answered a questionnaire about their experiences with the application.

For beta testing, the participants were each provided with a copy of Taptop to try in their own studio setups. Over the period of a week, they could use the application in whatever way they chose. After this time had elapsed, the participants submitted feedback on how it had performed. The two key things to establish from this were the various ways in which the participants utilised Taptop, and if they would then consider adopting the application over their usual method of control at the end of the trial period.

### Results

In the focus group questionnaire results, the two most frequent answers given by the participants for the features of Taptop they liked the most were its self-contained, ‘in the box’ format, and its ability to control the playback velocity of samples through a physical action. The concept of a musical interface being completely integrated into the same device as the sound source proved attractive to those participants who make use of hardware MIDI controllers. Although manufacturers put effort into making such devices more portable, not having to accommodate one at all would be desirable to a musician who has to travel or who has limited studio space. For those participants who use a DAW piano roll to control their virtual instruments, the input of note velocity through gesture was seen as a more expressive alternative to programming velocity automation within a DAW.

The most common feature of Taptop that the participants disliked was its reliability. If lighting was not at an optimum level then the application had difficulty in detecting the users movement, meaning that samples were sometimes not triggered when they were supposed to be. Since the environments that electronic music is performed in are generally dimly lit with sporadic bursts of very bright light, this is a significant problem that needs to be addressed. Another concern raised by the participants was that tapping a laptop too hard in an area where the hard drive is located may result in the drive being damaged. This is especially relevant for magnetic disk drives which are more susceptible to impact damage than solid-state storage (Pinheiro, Weber, and Barroso 2007). It has yet to be established whether or not long term use of the application has an affect on the hard drive of the laptop that it is run on.

The results of the beta testing are displayed in Table 1. Feedback was generally positive with 3 out of the 5 participants stating that they would consider using Taptop in place of their usual method of control. Participant 2 encountered issues with Pure Data being unable to stream video from the laptop webcam, thought to be caused by a compatibility problem between the ‘pix_video’ Pure Data object and certain versions of the Mac OS X operating system. For this reason, they were unable to get the application working in their studio setup and therefore stated that they preferred their usual method of control to Taptop.

| | Usual method of control | Taptop preferred | Taptop primarily used for |
|---|---|---|---|
| Participant 1 | MIDI Keyboard | Yes | Triggering samples to accompany singing |
| Participant 2 | Piano Roll | No | Not used* |
| Participant 3 | Drum Pads | Yes | Programming Hip-Hop beats |
| Participant 4 | Piano Roll | Yes | Auditioning synthesiser patches |
| Participant 5 | MIDI Keyboard | No | Generating ideas for beats on the move |

Table 1. Results of beta testing. Feedback was generally positive with three candidates willing to consider using Taptop to replace their current control method. * Participant 2 was unable to run the system due to a compatibility problem with Pure Data on their laptop.

Participant 5 also stated that they preferred their usual method of control, a MIDI keyboard, to Taptop. While they thought that the application was useful for generating ideas on the move, they enjoyed the tactile feedback of keys being depressed when performing on a hardware device. It is interesting to note that Participant 4 used Taptop in conjunction with software synthesisers rather than with software drum machines and samplers, as was its intended use. They commented that the application provided a more immediate way of interfacing with synthesisers when auditioning patches than their usual method of control, a DAW piano roll. Participants 1 and 3 used Taptop for its original purpose, controlling drum machine and sampler virtual instruments. They both stated that they preferred Taptop over their usual hardware set ups due to the ease of portability that it afforded them.

## Conclusion

We have demonstrated a real-time method of virtual instrument control that uses only the built-in webcam and microphone that come as standard with most laptop computers. The development of this application sought to address a number of the issues associated with current methods of virtual instrument control, particularly concerning software drum machines and samplers. One objective was to release musicians from the burden of transporting and accommodating hardware MIDI controllers through a gesture control system that possessed the same functionality. This was achieved by exclusively utilising the built-in features of a laptop computer to control the virtual instrument; the only external component required being a small mirror attachment. By basing Taptop's control metaphor on a bank of drum pads, the functionality of the application is largely identical to an already well established music control interface.

Another objective was to explore the potential of the computer as a performance instrument through the development of an expressive method of control for virtual instruments. Normally, without the use of an external device, musicians are restricted to composing on a computer via their DAW piano roll. Since this method of control is incapable of facilitating real-time performance, it is understandable why many musicians hesitate to class the computer as a musical instrument (Wessel and Wright 2002). However, with such a wealth of music now being made exclusively using computers, it seems strange that this should be the case. Taptop expands the potential of the computer as a musical instrument by enabling a laptop to be used for standalone performance, where the audience can directly relate the physical gestures of the performer to the music they are hearing (Ciciliani and Mojsysz 2014).

Further work needs to be done in improving Taptop's reliability, particularly when being used in adverse lighting conditions. If the lighting is too bright or too dark, the motion detection algorithm is less likely to be able to detect user movement. Making the motion detection algorithm adaptive to different lighting conditions could be the answer to this, so that in difficult environments the sensitivity is automatically lowered increasing the chances of user movement being detected.

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# Towards a Live Interface for Direct Manipulation of Spatial Audio

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**Abstract** In this position paper we present research from the AHRC-funded project Transforming Transformation: 3D Models for Interactive Sound Design. The project entails exploration of a new interface for live audio transformation whereby sound can be manipulated through grasp as if it were an invisible 3D object. This approach contrasts with existing GUI-based systems, which primarily use 2D input and 2D visualisation. In the paper we describe the first phase of this research, which enables audio sources to be positioned and moved within a 3D space by grabbing them from a palette and controlling their spatial location using hand movements. Feedback regarding spatial location is provided through a visualisation of these sources within a virtual 3D space. Spatial trajectories can be 'drawn' in the air, and sounds can be 'rolled' along these trajectories thus providing a 'direct manipulation' interface to specifying spatio-temporal dynamics. We describe the design of the system along with findings of the initial system usability tests.

**Keywords:** 3D; sound design; spatial audio; live; direct manipulation.

## Introduction

Existing studies show a requirement for more usable and human-centred audio processing systems for live performance and highlight software design deficiencies as a barrier to musical creativity (Bullock, Beattie, and Turner 2011; Magnusson and Mendieta 2007). In response to such a requirement, we have set ourselves the ambitious goal of rethinking audio transformation such that sounds can be manipulated live, as though they are tangible objects suspended in the air. We imagine a system where a user can sit in front of an invisible, 3D space (e.g. a $1m^2$ cube), 'containing' a number of sounds that can be touched, grabbed, stretched, broken, and thrown. In terms of spatialisation, we anticipate the ability to 'throw' such sounds with inertia such that they 'bounce' off the sides of a virtual acoustic space until their mass slows them down. Our aim is thus to create a sound processing environment, the visual and interactive characteristics of which correspond more closely with 'everyday listening' (Gaver 1993) than with typical technology-centric approaches found in widely-used Digital Audio Workstation (DAW) and plugin-based environments. In this paper we describe the first stage in our research towards this goal: the representation and interaction with sounds in a virtual space such that they can spatially positioned in 3D with corresponding acoustic spatialisation using a multi-channel speaker system or binaural headphones. Our aim was thus to provide an output-independent (same 3D environment for multiple underlying spatialisation technologies) interface for 3D positional audio that feels live and direct to the user with high levels of usability and a strongly positive user experience. This research is aimed to be applicable across a wide range of application domains such as composition, live performance of new music, sound design, studio production and game audio. Furthermore, we argue below that whilst 'liveness' has performative implications is also an experiential quality of interfaces, that is interfaces can per se be more or less 'live'.

To illustrate this, we begin with the related 'direct manipulation' paradigm originally proposed by Shneiderman for interfaces that have the following properties:

1. Continuous representation of the object of interest
2. Physical actions or labeled button presses instead of complex syntax

3. Rapid incremental reversible operations whose impact on the object of interest is immediately visible (Shneiderman 1982, 251)

Norman and Draper subsequently build upon and problematise Shneiderman's concept by suggesting that *Direct Manipulation* is not a unitary concept nor even something that can be quantified in itself. It is an orienting notion. 'Directness' is an impression or a feeling about an interface capable of being described in terms of concrete actions that can be taken by system designers to make interfaces more-or-less direct (Norman and Draper 1986, 93). Norman and Draper propose two aspects of directness that can be designed into systems: distance, and engagement. 'Distance' pertains to the 'cognitive gap' between a system's representation of a task or environment and the human user's representation. 'Engagement' pertains to the 'qualitative feeling of engagement, the feeling that one is directly manipulating the objects of interest' and where 'the world of interest is explicitly represented and there is no intermediary between user and world' (Norman and Draper 1986, 94). We argue that both of these aspects of direct manipulation are, within the context of interfaces for audio transformation, key indicators of a highly positive user experience. A full discussion on direct manipulation and how it relates to user experience (UX) is beyond the scope of this paper, however, of particular relevance is the relationship between 'directness' and 'liveness' as set out by , which builds further on Schneiderman's framework:

> *Liveness* means the user interface is always active and reactive - objects respond to user actions, animations run, layout happens, and information displays are updated continuously. Directness and liveness are properties of the physical world: to examine and change a physical object, you manipulate it directly while the laws of physics continue to operate (Maloney and Smith 1995).

Our use of the word here 'live', corresponds to that of Maloney and thus differs somewhat from (although does not exclude) 'live' as in 'live performance' or 'live electronics', in that it refers to the intended liveness of the user interface as enabled through direct and pliable manipulation of the objects (in this case sounds) being interacted with.

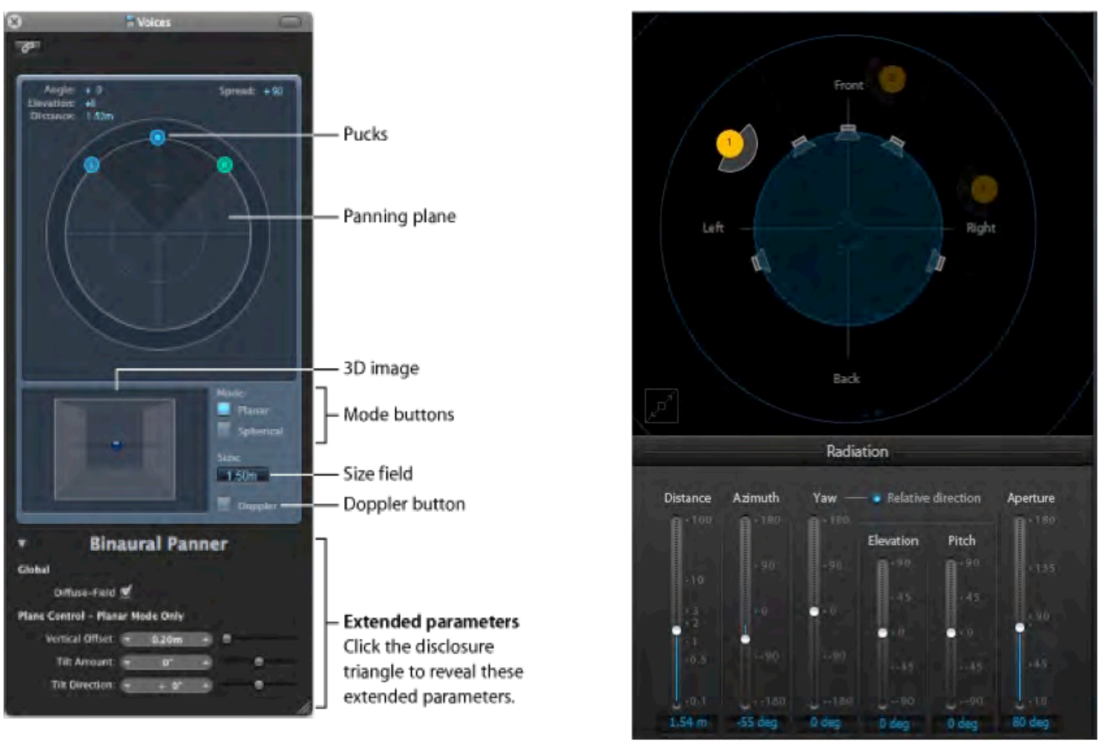


Figure 1. 2D approaches to spatialisaton UI: Logic Pro X's binaural panner (left) and Flux Spat plugin (right)

This contrasts with commonly-used commercial interfaces for audio processing in this case, spatial positioning. The use of a 2D input device such as a mouse, trackpad or joystick coupled with a 2D (single-plane) or quasi-3D visualisation immediately creates 'cognitive distance' for users by forcing them to internally 'map' between a 2D interaction model and 3D acoustic output. A typical example of this approach is shown in figure 1. In such interfaces, the user moves a small 'puck' representing a sound source within a circle (through the horizontal panning plane) or sphere (through a 3D panning surface) by moving the cursor. As the user drags the puck in physical 2D space, the sound's apparent location within the 3D virtual acoustic space changes. For tasks, such as simulating the sound of a car moving past the listener, a 2D interface may be sufficient. However, more generally, a 2D interaction model does not sufficiently mirror the human perception (or internalisation) of sounds occupying 3D space and having 'volume'[1] (Carello, Anderson, and Kunkler-Peck 1998). Rather, sounds are represented as point-sources, with the user positioned and controls from 'above' the spatial plane. Such interfaces are also problematic because they do not provide a uniform representation of sounds and means of transformation. That is, in a plugin-based environment, spatial position is usually controlled through one part of interface (the plugin-type UI), volume through another (a mixer UI). A DAW or typical live audio environment automations of spatial parameters over time are edited through yet another interface; typically using continuous visual breakpoint functions, or 'envelopes', with one-envelope-per-dimension for spatial position, thus extending 'cognitive distance' further by reifying spatial location into discrete geometric parameters. To do something as seemingly simple as position of a sound in space, lower its volume, create a spatial trajectory, edit the trajectory, and automate the sound's motion along that trajectory, users must navigate multiple visual representations, metaphors, and levels of abstraction creating additional cognitive burden and disjointed workflow (Norman and Draper 1986; Maloney and Smith 1995). We argue through the data presented in this paper that such an approach creates a 'disembodied' UX where aspects of the workflow disconnect the body's sense of sound and movement from its representation through the interface and interaction design (Dourish 2001). This is particularly important in live performance where the performer's actions are not only functional but can signify process and intent to the audience.

The requirement for an alternative approach is corroborated by existing studies, for example Peters et. al. conducted a survey with 52 respondents in which they asked a range of questions regarding technologies and practices relating to spatialisation (Peters, Marentakis, and McAdams 2011). Respondents were primarily male (85%) from Europe and North America, university-educated with an overall average compositional experience of 20 years, 10 years of which involved spatialisation. Some key findings of relevance to our research are shown below:

- Sixty-one percent of respondents thought the time spent with spatialization tools could be reduced
- Half of the respondents use fewer features than their spatialization tools offer
- 48% cited "usability, learning curve" as motivation for using their current setup

One of their recommendations based on their findings is that 'the learning curve must be kept reasonably shallow (i.e., gradual) with good usability (e.g avoiding cumbersome command line control)'. Perhaps surprisingly, 'Visual 3D representation of a sound scene' was rated by participants as having lowest importance (less than 'fairly' important) amongst technical features. Despite this, we maintain that a 3D visual representation and interaction model is key to achieving high levels of usability and UX in spatial audio systems, and seek to explore this through empirical tests.

## Existing Work

Our system builds upon existing approaches to 3D interaction in spatial audio processing and sound design. The idea of accessing temporal audio data through the mapping of a spatial interface was explored by Kobayashi and Schmandt (1997). The 'point-by-hand' interface provides users with the illusion of touching audio as 'objects' which increases the experience of directness within the virtual 3D space. However, the described system did not benefit from modern interactive technologies. It included head mounted sensors to track position and provided audible feedback notifications (of increasing loudness) to inform the user of their successful grabbing action. The 'un-grabbed' function required users to 'stand still' for 3 seconds. Our research takes as its starting point the classification approaches in the field of 3D interaction techniques, *Navigation*, *Selection and Manipulation* and *System Control* as described in Jankowski and Hachet (2013). Jankowski suggests that to avoid frustration amongst novice users for 3D interaction, the system should

[1] We use the word 'volume' here in the physical, not the acoustic sense.

adapt to the user's expertise and experience. Jankowski goes on to suggest that an interface with strong appeal and enjoyment factors will motivate users to perform 3D tasks. A 3D interface offers the possibility to capitalise on users' already-learned gestures such as grasp, touch and placement. This could be regarded as an application of the direct manipulation interaction paradigm described in the introduction. It also relates strongly to Löwgren's notion of interface pliability (Löwgren 2009).

This approach is further explored by Gelineck and Korsgaard (2015) who devised a system to evaluate user interfaces for 3D audio mixing. Of a particular interest is how users, in the context of 3D audio, prefer to use 3D tools e.g to grasp and position sound through hand-air gestures, rather using buttons to grasp and release sound as is currently used with Fairlight 3DAW.[2] Our system differs from and builds upon the work of Gelineck and Korsgaard in that it integrates the user within the immersive 3D environment, providing the ability to use both hands for gesture control over audio properties (for example using one hand for selecting a source via grasp, and using the other hand for manipulations such as volume change and drawing spatial trajectories) rather than imposing on hardware controls, to which the user must adapt. On a more fundamental level, whilst our proposed system builds on the virtual representation used by Gelineck and Korsgaard and , it differs in that its scope is significantly wider, seeking application not only audio mixing but any musical application requiring 3D sound spatialisation—and in the longer term a diversity of methods of audio transformation. Comajuncosas et. al. also describe a system whereby a Kinect interface is used to capture 3D gestures, which are used to perform real-time 'audio mosaicing' a process by which tiny audio fragments are concatenated according to their location on a timbre map (Comajuncosas et al. 2011). Of particular interest in this work are the perceived benefits of 3D interaction over 2D (via a mouse) in achieving 'an enhanced correlation between gestures and musical outcome [...] and increased performability' with in-air gestures 'amplifying the perception of the player manipulations'. These approaches in particular will become of increasing interest as our research progresses beyond spatialisation to other forms of direct and live sound transformation.

## Prototype System Design

Our system utilises TwoBigEars 3Dception as a spatial audio engine. 3Dception is capable of rendering a set of 3D positional audio co-ordinates for given sources to binaural, Dolby Surround or Ambisonic outputs. The binaural technique uses a psychoacoustic model to create the impression of sounds originating within a 3D space using conventional stereo headphones, for example a sound can appear to be coming from above or behind the listener. Our system therefore goes beyond existing work in not only providing 3D panning (which essentially moves sound around the surface of a sphere, see Churnside, Pike, and Leonard (2011)), but also acoustic simulation including room reflections and object occlusion. The initial system (figure 2) is implemented in Unity[3], a cross-platform game engine suited to 3D graphics and interaction. A Microsoft Kinect 2[4] is used as a motion capture device in order to detect the position of the user's hands as well their hand pose. The Kinect 2 was chosen as an initial input device due to the hand pose recognition built into the SDK, therefore enabling rapid development within the short timescale of our funded project. Poses currently used are 'hand closed', 'hand open' and 'index finger'. The user's hand centre position is captured by the Kinect and translated into a point within the co-ordinate system of a virtual 3D space so it can be visualized within a virtual environment (figure 2). This visual display represents a space into which audio sources (represented as spheres) can be positioned. The centre point of each sphere controls its positional audio location, which can be rendered in real-time through headphones or to a multi-channel speaker system. For example, if the user moves a sphere from left to right in the virtual space, it will simultaneously be localised from left to right in the playback system.

[2] http://www.fairlight.com.au/product/3daw/
[3] https://unity3d.com
[4] https://dev.windows.com/en-us/kinect/develop

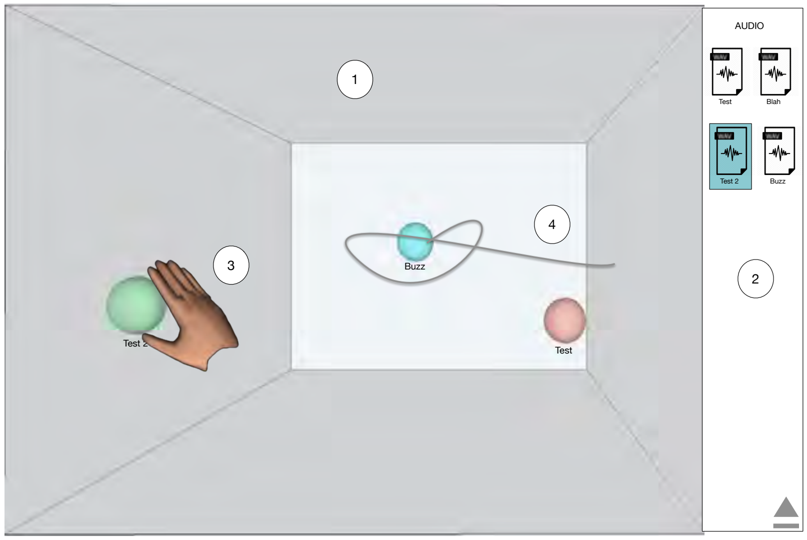


Figure 2. Original mockup of visual feedback for the system including 1) a representation of the virtual acoustic space; 2) a palette of sources to placed in the space via drag-and-drop; 3) an avatar representation of the user's interaction with the sources; and 4) a visual representation of spatial trajectories drawn by the user.

The visual display provides a cue to the user enabling them to accurately position their hand within the virtual space (using an avatar), whilst also providing a visualisation of the relative locations of the audio sources. A palette of audio sources is displayed to the user in a 2D panel on the right-hand side of the screen (labelled '2' in figure 2), where a 'source' can be either a soundfile or a live source from the computer's audio interface or built-in microphone. When the user's physical hand position is placed such that their hand position within the visual display is in front of an audio source, a 'hand closed' pose will cause the corresponding audio source to be 'picked up'. As the user moves their hand across into the virtual space, the audio source icon will change to a sphere and a 'hand open' pose will cause the audio source to be 'released' into the space. At this point, for soundfile sources, looped or non-looped audio playback will begin, with the spatialised position of the source corresponding to its co-ordinates within the space, with the listener's head effectively positioned in the centre of the space. Once an audio source is within the virtual 3D space, it can be picked up and moved around through a grab (hand closed) 'move' release (hand open) interaction. Finally, audio sources can be stopped by removing a source from the virtual space. This is achieved by grabbing a sphere and dragging it onto the 'eject' icon in the bottom-right corner of the audio source palette. Our system represents a 'spatially relative' model, that is sound sources are positioned in a fixed-size *virtual* space, with distances that are scaled up or down in relation to their actual perceived locations within a physical or binaural acoustic space. The system is also geometrically 'translated' in that although sound may appear (for example) to come from behind the user when spatialised, the bounded space with which the user interacts is always *in front* of the user. In practical terms, this means that in order to place a sound behind their head they place it in front of them, but behind the location of their head within the virtual space (i.e. behind the centre of the virtual space). This differs from the spatially 'absolute' model employed by , whereby sound sources can appear to be emitted from any point within a physical space, and users interact with the sounds directly at their perceived physical location. In a sense Müller et al's system is a more faithful implementation of the direct manipulation paradigm (see section introduction) than our design, but it is less general and less scalable. With our system, the sound could be output to binaural headphones or a large-scale ambisonic system and the interface remains consistent.

## Changing Audio Source Loudness

In order to change the loudness level of a given audio source, the user's left hand can be used, employing an 'index finger' pose to raise and lower amplitude. When an 'index finger' pose is detected, the ability to control amplitude is indicated on the visual display next to a sphere using a 'slider' widget following a traditional mixing desk 'fader' metaphor. As the user moves their finger up or down, the slider value will change causing a corresponding change in the level of the audio source. In future work alternative visual representations of audio amplitude will be considered.

### Hyperreal physics and spatial trajectories

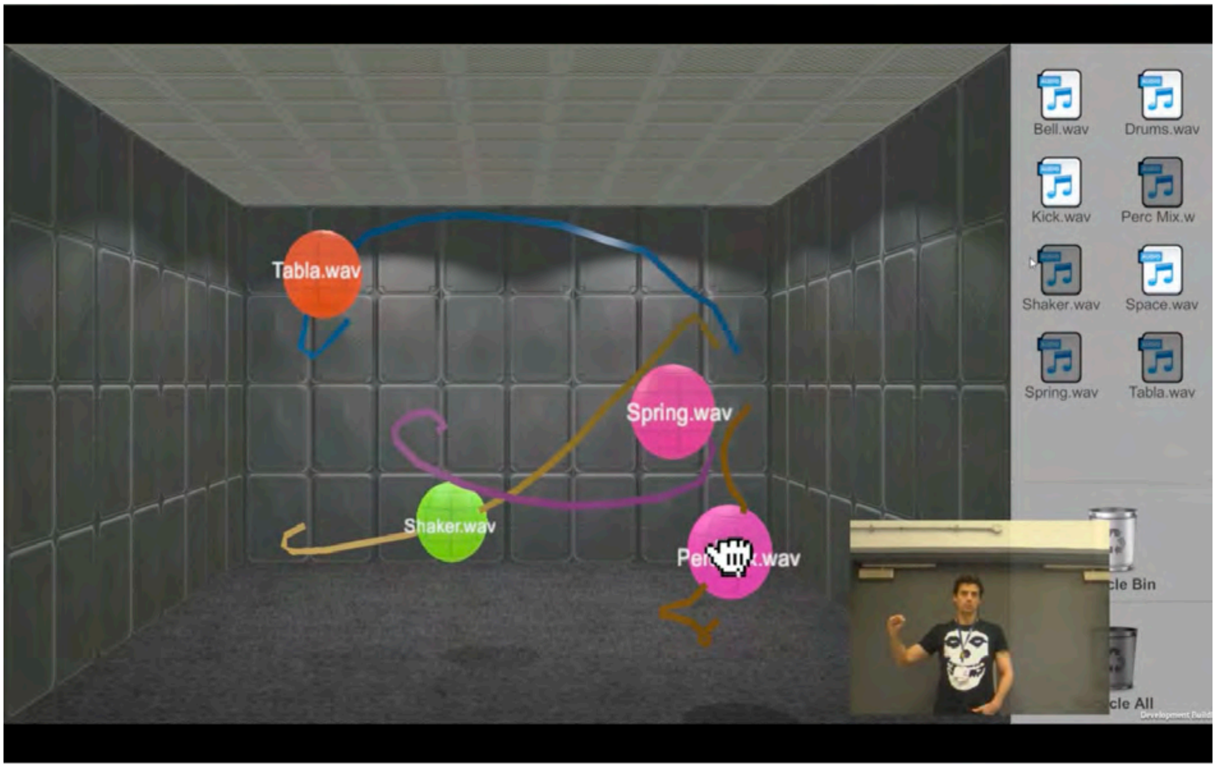


Figure 3. Screen capture showing the system in use with user input as picture-in-picture (bottom right).

Sources can also be given ‘physical behaviours’ within the virtual space. This includes the ability to ‘throw’ sounds, giving them inertia and thus moving them in the direction of the throw within the acoustic space at a rate determined by the intensity of the user’s movement. Sounds given such inertia may also slow down due to ‘friction’, and ‘bounce’ off surfaces or other objects placed within the virtual space. To automate spatial movement, the ability to draw trajectories within the virtual space is provided. Such a trajectory is indicated by the coloured lines in figure 3, which sounds may then be thrown along (analogous to rolling a ball along a curved tube).

## Initial Testing

Our eventual aim is to develop an end-user system that provides a positive and highly engaging user experience, surpassing that of traditional systems for spatial audio. In order to ensure this, we are undertaking an iterative process of testing and research. In the interests of rapid development initial tests were undertaken either by the authors, or using ad hoc ‘hallway testing’. In performing these tests on consecutive iterations of the system, a number of issues were identified that could be rectified through small but important enhancements to the design. These included;

1. Changing the colour saturation of a sphere to visually indicate its relative volume level,
2. Greying out sources in the audio palette to show they have been added to the space,
3. Adding a visual glow to a sphere indicating proximity to another sphere, thus aiding ‘same location’ positioning.

However, a number of more fundamental issues were identified relating to the choice of Kinect 2 as an input device. For example, the Kinect specifications require that the user is at least 1.4m from the device. This has implications for screen positioning, size and resolution. For example, in our tests audio source names were impossible to read on a 27" display at a resolution of 2560 x 1440. Operating at the required distance from the screen also decreased the sense of user 'immersiveness' (Ermi and Mäyrä 2005). More critically, we found that the Kinect 2 is unreliable as the user's palm orientation deviates from the plane parallel to the front surface of the device. In our initial tests users began by reaching into the virtual space without any particular consideration for palm orientation. Reaching forwards to grab an object with the palm approximately horizontal is a physiologically comfortable movement (the anterior forearm muscles are relatively relaxed). However, interacting in this way resulted in a poor experience with a large number of 'grab' gestures not working due to the Kinect failing to disambiguate 'hand open' and 'hand closed' poses. This was because of the hand being too flat in relation to the horizontal plane. In order to improve system performance, we found users needed to adapt their usage by consciously orienting their hand as close as possible to the (vertical) plane parallel to the front of the Kinect. Grabbing an object in front of the user with palm facing 'forwards' in this way is physically more awkward, putting a strain on the anterior forearm muscles. It therefore feels less comfortable and consequently use of the Kinect poses a mismatch between a comfortable 'grab' movement capitalising on commonly used actions—with associated muscle memory (Ebert et al. 2009)—and the pose recognition capabilities of the device, creating a hard limit on directness and 'naturalness' of interaction. Finally, whilst we found that most users readily understood the interface and could place and move sounds (with the above caveat for hand angle), some users were confused when asked to place a sound 'behind them'. In these cases the users in question moved their hand behind their own head, rather placing it at the back of the virtual space in front of them.

## Further Work

Our first priority is to conduct formal and detailed usability and user experience tests with the current system, to establish how well it meets our stated design goals using a combination of quantitative and qualitative methods. In the medium term will also seek address issues highlighted in the above findings namely: i) a lack of reliability and control in the user interaction, and ii) to clarify through the design that the acoustic space is in front of the user. On a practical level this will entail an investigation into alternative input devices, or alternative setups that address the palm orientation and proximity issues identified in our tests. Specifically, we aim to make the system operable from a seated position in close proximity to a screen and for the user to adopt a comfortable hand orientation. We will also seek to test better technologies for visualisation, these may include immersive displays and virtual reality headsets. Our research is currently at an early stage, but a future step will be to conduct further investigation into users' prior associations of gesture, action and visualisation with various forms of live audio transformation. Only with this understanding can we seek to align the representations of audio transformations provided in the system with human understanding and imagination. Such an understanding is a long-term task and will operate side-by-side with an iterative process of design, development and testing in which we will seek to implement a range of live audio transformations following a direct manipulation model. It is our hope that these will offer greatly enhanced learnability and a more positive user experience compared to existing systems.

## Conclusions

We have presented the rationale, design and initial implementation of a novel system for spatial audio positioning utilising 3D interaction and visualisation of a virtual space. More generally, we have described how direct manipulation, 'live' and pliable interface design concepts may be widely applied to systems for interactive audio transformation opening up a new field of investigation in audio interface design. We have described our initial design and tests, which have shown that our proposed concept and system work, and indicate strong potential for further work. However our results indicate a number of limitations in implementation, specifically with the Kinect 2 as an input device for direct audio manipulation. In particular, there is a minimum distance requirement of 1.4 metres from the device. This means that the display used for visual feedback must be sufficiently large for users to perceive details, or alternatively other visual feedback such as a virtual reality system should be considered. Furthermore, hand poses can only be recognised if the user's hand is oriented around 60 degrees of the device's front. As part of the ongoing development of the system, alternative sensors such as the LEAP motion are therefore being investigated. In conclusion, our research demonstrates a novel concept and provides promising implementation, serving as a strong foundation for further work.

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# Translating Graphical User Interfaces: challenges for the design and standardization of mid-air interfaces

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**Abstract.** This study presents a theoretical contribution on mid-air interface design. With the technological development of devices able to interpret gestures made by hands and arms as Kinect and Leap Motion, designers and developers might think beyond the traditional mouse and keyboard input. However, these interfaces that supposedly aim to be more natural and intuitive have found barriers to its acceptance by users and researchers, partly due to a lack of understanding of the variables involved in the project, as well as the lack of existing standards. This article aims to bring insight into the translation and understanding of these interfaces as language, establishing a communication process based on the following principles: (1) an understanding of Mid-air interfaces and its concept, (2) an analysis of the different ways to interact, (3) an understanding of native and intuitiveness of gestures and (4) generating insights for mid-air interface standards.

**Keywords:** mid-air interface, design patterns, gesture based interaction, freehand interaction.

## Introduction

In 2002, the film Minority Report, starring Tom Cruise brings out a dynamic, innovative interface where using only hands, without touching the screen, one can organize information, manipulate different types of forms and data, in an intuitive and natural way. Despite being an interface present only in Sci-Fi, it represented the future of interfaces and interactions, a mid-air interface.

More than a decade has passed, and the present has revealed to be a little different than imagined by the film producers. The technology to simulate some of the predicted interactions is finally available to designers and developers, but the popularity of mid-air interfaces still does not occur on a large scale. Designers and developers have not yet met the standards for design of this type of interface, in addition, the actual application of the technology in specific niches is still unknown. This paper aims to present a theoretical contribution, in a reflective way, about paths taken in mid-air interface design, trying to show some possible mistakes and successes in the process of translation of graphical interfaces, seeking for a syntax for gestural language.

## Mid-air interfaces

The primary instrument for human beings to communicate is the use of language. This may be spoken, written, and should follow a standard structure and convention (Oxford 2015) to enable the establishment of a communication process. Among these languages, one of the most typical ways to establish communication among humans is non-verbally, that is, by using gestures. From birth, humans begin to use us gestures, sometimes involuntary, but over time these gestures allow for an intention to take place, and they end up establishing communication when needed. For example, moving hands with the intention of waving good-bye, closing the hand and lifting up a thumb to communicate agreement to something (like gesture), moving an arm from one side to the other indicating where to put certain object, and even gestures combined with speech are examples of gestures made in the day-to-day lives. Based on that, it is plausible to say that gestures may also contain information, thus indicating that the use of gestures is a (kind of) language. In this perspective, Billinghurst & Buxton(2014) define a gesture as "the motion of the body which contains information". Saffer(2009) explains the concept of gesture attributed to any physical movement detected by digital sensors, which generate a response without the aid of traditional mechanisms, such as a mouse and a keyboard. This definition reflects what happens in the application of gestures in human-computer interaction (HCI), which has in its concept the importance of detecting a gesture. The detection of a movement is associated with the use of gestures as a language, as a way of communicating with a system. As part of the human-computer interaction, the interaction design defines the structure and behaviour of interactive systems (IxDA 2015). Thus, to design a system capable of interpreting Sign language system it is necessary to understand the relations (interactions) that occur between the user of the system and the product itself, and that is mediated by an interface. Johnson reaffirms the importance and function of an interface, which “acts as a kind of translator, mediating between the two parties, making one sensitive to the other.”(Johnson, 1997, p18)

Generating the establishment meanings and by consequence the translation of an interface is understood by Saffer (2010, p. 4) as the "art of facilitating interactions between humans through products and services." While the gestural interaction from smartphones and tablets is already quite popular through touchscreen displays, this "language" is still maturing over the use of the movement of hands and arms (or even the whole body) to control different interfaces. This type of interface, known as mid-air interfaces have been used in games such as Microsoft Kinect (released in 2010) and recently by other devices such as Leap Motion (released in 2014) and MYO (released in 2015). However, its application in other contexts such as health software, education, entertainment is still in an embryonic stage. This fact may partly be associated with improved reading technology and interpreting gestures, as well as the beginning of the process of popularization of technology, which begins to allow for devices at a more affordable cost to users.

Research related to interpreting gestures has already been carried out for more than two decades (Buxton 2007). However, much of the effort and research regarding the interpretation of gestures have been related to technical aspects such as algorithms that could track the movements more accurately, sensor optimization, etc. So the challenge is how to design graphical interfaces (visual elements shown on the display) so that they are consistent with the paradigm of gestural interaction, intuitive and that provide a satisfactory user experience. Understanding gestural-interaction as a language, especially in a communication context, permeates the understanding of how potential users use gestural interaction, as well as the better way to translate this language to visual elements in the graphical interfaces, therefore allowing interaction.

Regarding the translation of these interfaces in addition to the lack of standards, there are few consistent frameworks for the design and evaluation of mid-air interfaces (Cabreira & Hwang 2015). Some authors associate the concept of mid-air interface to the perception of a natural user interface (NUI) and more intuitive, because the interaction is based on gestures (O’hara et al. 2013; Wigdor & Wixon 2011). It is suggested that this interaction paradigm may prove to lower barriers between users and interfaces (Grandhi et al. 2011). However, when using the same principles of construction of graphical interfaces that are used for different interaction paradigms, different mid-air developed interfaces have received criticism regarding its usability (Malizia & Bellucci 2012; Norman 2010). Therefore, translate and understand the mid-air interface design is presented as a process still under development, searching for answers and standards.

## Different ways to interact

Throughout history, human-computer interaction has been established mainly by interfaces that support the process of interaction established between man and machine. Initially this interaction was established by interfaces of a category called "command-line interfaces", where the user would type commands and the software would respond by processing them. With the maturation of technology and enhancement of electronic graphical components there was the emergence of the first Graphical User Interfaces, or GUI, i.e., metaphors of user's everyday actions, making the interaction became friendlier. This strategy was responsible for the expansion of computers in homes and professional environments, popularising them on a global scale (Saffer 2010).

Coupled with the concept of having a user-friendly interface (GUI), the WIMP paradigm (short for "Windows, Icons, Menus and Pointers") still holds the majority of the graphical interfaces. This was initially used at the interfaces of the Xerox Alto computer (1973), Apple Macintosh (1984), and came to become popular mainly with computers that started to use the Windows operating system. This paradigm is mainly characterised by the use of metaphors: visual elements that have real object references. This strategy in the interface design was conceived in order to reduce the learning curve, linking the role of screen elements to their function in a non-digital environment (e.g. Trash to delete files).

The visual elements that make up the WIMP pattern are responsive to an interaction model that remains to this day from the use of the mouse as a navigational tool (Shneiderman & Plaisant 2010). Thus, the projected GUIs become responsive to point and click pattern, showing the user what is clickable or non-clickable from different forms of feedback, especially when the mouse is under an interaction element (known as hover).

With the release of iPhone in 2007, the touchscreen gestural interaction begins to become popular along with smartphones and tablets. Its main differences compared to interaction is the inclusion of gestures (swipe, pinch, etc.), allowing tasks performed in interfaces once mediated by mouse now to be rethought to a new model where the interaction could occur with 1, 2, up to 5 fingers, even allowing the combination of two or more fingers at the same time. Due to this new paradigm, some visual characteristics of the graphical interfaces become modified, partly because of the very evolution of graphical interfaces from websites, but also by standards set by own systems (Apple, Android and Windows Phone). Furthermore, the amount of information arranged in the users' screen becomes reduced due to the size of smartphones, also allowing a reduction of the cognitive load of the interface. This perspective in the creation of interaction design is also associated with the concept of the first mobile interfaces and system design. (Wroblewski 2011)

In gestural interaction using hands and arms (mid-air interface), the vocabulary used for gestures becomes enlarged, this is due to both the use of fingers as input data and the two hands, which are combined combination in various gestures (open, close, move the hand, for example). Thus, the variables involved in the design of an interface are also extended because there is a need to understand how this paradigm influences the design of different visual elements shown on the interface. A major difference between the input point and click (desktop computers) and mid-air interfaces is associated with the fact that, in most cases, devices that interpret gestures use a camera. Thus, this means that any user's movement in the device detection area is regarded as an information, allowing involuntary gestures to be interpreted as commands in an interface (a phenomenon known as mic live) (Chaudhary et al. 2011). This feature also directly affects the interface in relation to visual elements; certain navigational gestures are likely to be triggered by the user movement of hand (even if unintentionally). In order to getting the hang of this feature, try browsing a website without clicking, trying to figure out different ways to click / activate a button. Furthermore it is important to reflect on the choice of application gestures set to avoid false positives (Wigdor & Wixon, 2011) or ambiguous gestures, or gestures that get closer as they are being executed and that may be confused by the system with another gesture. In the picture below you can see the gestures of an application and the transitions between them, showing possible points of ambiguity and / or false positives.

Another difference in mid-air interfaces, especially in relation to the touchscreen / mouse is the lack of haptic feedback. The touchscreen interfaces, although they have a paradigm of gestural interaction, frequently use the gesture "tap" as it follows the standard point and click of the mouse. In mid-air interfaces this standard should be rethought, precisely because it is not possible to click buttons or simply tap surfaces (Ren & O'Neill 2012). Therefore, it is necessary to reflect on the navigation strategy used, so that the graphical interface presented to the end user represent a coherent mix of visual elements that may trigger the correct gestures designed for each specific command. Also, considering which metaphors / patterns of graphical desktop paradigm or touchscreen interfaces should be kept / modified, or redesigned in order to optimize the user experience in mid-air interfaces.

## Naturalness and Intuitiveness of gestures

Conceptually, this idea of mid-air interfaces (NUI or touchless) seems to be promising, as it can optimize satisfaction for the use of a system, as it allows the user to use his/her own language, gestures, movements (appropriated during his life) to interact with an interface. However, although some gestures can are commonly used by most of the population, this fact does not guarantee that the interface of a system might be "natural", simply because it utilizes gestures. At some point the user should probably learn this gesture to later pass to use it for granted. Herein lies one of the main discussions of the term "natural interface"; the so-called interfaces try to simulate the interaction of day-to-day lives or simply have a higher degree of freedom and expression when compared to a mouse or keyboard (Malizia & Bellucci, 2012). Furthermore, a gesture may have different cultural aspects, i.e. be interpreted in different ways by different people. Under the interaction design, Norman (2010) also suggests that the "natural user interfaces are not natural," because they do not follow some basic rules of human-computer interaction, especially related to feedback and navigation.

Because of criticism against the concept of mid-air interfaces and its application, Malizia & Bellucci (2012) state that the initial idea of mid-air interfaces would be to identify possible actions and pre-existing gestures of people, identified from people's manipulation with different objects and tasks, for, then transport them to the digital environment. However, part of these interactions are associated with a context which sometimes ends up getting lost in the digital environment. The naturalness of these interactions is something that is taken as purely a problem of representation – ensuring that they are correctly represented in the interaction mechanism itself. In this sense, natural interactions are something "detached from the social context in which they might be deployed; they are not constituted by the context, but brought to it." (Malizia & Bellucci 2012)

Regarding the intuitiveness of gestures, the literature indicates that dynamic gestures - gestures that have movement from an initial position to a final position - have preference with users. The use of pantomimic gestures is also considered more intuitive and easy for users (Grandhi et al., 2011). As an example, when simulating an activity to cut an object, users tend to move hands up and down, with the open palm, simulating the cutting of a real object. However, part of this research does not list the execution of the gesture with the display of the GUI, but represent a reaction of users to an image or given scenario. Another possible problem is that pantomimic gestures and symbolic gestures are often associated with culture, and may thus differ from region, customs, etc.

As an alternative to the process of translation and design of graphical interfaces for the mid-air type interactions, Ardito et al. (2014) suggest the use of manipulative gestures, i.e., from direct manipulation of elements in the interface provide gestural navigation. According to the authors, rather than causing users to learn and / or remember a vocabulary of gestures so often artificial, it would be more intuitive if the user could directly manipulate the interface elements from the recognition or discovery of a designed function. The native gesture might be improved through the use of an object or interface element that refers to a metaphor of an object or daily action of the day-to-day users.

## Looking for Patterns

As already mentioned, with the emergence of the first graphical user interfaces (GUI) and standard WIMP interfaces have become more user friendly, and began to popularize. One reason for this popularity is the use of interface standards. They describe design solutions to be applied in specific contexts (Pauwels et al. 2010). As an example, the organization of content in tabs, or the carousel menu type, have different ways of organizing and allow navigation in content. The design patterns express a language, and that happens to be associated with the interaction paradigm. The interfaces using the mouse as interaction (desktops and laptops) already have a large library of patterns established. With the development of touch screen interfaces, there was a translation of standards for this interaction paradigm. As a result, some patterns have changed and new standards go to be created and adopted by designers and developers.

The vast majority of these patterns follow the model WYSIWYG (What You See Is What You Get). However, with the popularization of interfaces for smartphones, vocabulary standards begin to contemplate gestures and, as mentioned, different from the standard point and click, one can use many gestures to the interaction. This fact has gradually allowed the insertion of standards that are not displayed in the user interface, but activated from the use of gestures.

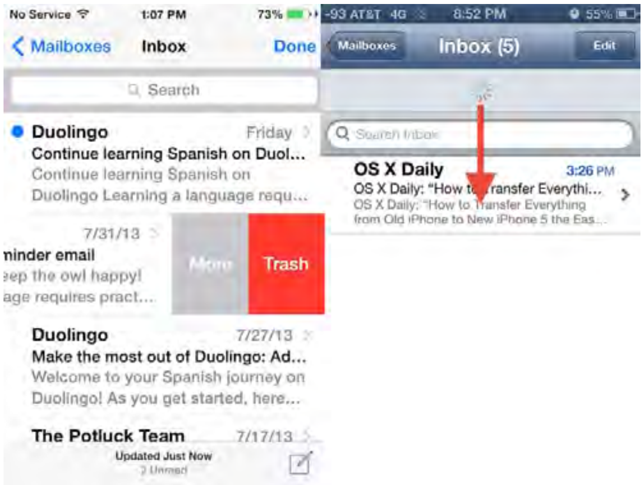


Figure 1. Swipe gesture to right (reveal more options) and Swipe down (refresh mail)

Examples in Figure 1 show two interface standards that are viewed only from the gesture. In the first example (left image), the options of "more" and "trash" only appear after the gesture swipe left. The same applies to the second example with the “refresh” action (right image); after you perform the gesture swipe down, the interface provides the feedback, so checking for new emails. The mid-air interaction still goes through a maturation and discovery process. With the work of designers and developers , as well as testing with users, it is expected that interface patterns will be designed and validated . Thus, based on the observation of the mid-air paradigm and reflection on interfaces, the following table presents insights that can assist designers in the development of these applications taking into account differences in relation to the interaction with the cursor paradigm.

| **Graphical User Interface (Desktop Paradigm)** | **Mid-air Interfaces (Gestural Paradigm)** |
|---|---|
| Control is given by mouse or keyboard | Direct Manipulation using hands |
| More accuracy, less immersion | Less accuracy, more immersion |
| Makes use of mental pattern already used at previous softwares related to computing experience | Makes use of users assumptions, discovery and logic conclusions |
| Emotionally related to work | Emotionally related to entertainment |
| Ideal for task productivity and efficiency | Ideal for social and collaborative tasks |
| Interface is visible and graphic | Interface is physic and can be either visible or invisible |
| Interface depends on targets (buttons, menus, etc) | Interface focuses on gesture, not necessarily dependent on an specific position on the visible screen |
| Long-term duration | Fast-execution interaction and short-time duration (except for games) |
| Fatigue is felt after long-term interaction | Fatigue attributed to gestures which imitate the movement of cursor (gorilla arm) |
| Browsing with different hierarchy patterns | Browsing with few hierarchy patterns |
| Naturality in interaction is at the cursor | Naturality in interaction is at the relationship between gesture and interface |

Table 1. Insights and differentiation between desktop and mid-air interfaces

## Conclusion: translating mid-air interfaces?

With the development of gestures interpreting-able devices, it is up to designers and developers to understand in more depth the variables that make up this type of project. One possible way to translate this type of interface may become possible through the observation of how the process of creating gestural interfaces for smartphones took place, and from the touchscreen interfaces seek clues to the definition of standards for mid-air interfaces. This does not mean copying the visual elements and interaction process, but to understand and build a visual and gestural language for the design of mid-air type applications. This paper aims to demonstrate some important concepts related to this paradigm of interaction, seeking to generate insights for translating and mid-air interface design.

## Additional Information

**Acknowledgements.** This work was undertaken with support from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil, grant Doutorado Pleno no Exterior–Proc. BEX BEX 13430/13-0.

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# Artist-aware, zero install immersive virtual environment for collaborative live performances

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**Abstract.** The prototype of immersive virtual environment for collaborative live performances based on Krestianstvo SDK will be shown. This environment is developed using Virtual World Framework (VWF) and ADL Sandbox project. The prototype will show how the Virtual World Framework being extended with Ohm (OMeta) language a new object-oriented language for pattern matching and OSC support could be turned into the artist-aware zero install collaborative virtual environment. An artist could easily create tools, own domain specific languages, parsers for OSC messages and simulations inside highly distributed computational environment. Several running browsers or desktop versions with running prototypes define the replicated state of the whole computation. Using an avatar, an artist interacts with the virtual world and adjusts the properties of its virtual content. Artists share exactly their online activities and computation within a united simulation space. They could interact with virtual world's content by using real physical objects sending OSC messages.

**Keywords:** virtual world, human-computer Interaction, performance art

## Introduction

Let's look at today's software paradigms, which are available to a modern artist. In simple words these would be: "Tools", "Programming languages" and "Simulations". Actually, none of them are artist-aware by itself. And only the fundamental interconnection of all of them may leads to the new entity, which we could name "Virtual Environment", propagating itself in an artistic conformable immersive form.

### Tools

Why not "Tools"? The best case of using tools in an art context is when an artist could modify the tool implementation at runtime. And there is no distinction between development and runtime modes. For example, the tools programmed using dynamic software like Pure Data, Max/MSP, VVVV or SuperCollider include such mode by default, if an artist distributes the tool with the interactive development environment. But, these tools still stay isolated each of other or grow into a huge complex one interconnected engineering tool. Mostly only experts can supply and support such tools. Sometimes there is no any possibility for reconfiguration or adaptation of them by a people from other disciplines, like artists. In other words, such systems provide a static hardware and software templates for filling them up with the artistic generated content. That forces an end-user to create artistic scenarios in a form of dynamic data using a static computational paradigm. Finally, these systems are used like static viewers with rich human-computer interactive interfaces. The ability of making changes of a tool at runtime leads artists to use more or less "Programming languages" in a form of live coding in common.

### Programming languages

Why not "Programming languages"? As with tools the best case of using programming languages, will be programming by an artist his own domain specific language (DSL). In other case, an artist forced to learn a general purpose programming language with a set of art-specific libs and APIs. For example, highly dynamic Self and Smalltalk programming languages are considered to be the simplest languages with the best self-explorative environments. But even they are about prototype and object oriented paradigms. And they disclosed their features only in using reflectivity, homoiconicity and meta properties while experimenting with constructing the new languages.

## Simulations

So, the last thing “Simulations” throws an artist into the paradigm of simulating, modelling and gaming. Simulation behaves like an artefact closed in itself and introduces a biological inspired propagating mechanism. An artist feels more comfortable performing inside simulation, as this paradigm completely blurs the border between development and runtime modes in software or software at all.

## Virtual Environment

Things would change if we look at “Tools”, “Programming languages” and “Simulations” as self-exploratory elements of the virtual worlds and the computation-centric live programming environments. The virtual worlds represent the new computational paradigm and the new form of software, where everything is just some form of a computation. End-user could generate or change the content of a virtual world in real-time (Figure 1). The user also is represented in a virtual world as a computational process, an object known as avatar/software agent. Moreover, user-defined programming languages hold up all interactions inside a virtual world in the form of live programming. A full-body immersion environment, which is built using virtual worlds, scales conformal up to the unlimited number of hardware and software nodes.

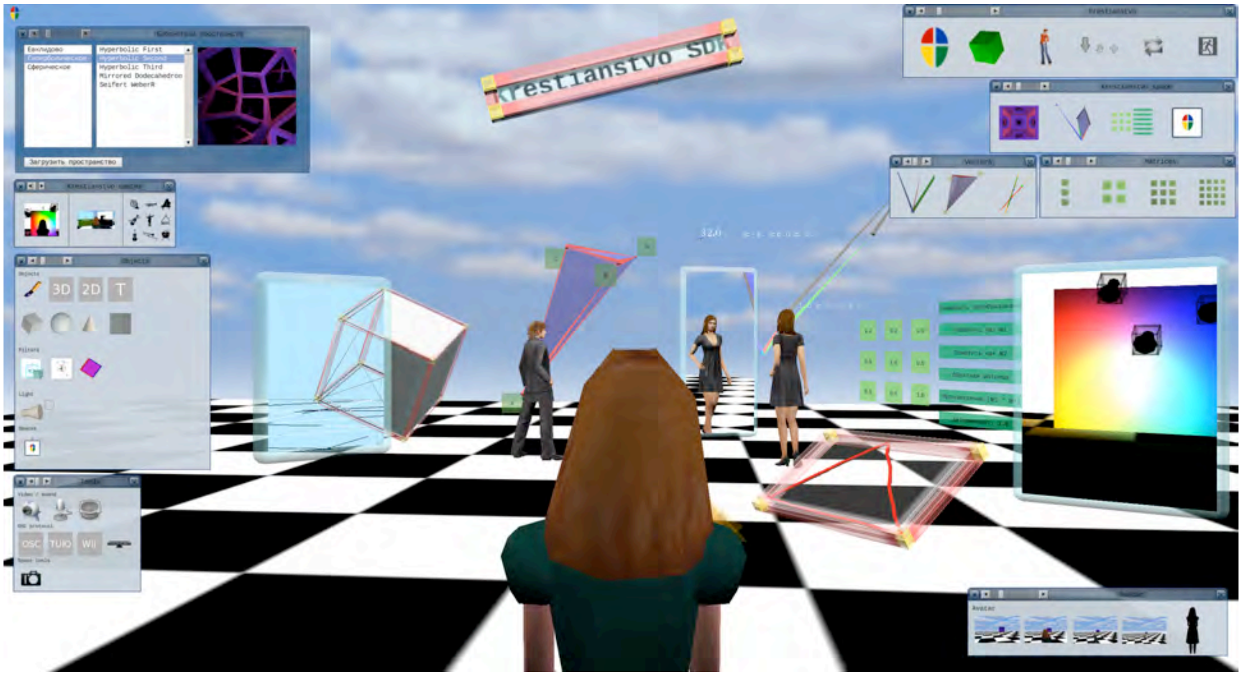


Figure 1. Virtual learning environment Krestianstvo SDK

Virtual worlds provide all-in-one solution and the ability for the programming code to be delivered in a lightweight manner through the network. They support easy synchronisation for many users to interact with common objects and environments. These objects can be programmed on quite different languages. In addition, they can coexist alongside with each other in the same replicated virtual world and holding the same simulation.

## Prototype demonstration

The prototype will show an immersive virtual environment for collaborative live performances based on Krestianstvo SDK. This environment is developed using Virtual World Framework (VWF) and ADL Sandbox project. VWF provides a synchronised collaborative 3D environment for the web browser. Continuing the Open Croquet research effort, VWF allows easy application creation, and provides a simple interface to allow multiple users to interact with the state of the application that is synchronised across clients, using the notion of virtual time (Smith 2003). A VWF application is made up of prototype components, which are programmed in JavaScript, which allows a shared code and behaviours used in distributed computation, to be modified at runtime.

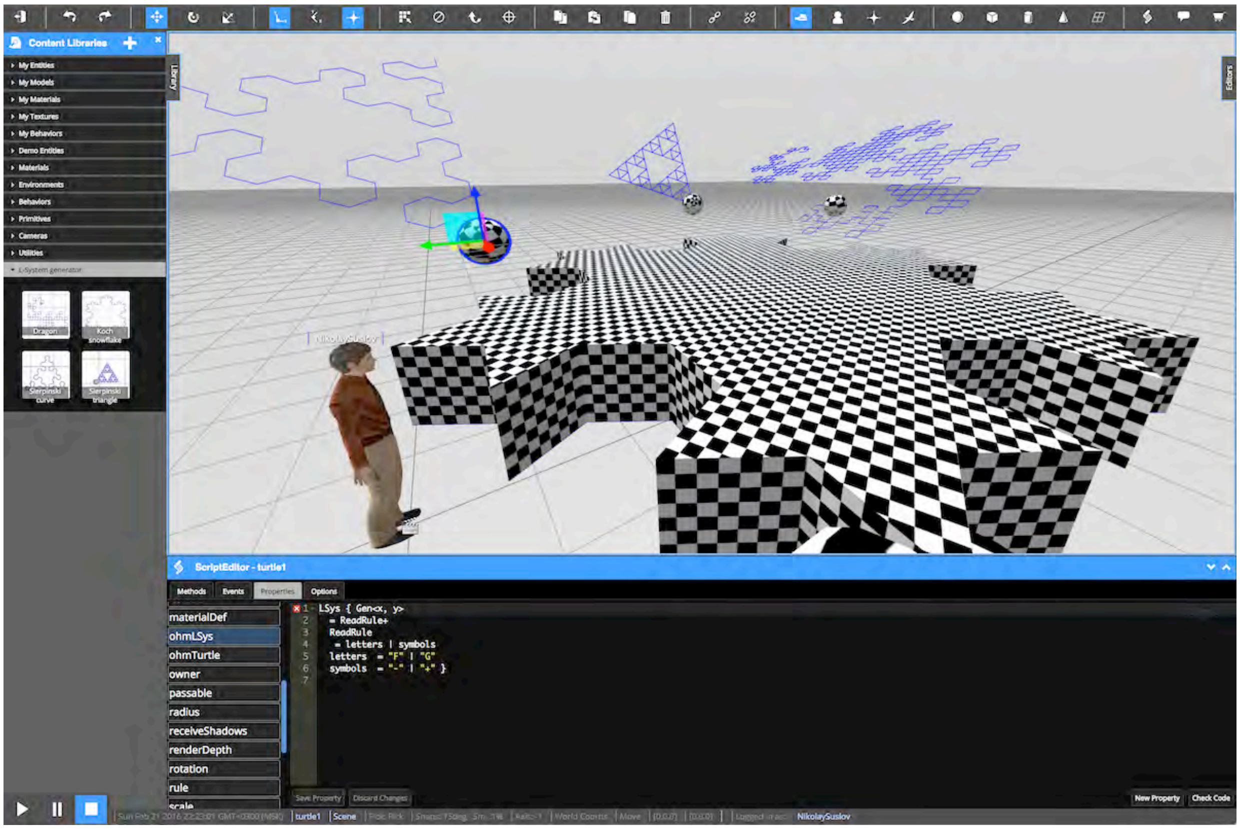


Figure 2. Virtual environment in web browser

The prototype shows how the virtual world framework being extended with Ohm (OMeta) language (Suslov 2015) a new object-oriented language for pattern matching (Warth 2007) and OSC support could be turned into the artist-aware, zero install immersive virtual environment for collaborative live performances. An artist could easily create tools, own-domain specific languages, parsers for OSC messages and simulations inside highly distributed computational environment (Figure 2). Several running browsers or desktop versions with running prototypes define the replicated state of the whole computation (Figure 3). Any modification in a source code is replicated immediately to all instances of it. Adding new nodes is done just by starting the new browsers and connecting them to the already running virtual world. Using an avatar, an artist interacts with the virtual world and adjusts the properties of its virtual content. Artists share exactly their online activities and computation within a united simulation space (Suslov 2012). They could interact with virtual world's content by using real physical objects as controllers sending OSC messages (Figure 4). The virtual world's architecture takes everything on a distributed computation. Artists do not need to think about an underlying software program architecture while preparing their content inside virtual environment.

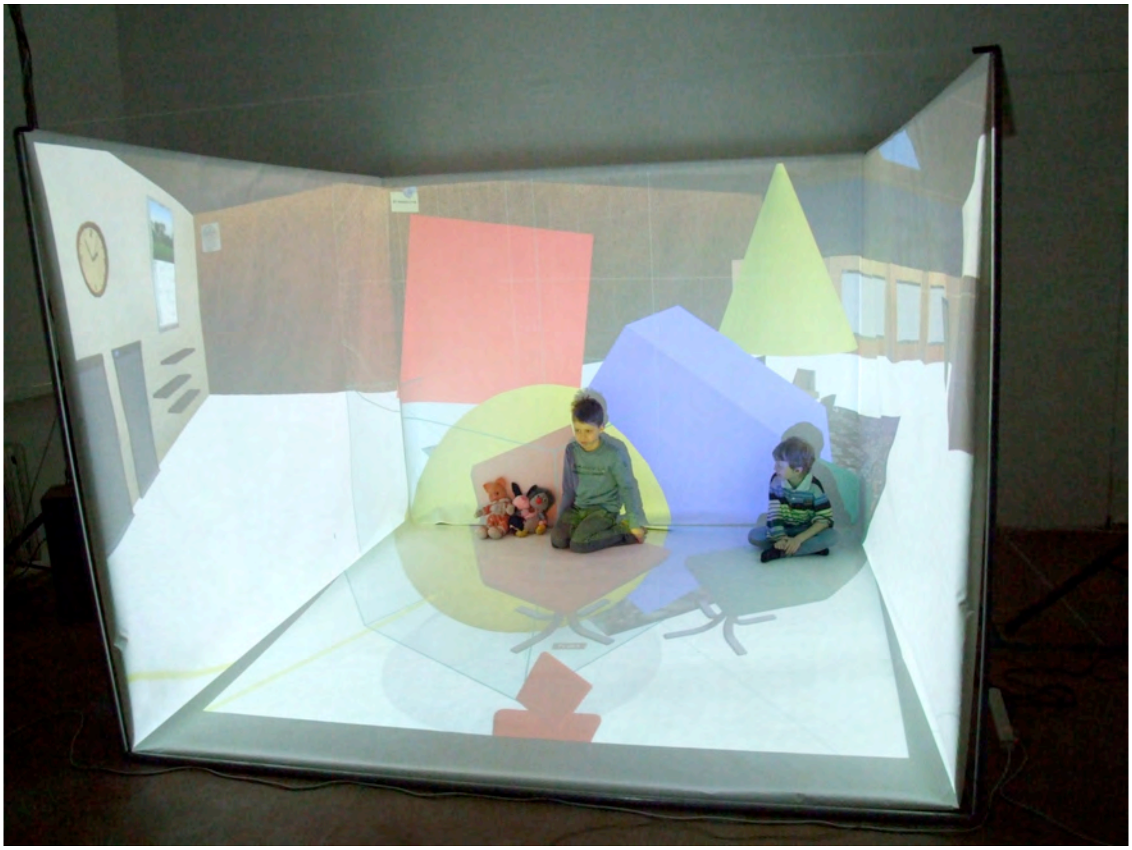

Figure 3. The CAVE prototype using desktop version of virtual environment

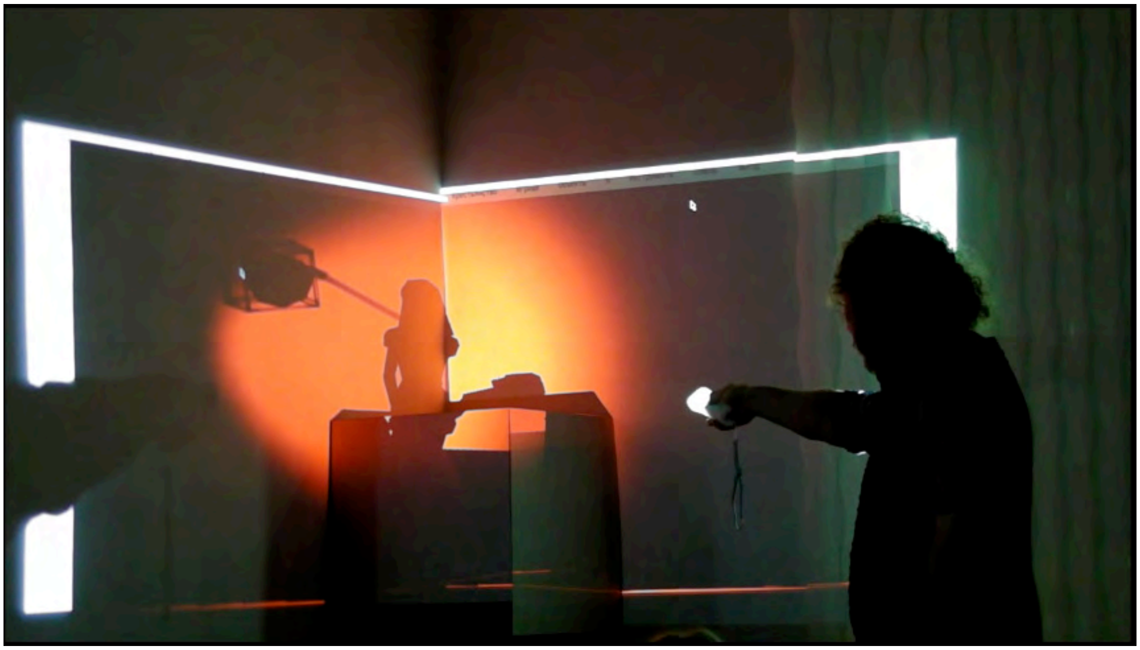

Figure 4. An experiment with a virtual light source controlling with Wii remote

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# Rainforest sound installation

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**Abstract.** The Rainforest sound installation creates an interacting sonic element in space. It's made of a set of original porcelain shapes, which are in fact an 8-channel audio system. The porcelain shapes are individually resonated by the attached solid drivers. The interactive live interface is build in Max/MSP. The main input into the system comes from the live camera feed and is based on the actual position of the listener. The detected movement is than translated into a specific soundscape, which is triggered on the fly. The sound installation mimics a living organic element, which is suspended off the ceiling and interacts with its surroundings.

**Keywords:** porcelain design, multichannel sound, Max/MSP, solid drivers, movement detection

## Introduction

The Rainforest sound installation is based on an initial prototype called Sound Extrusions. This prototype was designed, manufactured and tested in the span of five months in 2013-14 in Brisbane, Australia, as part of the artist in residence position at The Edge[1]. The name of the second version of the installation, the Rainforest, also references the David Tudor's original approach to the object sonification strategies. The project itself primarily investigates novel use of the porcelain material and explores its sound resonant qualities. This installation piece also represents a specific live interface which generates soundscapes. It can be though of as a sonic open system producing unlimited number of soundscape variations based on listener's changing position. This *movement – interaction – soundscape* concept had been already used previously in installations such as Myron's Krueger *Videoplace* (1975), David Rokeby's *Very Nervous System* (1986-90) or Rolf Gehlhaars's installation *sound=space* (1894) just to name few original realizations. Nevertheless the novelty of the Rainforest installation is based mostly on the exploration of the experimental nature of the porcelain design and it's unusual use in the sound and interaction domain.

## Sound installation design

The organic-looking porcelain shapes are in fact an 8-channel audio system, which interacts with the position of the listener. The actual use of porcelain crafting proved to be quite an exciting and innovative experiment in acoustics and porcelain design.

All of the porcelain shapes are amplified resonators using solid drive (vibration) speakers and are applied to all of the porcelain shapes to deliver a spatial hearing experience. The installation itself is suspended off the ceiling, while the integral part, the supporting base section, is made of individual interconnected triangular pieces. The base section is suspended in an angle and the design evokes a humming bird in flight or manta ray shape.

[1] The Edge (Centre for Arts, Technology & Enterprise); more information can be accessed online at http://edgeqld.org.au

Figure 1. Rainforest sound installation

The installation behaves as a living element. When it notices the listener’s movement in the space, it plays a start-up sequence, it 'stretches out' and plays a so-called 'wake up song'. From this point on, as the listener moves around the space underneath the installation, it follows him with the live generated soundscapes across the full 8-channel audio system.

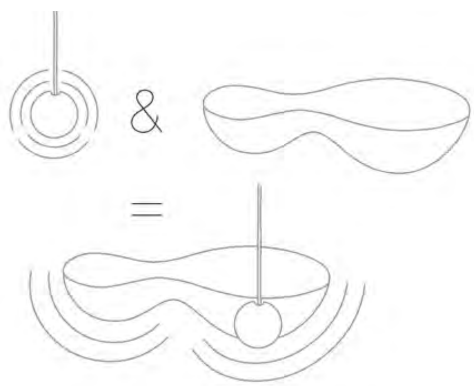

Figure 2. Rainforest – the porcelain shapes with solid drivers schematics

## Porcelain Design, Manufacturing & Sonification

The porcelain shapes were designed as simple shapes and slip-cast from the highest quality porcelain available in Australia, the Southern Ice porcelain. The original shapes were hand modelled as prototypes in clay and were used for the original plaster mould manufacturing. The shapes had to be casted in 1 mm porcelain wall thickness to ensure the highest possible resonance response. This presented a lot of manufacturing difficulties and in the end, only one out of three slip-cast shapes in general, were successfully produced without any defects. A kiln at the Queensland College of Arts (QCA) was used, thanks to my research student status at Griffith University at the time. This allowed me to take care of the whole manufacturing process and aim for the thinnest shape's wall thickness possible. This manufacturing phase wouldn't be possible without the excellent mentoring of Corey Biever, a Brisbane based experienced porcelain maker and ceramics technology expert.

Figure 3: Rainforest – the porcelain shapes with solid drivers in detail

The highest porcelain grade available made it possible to transfer the full upper audio spectrum and create rather brittle sounding shapes. Nevertheless the bottom end of the audio spectrum doesn't transfer well in the porcelain material especially in such a small surface dimensions. The actual solid audio drivers are partially attached with a silicon paste, which was applied to the edges of the driver's surface. This attachment creates the needed adhesion, but still leaves enough room for the direct vibration transfer onto the shape's surface. The central part of the driver's surface is touching directly the porcelain shape (this represents a problematic attachment of the small flat surface of the driver onto the round porcelain surface). Small portable X-Vibe solid drivers[2] designed for mobile applications were used, with the output audio power of 1W. There were used two types of the porcelain shapes: small ones measuring 25 cm and the bigger ones measuring 35 cm across the full shape's length. Because of the missing low and mid-low audio spectrum, a special solid driver, with the output audio power of 5W, had to be used as a sub-woofer and attached to the base section of the installation. The central suspending base component acts as a solid drive sub-woofer, which in turn complies with the *solid driver sonification* concept used throughout the whole installation.

This experiment, using the porcelain in conjunction with audio, represents a rare example when porcelain objects are coupled with the solid drivers. In order to be able to smooth out the irregularities present in the varying porcelain shape thickness, an extensive filter section has to be added in to the Max/MSP patch. The EQ section than allows the sound installation to 'be tuned' properly and to reflect each shape's resonant properties and overall sound EQ characteristics. The tuning section consists of a set of individual parametric EQ filters attached to each of the audio output channels. The purpose of the tuning phase is also to ensure, that the sound travels seamlessly across the whole 8-channel audio field without additional shifts and inconsistencies in the sound color properties and perceived loudness. The shapes also had to be suspended on sets of invisible strings in order to bring the most from the mid and low-mid spectrum. The strings are attached to the shapes by using a small hidden glued wooden objects with a miniature slots.

[2] X-Vibe solid driver; more information about the solid driver can be accessed online at www.goxdream.com/x-vibe.php

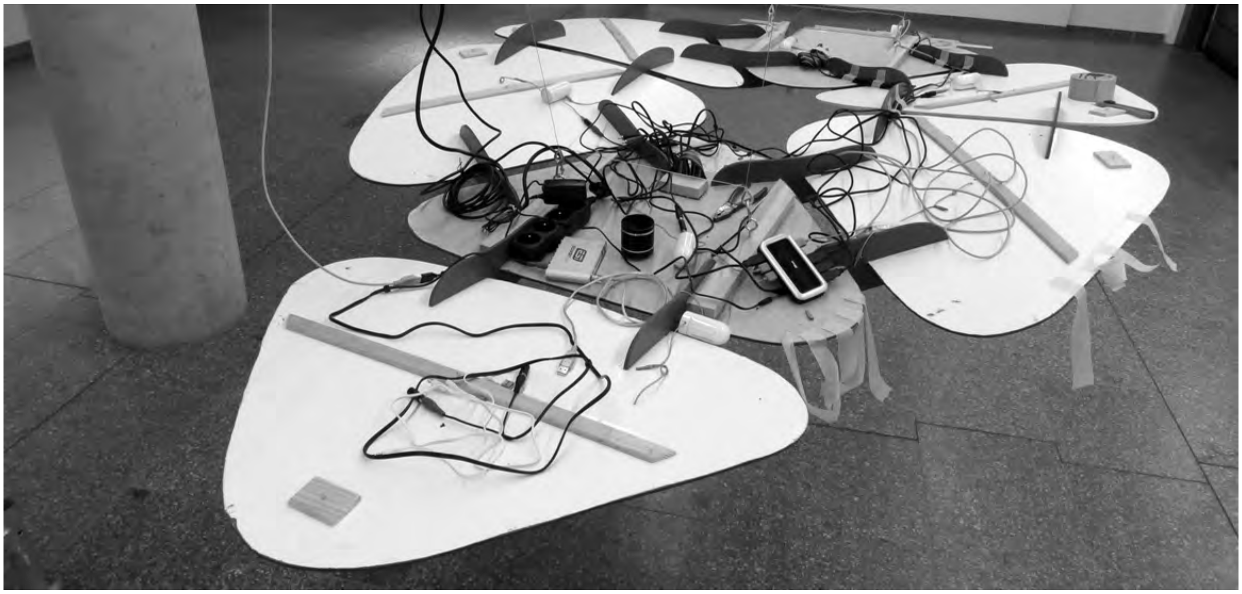

Figure 4: Rainforest – the suspending base detail & overall audio setup

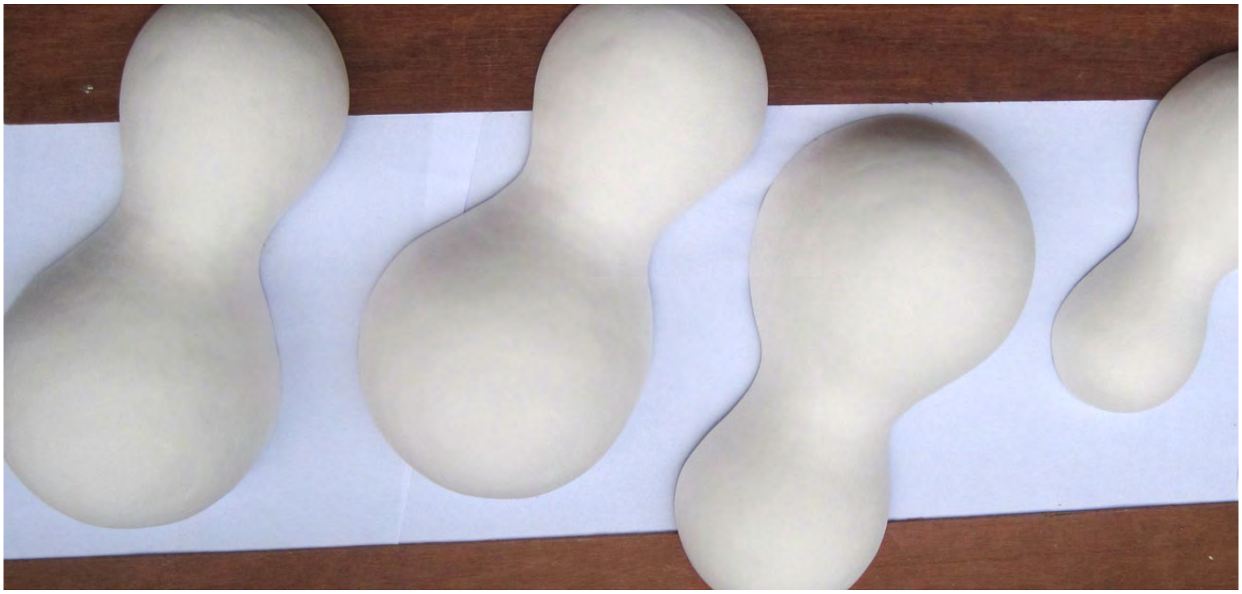

Figure 5: Porcelain shapes manufacturing – the bisque firing

In commercial solid drive applications a special hardware EQ modules are used to bring the hi-fi audio quality into such setups[3]. They are introduced to the signal path in order to compensate the specific frequency attenuation and the acoustic property irregularities of the vibrating materials – specific presets for glass, wood or other materials can be than designed and applied to create flat response curve of the audio system.

The Ambisonics engine[4] is used to control the position of individual sound sources in the installation. It has to be noted, that the use of the Ambisonics was not intended as regular setup of the Ambisonics environment from the very beginning, but rather represents a repurposed and creative use of an existing technology, which allows for an interactive placement of sound sources across the sound installation. Also the porcelain shape 'speakers' are not distributed evenly, and as such, they are not intended to create consistent sound field in the way the Ambisonics work. The Ambisonics engine was selected, because it also offers a convenient graphic interface for the realtime sound source position visualization.

## Interactive live interface – the Max/MSP patch

The heart of the interactive element of the sound installation is the Max/MSP patch. The patch runs on a laptop in the Max/MSP runtime environment.

In order to capture the listener's interaction and movement, the Max/MSP Jitter library was used. Live webcam video stream is fed into the patch, while individual video frames are analysed for specific colour boundaries changes. The colour of the floor is subtracted in the process, so a clear image of the moving silhouettes of listeners can be obtained. The actual position of the listener is acquired from the video stream using the Jitter Max/MSP *jit.findbounds* object. The $x$ - $y$ axis position of the listener is based on the Cartesian coordinates and is derived from the installation area projection onto the floor. The projected plane is than translated into an Ambisonics sound 2D position. The camera itself is suspended from one of the central base components and is setup to cover evenly a one meter radius around the installation.

The change of the listener's position is also continuously evaluated and sounds are triggered, when the acceleration of the listener's movement exceeds a specific set threshold. The soundscapes are generated on the fly from the pre-recorded sounds, which are stored in two separate audio banks: the *drone sampler section* and the *solo sampler section*. Every time the movement acceleration of the listener exceeds a preset value a solo sound theme is added to the soundscapes as a spatialized element following the listener's actual position. The *drone sampler section* builds up the underlying vibe and mood of the soundscape, while the *solo sampler section* sound theme bank follows the moves of the listener across the installation audio field. The selection of the sound samples itself is triggered randomly and ensures, that a new original sound combination always creates an original soundscape.

[3] Solid Drive®; more information can be accessed online at http://soliddrive.mseaudio.com

[4] Ambisonics Tools from the Institute for Computer Music and Sound Technology ICST, Zurich University of the Arts can be accessed online at: https://www.zhdk.ch/index.php?id=icst_ambisonicsexternals

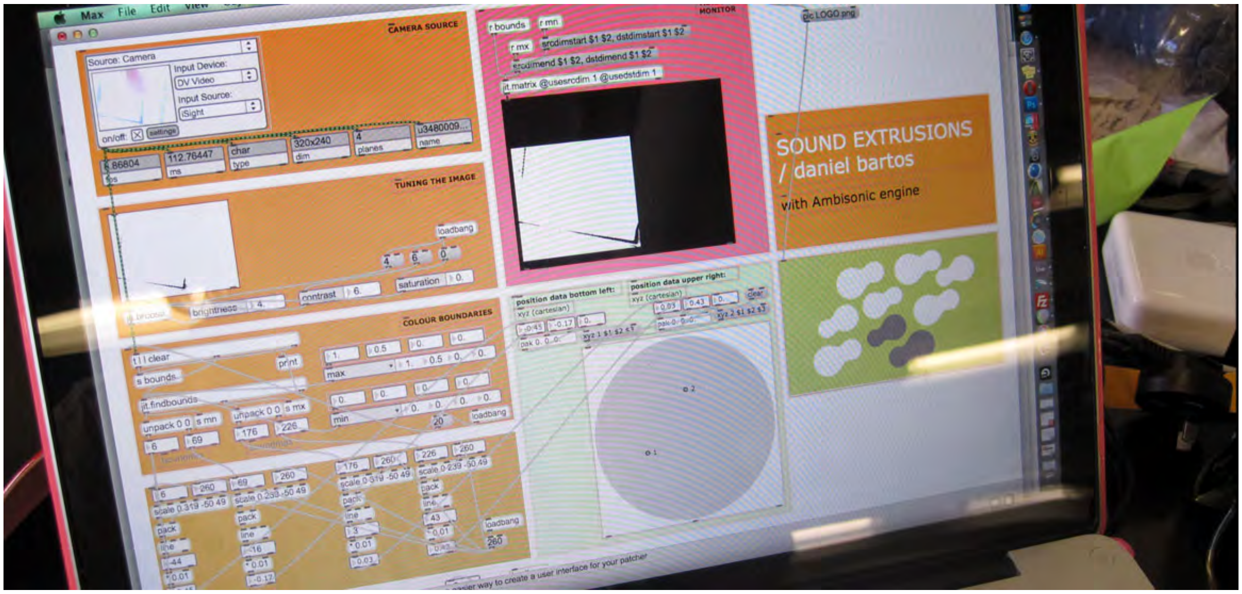


Figure 6: The original Max/MSP patch

## Lookout & Conclusions

The porcelain production proved to be the bottle neck of the whole production, as this was expected from the very start of the project. The manufacturing itself took more than three months to complete due to the details of manufacturing process involved. Two original shapes were modelled in clay. The clay models were than transferred into two negative plaster moulds. The process of mould drying, of such a rather larger size, takes weeks to dry out completely. The success of the following porcelain slip casting depends on the quality of the materials used and it's respective handling. Casting of such a thin porcelain walls presented a problem on its own and many shapes were broken during the process – a regular 'safe' wall thickness would be around 3 mm in this type of object casting. The bisque firing takes also minimum of 24 hours to complete, as it involves the cooling phases as well. The final firing with applied glazes is also crucial and a porcelain shape design has to be taken into the account as the porcelain properties change in the range of higher temperatures above 1200C°. The shapes become elastic during the process of porcelain vitrification and if not correctly suspended, they can come out of the kiln distorted. The whole production process takes weeks rather than days or hours. The shapes have also great degree of variation of the wall thickness and the acoustic properties are not consistent than. Having said that, a series of measurements in an anechoic room would be a perfect addition to the project, but was not realized yet. The best sounding sounds projected through the shapes were the ones capturing physical impact of small objects on a hard surface. For example rainstick sounds or impacting pebbles sounded very realistic, especially in the overhead position. The position sensing ability has it's own specific limitations: because the patch is using the *jit.findbounds* Jitter Max/MSP object, the interaction is limited to one listener at the time. Another solution would be using more advanced techniques from the CV package[5], which would give the whole project more interaction possibilities – as for example creating polyphonic soundscapes interacting with multiple listeners at once.

Overall, the Rainforest installation represents rare use of the porcelain material in a sound installation experiment and creates novel state-of-the-art element with an unique design rather than a special hi-end submersive audio field.

[5] Computer Vision for Jitter by Jean-Marc Pelletier; more information can be access online at http://jmpelletier.com/cvjit

## Additional Information

**Daniel Bartoš** is sound and multimedia artist from the Czech Republic. The most important attribute in his work is represented in the blend of digital realm within the tangible analog world. The preferably invisible digital interaction opens up new creative world of experience. Daniel is focused on sound, multichannel setups and interaction programming, while using other media platforms in the process as photography and animation. The mixture of digital realm with the physical aspects of sound and interaction is especially true for the following projects: *Motion Origami* – gesture based experimental music instrument using Leap Motion; *Rainforest – a* porcelain sound installation as an interacting living element; *e-didjeridoo instrument* (electro – extended – enhanced) – where the traditional Australian music instrument becomes an expressive breath controlled synthesiser. Daniel works with Music Academy in Prague on various sound and multimedia projects collaborations and is current doctoral student at the Centre for Audiovisual Studies at FAMU, Prague. In 2013-14 Daniel has won a 6 months long art residency position as a Sound resident at The Edge institute in Brisbane, Australia.

**Web:** www.danielbartos.com/rainforest; www.danielbartos.com/sound-extrusions

**Video:** https://youtu.be/Pz2Erx-JTWc

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# Gestural Control for Musical Interaction using Acoustic Localisation Techniques

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**Abstract.** Acoustic Localisation principles for tracking technology are well researched and have many applications in medicine and industry. In creative technologies optical technologies are more prominent. For creative music technologies we know from our own research into the applicability of acoustic localisation techniques for audio in the frequency range of standard audio equipment, that acoustic localisation techniques are potentially a straightforward choice. We also know that the technology is scalable from tracking in large performance areas to smaller areas with lower latency, required for gestural tracking for real-time interaction. As a proof of concept we prototyped two implementation of the principles, using handheld microphones and standard, commercially available loudspeakers, firstly for a Theremin - like pitch control interface and secondly, a spatial trigger for percussive sounds.

**Keywords:** Acoustic Localisation Techniques, Theremin, Gestural Control, Interface for Musical Expression.

## Introduction

Acoustic Localisation (AL) principles for tracking technology, particularly techniques using ultrasound, are well researched and have many applications in medicine and industry (Holm 2012). The principles for AL are not limited to ultrasound however, they apply to audible sound as well. This makes the use of them for tracking technology particularly interesting, namely for applications where audio equipment is already present, like in many audio, audiovisual and multimedia applications and particularly for interactive arts and new interfaces for musical expression (Schlienger and Tervo 2014). In creative technologies optical technologies are more prominent (Schlienger 2014), but there are a number of applications using AL (Rishabh, Kimber, and Adcock 2012; Filonenko, Cullen, and Carswell 2010; Janson, Schindelhauer, and Wendeberg 2010; Seob Lee and Yeo 2011).

We also know that implementation of AL principles is scalable. Tracking of performers in traditional performance areas like stages in concert halls are as feasible as tracking of small gestural movements which require very low latency and high update rates, for example for real-time interaction with virtual instruments.

For low latency applications, the authors of (Gupta et al. 2012), describe an implementation which arguably provides similar functionality to what we suggest. However our Time Difference of Arrival (TDoA) approach in lieu of Doppler, brings advantages in applications where the tracked object's identity needs to be known. For our test implementation of a Theremin like instrument, the differentiation between the left and right hand, for example, could be achieved by using separate microphones. In the Doppler scenario described in (Gupta et al. 2012) this differentiation would have to be achieved by other, more complex means.

Further, from our work with the Workshop on Music, Space & Interaction (MS&I) (Schlienger 2016a), we know about the need for simple, ubiquitous and pervasive interfaces which do not hem in the flow of gestural explorations of space. What is more, our findings from the workshop suggest that interfacing technology in form of sounding objects provides a particular engaging tool to immerse performers as well as audiences in a spatially interactive performance. We thus describe two applications here, using AL, which answer these requirements as a proof of concept for the feasibility of the principles in low latency applications needed for interactive sounding objects.[1]

Both applications work on the basis of moving a handheld microphone but arguably the microphone could be attached to any type of moving object.

To summarise our rationale, we argue for a broader implementation of AL using mainstream audio equipment as the principle provides competitive alternatives to many other solutions as we showed using the literature in our previous work (Schlienger and Tervo 2014). Namely, by using sound in the frequency range supported by standard, main street, audio equipment, we see a possibility to improve on the performance of, for example, optical tracking systems due to the diffraction of sound around objects, allowing for tracking in non-line of sight situations. Whereas the focus of our previous work describes novel applications for larger performance areas and stages, our contribution here is to show that the AL principle can also be applied in smaller, gestural applications, for which other technologies are usually implemented: To stay with our examples, capacitance for the Theremin and optical tracking for gestural triggers. Our point is, the AL principle, using ubiquitous technology, has broader and more pervasive potential than its current state of rarity portrays.

The following sections describe our work in MS&I in more detail, give more details on AL principles followed by a description of our prototype implementations. The Matlab scripts using the Playrec Utility library are available to download and form part of this publication as an appendix (Schlienger 2016b).

# Method

## Workshop on Music, Space & Interaction

The workshop on MS&I runs now in its third year at the University of the Arts Helsinki, and uses Participatory Design approaches (Robertson and Simonsen 2013) to explore the affordances of technology for spatial interactivity in interactive musical applications. We use interdisciplinary, free improvisation as a method (Andean 2014) to explore existing and possibly new technologies without the restrictions of habits, genres or conventions. This approach to technology design draws on the notion of Designing Culture (Balsamo 2011) and on the notion of mess in ubiquitous computing (Dourish and Bell 2011).

The data gained from the workshop is ethnographic in nature, it consists of notes and participants written contributions along with some audio and video documentation. Some insight can be gained from the workshops blog the participants are encouraged to contribute to (Schlienger 2016a).

The applications we describe in this paper are based on our early findings from the workshop which provided us with the idea of spatially interactive sounding objects: These are things in a space which might be actual physical objects but also virtual objects which can only be heard in a particular position, rather than seen. On this notion we developed the idea of a spatially controlled pitch - object, probably most descriptively described as a Theremin - like instrument and a percussive - object, whereby at distinct positions percussive sounds can be triggered.

[1] We describe a proof of concept for larger scale applications in an article accepted for presentation at the NIME2016 conference

Figure 1. Workshop on MS&I, (Courtesy of Timo Pyhälä, 2015)

## Acoustic Localisation

As we are only interested in AL in respect to sound which can be produced by standard audio equipment, we refer to AL in the rest of the text in reference to the frequency range form roughly 20 Hz - 30 kHz. Further, we are interested in the Time Difference of Arrival (TDoA) technique specifically, as this is the approach taken for the implementation we are working on for tracking in larger spaces. Compared to other AL approach, Doppler, for example, TDoA techniques lend themselves better to applications where the identity of the tracked object needs to be known, as the position estimation happens actively for a sender or a receiver's own position, Doppler or also echo-location relies on an estimation based on an indirect measurement. The principle of TDoA measures the time difference between the sending of a signal and its recording at one (or several) receiving microphones. From the correlation of the recorded and the original signal the time delay can be calculated directly. As the speed of sound through air is known *a priori* the distance of the receiving microphone from the sound source (the loudspeaker in this case) can thus be derived from the time difference. Using several such measurements, a position estimate can be trilaterated. The technique thus works in principle for 3 dimensional localisation.

For the prototypes discussed here we use the most simplest of principles, namely one single distance reading. *Nota bene*, this limitation to a single dimension is not a limitation of the AL principle! Trilateration from 4 distance measurements can be used to estimate an absolute 3D position. However, for the applications we discuss here, simple distance measurements between one sender and one receiver are, indeed, sufficient. We would like to stress that although a single distance reading is not enough for a 3 dimensional, absolute *position*, the application can still be spatial in character, as the distance reading is available *radially* from a fixed point of the receiver or sender which allows for 3 dimensional interaction with the object.

## Experimental set up

To demonstrate the applicability of AL for applications which are latency sensitive we prototyped two musical applications. The first application is a Theremin like instrument wherein pitch can be gesturally controlled. For the second application, we implemented a gestural trigger mechanism for percussive sounds. Both implementations require to move a microphone in front of a loudspeaker emitting a high pitched measuring signal just above the frequencies audible to the human ear and within the frequency range of standard audio equipment. (Depending on the type of loudspeaker, 17-30 kHz.) The loudspeaker used for our tests was of type Alesis M1 MK II, the microphone of type Sure SM58.

The applications were implemented in Matlab R 2013a, using the Playrec (Humphrey 2011) utility. Playrec allows for non-blocking soundcard access and thus continuous and simultaneous play and record. This could have been achieved natively in newer versions of Matlab, but Playrec provides insight into the sample-by-sample workings which was considered helpful for prototyping. A simple Max Patch received the measurements from Matlab via udp and dealt with the content audio.

Patches and Playrec Script are available online (Schlienger 2016b). The processor running Matlab was an 11-inch, Mid 2011 MacBook Air, 1.6 GHz Intel Core i5, running OSX 10.8.5, the soundcard a DigiRack 002.[2]

The room in which we tested the applications is a typical living room without particular acoustic treatment, with a reverberation time below 0.4 seconds, 6 by 3.5 meters with 2.6 height.

Both applications are latency sensitive: For musical interaction, in order to play within an ensemble as well as to be able to play an overdub for a multitrack recording it is crucial that the performer can monitor her or his playing in real-time or in a very close approximation to real-time. To define the criteria of what shall be considered a close enough approximation, the following thoughts were decisive:

- Latency up to a length of 10 ms is generally tolerated by musicians in performance situations as well as in the recording studio.[3]
- Just over 10 ms at 48 kHz sampling rate can be achieved with a buffer size of 512 samples. This also happens to be the lower limit at which our current set-up runs stably.
- The actual, overall latency between is somewhat higher: We can calculate this by measuring the time it takes a signal to arrive at a microphone at a millimetre distance from a loudspeaker. Possibly due to hardware restrictions and processing power of our set-up, our best achievable latency is often as high as four times the buffer size.
- For many mainstream sound cards 20 ms were considered acceptable until fairly recently.
- We further estimate typical gestures for these application to stem from arm movements of a stationary person, so we scaled the functionality of both applications to a range of 1 m.
- The trajectories through air which can be expressed in 512 samples at 48 kHz represent a distance of 3.66 metres. For gestural interfaces we consider this adequate.

This last point might need some more elaboration: The length of the buffer we iterate when calculating the time delay between two signals sets the limit of the longest time delay we can actually measure. We cannot measure time delays which are longer than the window that the buffer provides. As we translate the time delays to distance covered by sound, the window sizes also stand for maximum distances that can be estimated within a window. These relations between window sizes and time delays and distances covered by sound, respectively, are further dependent on sampling rate. So with an increased sampling rate we need to higher the window size to cover the same distances. The higher sampling rate does not only provide a higher update rate, but also allows for measurement signals at higher frequencies.

| | **44.1 kHZ** | **48 kHz** | **96 kHz** | **192kHz** |
|---|---|---|---|---|
| Measurement signal top frequency (Nyquist) | 22.05 kHz | 24 kHz | 48 kHz | 96 kHz |
| 1 sample | 0.0244 ms | 0.0208 ms | 0.0104 ms | 0.0052 ms |
| 1024 sample window | 23.2199 ms | 21.3333 ms | 10.6666 ms | 5.3333 ms |
| 2048 sample window | 46.4399 ms | 42,6666 ms | 21.3333 ms | 10.6666 ms |
| Maximum distance represented by window 1024 | 7.9644 m | 7.3173 m | 3.6586 m | 1.8293 m |
| Maximum distance represented by window 2048 | 15.9288 m | 14.6346 m | 7.3173 m | 3.6586 m |
| Distance in one sample | 0.0077777 m | 0.0071458 m | 0.0035729 m | 0.0017864 m |
| Samples to travel 1 m | 128.5714 | 139.9416 | 279.8833 | 599.7667 |

*speed of sound = 343 m/s*
*time for sound to travel 1m = 2.9154 ms*

Table 1: Overview of Relations between Sample Rates and Distances Covered by Sound

[2] For the video demonstration we used Meyer Sound MM-4XP, the Motu 16A soundcard and AKG c417 Omni Lavalier Microphones, and the same processor.
[3] We differentiate here between what is tolerable and what is noticeable: even latency as short as 1-3 ms can be noticed, for example as comb filtering by singers monitoring themselves on headphones.

## Proof of Concept for Low Latency Applications

We chose the two applications as proof of concept for low latency applications for the reason that they show conceptual differences in slightly different requirements. Thus, we look at the applications separately:

### Pitch Control

Gestural pitch control with a Theremin is a skill which needs to be acquired through practice. Similarly, our take on the concept is not meant to simplify musical playing: With a stable and controlled hand it should allow for stable, controlled pitches and the (skilled) playing of melodic material.

The pitch range covered within 1 m we set too 80 - 6000 Hz, as we believe this to be roughly representative of the frequency range of interest for most musical applications. We experimented primarily with sine waves, but this was an arbitrary decision, and other sound material could, of course, be used instead.

### Percussive Control

We generally associate percussion playing with hitting an object with our hand, or with a stick, or similar. Our implementation of gestural percussive control is thus somehow quite abstract, as moving the microphone through a particular distance to a loudspeaker triggers a sound. There is a commercial implementation doing a very similar thing though, Aerodrums (Aerodrums 2016), using optical tracking. Similarly to our scenario, the lower latency limit is set by the system buffer size, however, their implementation allows for settings as low as 128 samples per buffer, albeit at 44.1 kHz sampling rate.

## Results & Discussion

We achieved latencies for both application scenarios we considered sufficiently low for a proof of concept. (Typically around 10 - 20 ms) We are also confident that these numbers can still be improved on with further development.

For the pitch control application, we found that our current, averaging, smoothing algorithm[4], makes it difficult to know if the gestural position responds to the proper pitch location or if the algorithm is averaging out under the influence of a few wrong readings. For pitch sensitive application averaging filters don't seem to be the best choice.

One peculiarity we can report for the percussive control application: Despite the latency being quite high at 512 or more samples per second (48kHz sampling rate) we didn't really notice this at first, as we seemed to just make a mental note where it was that the sound triggered when we tried it out the first time. As we knew that there was some latency we then investigated and came to the following insight: As it happens, the fact that in these air-drum type applications the performer is not actually hitting a physical object, the latency, (as long as constant and not varying) has the effect of moving the virtual object further away from the place where the performer thinks she or he will hit it. In this sense it is actually easier to live with the latency of such a virtual sound object than it would be to live with the latency of a physical object triggering a virtual sound source. The lack of haptic response means that, for our scenario, the virtual object is just further away than the performer would initially presume if we knew at what distance measurement the sound is being triggered.

The need for a mobile device to be held by the performer, even as a clip on wireless microphone, remains an obstacle towards totally transparent interfacing. Yet, compared to Doppler techniques which would allow device - free tracking of gestural movements, we see great advantages in the mobile device approach as the identity of the tracked device is known to the system.

[4] The algorithm calculates averages over time, the smoothing creates a lag and the interpolation of positions result in slurring of the pitch

A further caveat applies to both Doppler as described by (Gupta et al. 2012) and our (current) TDoA approach: With measurement signals in the frequency range between 18 to 30 kHz we lose the advantage of acoustic tracking over optical tracking to a certain extent: The much praised advantage of AL in view of the requirement of line of sight between tracked object and a camera in optical tracking systems, is much reduced at high frequencies, as the corresponding wavelength do not diffract around obstacles but reflect if the obstacle is wider than the wavelength in question. AL still works in the dark, certainly an advantage over some optical tracking systems. We are thus very interested into further research about the possibilities of using the audible sound of the content in an audio application as a measurement signal, or certain frequency bands within the content audio.

The resulting proof of concept - applications are being demonstrated in the appended video clips available online via the following link: http://creativemusictechnology.org/lowlatencyapps.html

## Conclusions and Future Work

We showed with a simple implementation that AL techniques are feasible for pitch control and percussive triggering of sounds in musical applications. We also showed that more research is necessary, and that the current implementation can not be considered the state of the art of what is possible: With a more advanced implementation, a direct comparison with commercial systems on the market using optical tracking, for example, will provide an actual evaluation, which we can not sensibly provide yet with the current, rudimentary, example code. We also point out that these limitations are not due the principles of AL but due to the basic nature of the prototyped implementation. To summarise, we think we have a couple of interesting virtual sounding objects whose affordances we will explore much further in the workshop on MS&I. we would also like to invite interested parties to look at the code appended to this paper, available online (Schlienger 2016b). The whole project is intended to be open source, and an implementation as a Pd and/or Max MSP object is planned.

**Acknowledgements.** We would like to thank all the participants past present and future of the workshop on Music, Space & Interaction. This research is made possible by a Kone Foundation Researchers Grant.

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# AV Zones – Tablet App for Audiovisual Performance

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**Abstract.** We have identified potential for tablets to be used as stand-alone tools for audiovisual performance, and not simply as controllers, due to their portability, expressive capabilities of multi-touch, and processing power. To explore this potential, we have developed AV Zones (AudioVisual Zones), an iPad app for audiovisual performance. In a preliminary phase, we conducted interviews with audiovisual performers and a workshop, to understand user needs and desires. We then developed AV Zones, an iPad app for audiovisual performance, composed of an audio sequencer/looper with a visualizer. It explores the interactive potential of a touch screen tablet for integrated musical and visual expression. By default, 3 audiovisual columns or "zones" allow for the manipulation of 3 audio loops. These zones are metaphorical adaptations of channels in a standard audio mixer.

**Keywords:** audiovisual, multi-touch, tablet, multisensorial, touchscreen.

## Introduction

The popularity of multi-touch tablets, particularly since the introduction of the Apple iPad in 2010, have led to the development of numerous applications for music performance. Tablets are sufficiently powerful to run audio applications, and relatively affordable. Coupled with the immediacy of multi-touch, they can offer simultaneous interaction capabilities to musicians that go beyond what a laptop with a trackpad can offer. Although touch screen controllers for music such as the JazzMutant Lemur predate the iPad, the affordability of the iPad, and its processing power for audio made it a popular choice for musicians since its launch. Lemur itself has been ported to iPad (https://liine.net/en/products/lemur/), where it competes with other popular touch screen controller apps such as Touch OSC (http://hexler.net/software/touchosc). Reactable, a self-contained instrument, is another notable tangible music tool to have been ported to iPad, among other devices (http://reactable.com/mobile/). The field of tools for audiovisual performance targeting tablets is less varied than the field of tools for music performance. Few apps (tools or art pieces) for tablets aim to be used in a performance context for both audio and video output. Notable exceptions are Variant and its predecessor Thicket (http://intervalstudios.com), and Takete (http://refinedstochastic.com/takete.php). Due to the portability, expressive capabilities of multi-touch, and processing power, we have identified potential for tablets to be used as stand-alone tools for audiovisual performance, and not simply as controllers for other devices. To explore this potential, we have developed AV Zones.

## Previous Work

In a preliminary, ethnomethodological phase, reported in Correia and Tanaka (2014), we conducted interviews with 12 audiovisual performers, asking them about their practice, the creative tools they use, their needs and desires as performers. This brought forth a series of key issues we retained as important for live audiovisual performance: modularity, flexibility and reconfigurability; ease of hardware/software integration; instrument-like expressivity and fluidity; integration of environmental elements; generative capabilities and diversity; communication of process to the audience; reliability and speed. The ideas from the interviews then informed a brainstorming workshop, with 19 participants. The five breakout groups produced five sketches of procedural audiovisual performance tools. Two were particularly successful in addressing the challenges set out in the workshop. Both rely on the expressive potential of multi-touch interaction, employing different solutions for reconfigurability: the former allows for loading and manipulating vector graphics, and the latter adopts a simplified data-flow mechanism for customization. The key issues identified from the interviews and sketches from the workshop influenced the design and development of AV Zones.

## AV Zones

AV Zones (AudioVisual Zones) is an iPad app for audiovisual performance, composed of an audio sequencer/looper with a visualizer. It explores the interactive potential of a touch screen tablet for integrated musical and visual expression. By default, 3 audiovisual columns or "zones" allow for the manipulation of 3 audio loops. These zones are metaphorical adaptations of channels in a standard audio mixer. Each zone had 3 XY pads for audio manipulation: pitch shift, delay and filter. Each zone has its own sequencer as well. A visualization of each sound is overlaid on to the respective zone. There are 9 sounds available per zone, which can be replaced. Performing different gestures on each XY pad creates different results. The application is scalable: the number of zones, XY pads and sounds can be modified in the code. In a performance, only the iPad is used for audiovisuals: the visuals from the iPad are projected behind the performer, and the sound comes from the iPad as well. What the performer sees is also what is projected on the screen. The interface is shown in the screen, allowing the audience to better understand the performer's actions (figure 1; video: https://vimeo.com/144976072). AV Zones has been performed at: MonoShop opening, Berlin (May 2015); EAVI XIII, Amersham Arms, London (October 2015); VJ London, Juno, London (December 2015); and Seeing Sound, Bath (April 2016). AV Zones is open source and work in progress, built with openFrameworks and Maximilian add-on. The app is still being finalized, and will be submitted to the App Store within a few months. Meanwhile, the code is available on GitHub, and the app can be side-loaded manually on an iPad using Xcode 7 (https://github.com/AVUIs/AVZones).

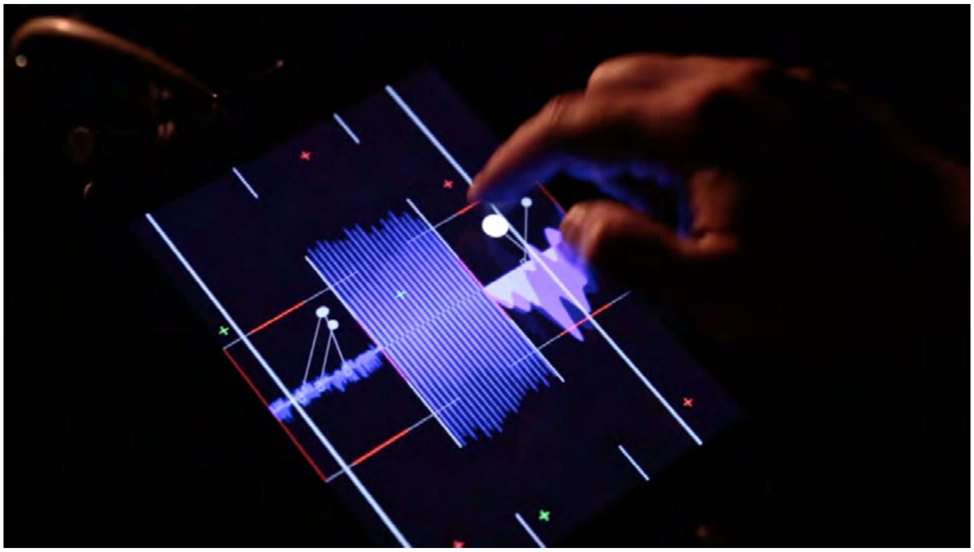

Figure 1. AV Zones

## Biography

Nuno Correia is a researcher, media artist and musician. He is interested in enabling interactive multi-sensorial experiences. Since 2000, he has been teaching and conducting research in media art and design, in universities in Portugal, Finland, Estonia and the UK. Nuno holds a Doctor of Arts degree in new media from Aalto University (Media Lab Helsinki), with the thesis "Interactive Audiovisual Objects", and an MSc in innovation management from the University of Lisbon. Currently, he is a researcher at Goldsmiths, University of London (EAVI group), working on the project "Enabling Audiovisual User Interfaces". Nuno's work has been presented in more than 20 countries.

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# SKR1BL

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**Abstract**. SKR1BL (2016, c. 10mins) is an audiovisual composition for solo laptop performer with gestural controllers. The score consists of 'sampled' graffiti tags that are formally arranged to highlight similarity and variation, and to provide opportunities for sonic contrast and counterpoint. The performer creates fine detail through interpretive, intuitive and exploratory responses to the score, sound library and DSP processes. The work is part of a wider study on the use of graphic notation in live electronics to create a body of work that falls in the gaps between improvisation and repertoire.

**Keywords:** Non-musical performance interface, embodiment, timing, mapping strategies and design, (un)control

## Introduction

Grounded in Hip-Hop culture, there's a musicality to tagging with rhythms and repetitions, and importantly, tags seem spontaneous and improvised, yet crafted and cultivated. The visual style is reductive, symbolic and object oriented. The morphology and material character of the tags guides the performer in respect of sound shape, texture and gesture such as granular microstructure due to combined qualities of a repetition, the graffiti surface and the marking paint or ink. The performer should look for established direction and extensions of movement and make connections in material though superimposition, stratification, juxtaposition, and interpolation. The overall duration of the work, and of individual passages, will vary as a function of the interactions between the different elements.

Graffiti tags are by turn angular, abstract, reductive, compressed, contained, expressive, expansive and iconic, with lines that connect and organise, shifts in weight, arcing trajectories, ASCII like decoration, punctuation and texture, with embodied formal and filigree qualities. Their use in notation provides the "something to hold on to factor" (Landy 1994b). This work might be described as chamber electronics, and is characterised by fast moving details, developments and interactions between sound objects and technique. The score provides a framework for returning to scripted play and guides the overall direction of the work.

Tags may demonstrate some common gestures, but also contain improvised variations. At this stage the work is focused on human structuring, performance and remediation, but technologies for archiving and gesture following graffiti tags are available (Roth 2010, Caramiaux 2012), and the production of scores might develop by investigating processes of graffitization (Berio and Leymarie 2015).

Links between graffiti and the structuring and performance of music and sound can be found in the view that tagging is an embodied form of interiorised repetition of developing skills, style and serial objects (Brighenti 2010). It's possible to identify a mapping between formal expression of character, changes in direction and the speed of the gesture, "mak[ing] the most expressive mark possible in the fewest amount of lines in the shortest amount of time" (Roth 2009).

Design theory and literature such as Kandinsky's writings on Point, Line and Plane (1926) provides some insight into ways in which the formal qualities of tags might be interpreted in musical ways as an aid to score creation. Kandinsky examines the tensions inherent in curves and angles. Tension refers here to the potential for movement and resolution. Like springs, curves and angles are lines under tension, and could potentially resolve to straight lines. Morphology and taxonomy offer additional frameworks for visual analysis (Roth 2009, Schaeffer 1966, Smalley 1997), while gestural and situated aspects of graffiti tagging can examined for indicative relationships (Smalley 1996).

There's a material link between the form and impact of graffiti tags and the material qualities of the surface, space and tool (Chmielewska 2007). The graffiti surface will possess varying qualities of texture, from the very smooth to the very rough, affecting the ease of marking or paint transfer and coverage. The combination and contact of spray or ink and surface can map to malleability and fluidity in an object/substance field (Smalley 1996).

Graffiti scores are ideally suited to gestural interfaces such as the graphics tablet and stylus, not least because of the inbuilt link to penmanship and calligraphy. Graphics tablets allow us to re-scribe the gestures contained in the tags. This creates a shared energy and morphology, and we can develop the stable, scrutable, learnable response required for more sophisticated expression (Croft 2007).

The base sonic material consists of fragments of early Hip-Hop that are distributed across a number of DSP layers. A graphics tablet, 3D space navigator and midi controllers are used to trigger and scan material, which is subject to further processing and manipulation in a manner reminiscent of both early tape works and modern turntablism. Typical gestures include scrubbing and scratching, dipping, oscillation and bowing (Wessel et. al. 2002). The live video component remediates the graffiti further using similar mapping strategies to the audio part.

The work addresses themes of non-musical performance interface in the use of devices like the graphics tablet and 3D space navigator, embodiment in the re-mediation of graffiti signature, timing and flow, mapping strategies and design in the interaction of the different DSP layers such as inverse crossfades and useful ranges, and (un)control and unpredictability in the self-sampling processes as the performer's attention and intention shifts between layers.

A video example can be seen at: http://vimeo.com/155386533

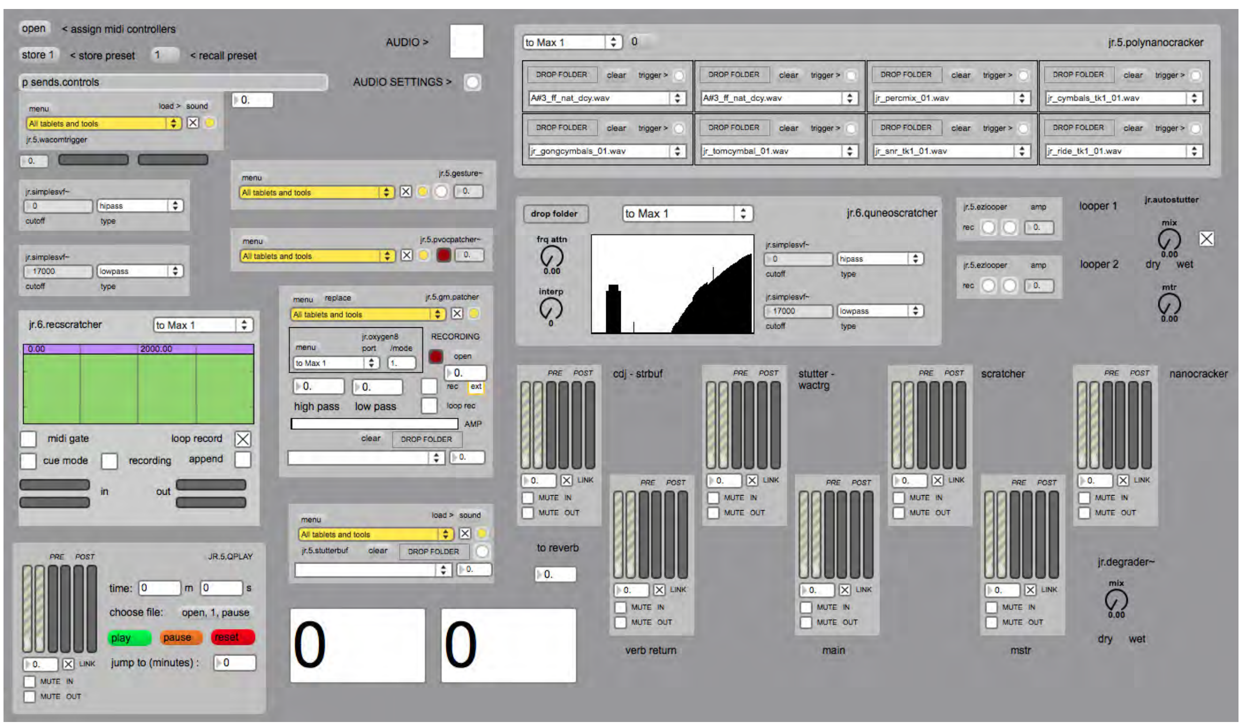


Figure 1. SKR1BL performance MaxMSP patch

Figure 2. SKR1BL score fragment

Figure 3. SKR1BL video processing screenshot

## Biography

Jules Rawlinson (b.1969, UK) designs sounds, visuals and interactions, and performs with live electronics. Jules recently collaborated with Matthew Collings on 'Requiem for Edward Snowden', which blends live electronics with a chamber trio and realtime visuals. Following sell out performances in Edinburgh and Glasgow, this work was selected for Creative Scotland's Made In Scotland showcase at Edinburgh Festival Fringe in 2015, and has played at Aberdeen's Sound Festival and Utrecht's Gaudeamus Muziekweek. He is a founding member of the LLEAPP network (Laboratory for Live Electronic Audio Performance Practice), which has fostered an ongoing and reciprocal series of workshops and events at a number of UK institutions. Jules has a PhD in Composition from Edinburgh College of Art, University of Edinburgh, where he is a lecturer in Digital Design. For more information visit http://www.pixelmechanics.com

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# DOCTORAL COLLOQUIUM

## Introduction

Joe Watson

The Doctoral Colloquium saw a wide-ranging, international cohort of PhD researchers explore key live-interface themes through presentation, performance and discussion. Professor Sally Jane Norman provided invaluable insight and cogent analysis throughout the day, particularly in her chairing of the afternoon's group discussion. Stuart Nolan gave a talk that seemed magically to synthesise all of the issues explored through the day, and proved a fascinating supplement to his ICLI keynote address. Issues explored by this group of 'creative extremophiles' included questions of hybrid spaces, processual rather than static approaches, the modelling of agency rather than agents, the subverting/diverting/hijacking of mapping techniques, fracture and layering, potential futures and rhetorical devices.

# Is There A Place In Human Consciousness Where Surveillance Cannot Go? Noor: A Brain Opera

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**Abstract**. A plethora of global initiatives whose goal is to map every neuron in the human brain are underway (Society For Neuroscience 2015). These investigations have releases an abundance of new technologies, research and methods. They also raise questions concerning privacy, surveillance, autonomy and consciousness. Are we nothing more than our electroencephalographs (EEGs), functional magnetic resonance images (fMRIs) and other biometric data? In the future could this information be used for security identification, thought reeducation and manipulating memories? Currently, new types of consumer-grade brain sensors are being developed for medical applications, though they are also appropriated for artistic explorations. What kind of dramatic structures, interventions, methodologies and contexts will emerge as the brain itself begins to drive the performance experience? To metaphorically respond to these questions I have developed an interactive 'brain opera' Noor (which translates as 'light' in Arabic) based on a simple question, "Is there a place in human consciousness where surveillance cannot go?"

**Keywords:** posthuman, consciousness, brain, surveillance, EEG, HCI, brain mapping, BCI

## Introduction

There has been a rise in the use of consumer-grade electroencephalograph (EEG) brain readers, or Brain Computer Interfaces (BCIs) by contemporary artists (Duenyas 2012), (Abramovic 2011), (Park 2013), (Withers 2015), creating interactive performances based on tracked and readable states of mind. During the 1960s and 1970s, musicians Alvin Lucier, Richard Teitelbaum and David Rosenboom experimented with the control sources of biofeedback and brainwaves producing sonic events that played up, enhanced and completely reinvented their original source material. Lucier collaborated with physicist Edmund Dewant, making *Music for Solo Performer* (Lucier 1965), the first brainwave music composition performance using EEG electrodes. In the 1973 film *Homage to John Cage* by video artist Nam June Paik (1973), Cage wore electrodes strapped to his forehead while Paik fiddled with the knobs on a transmission wave box. That same year artist Nina Sobell created 'brain wave drawings (Sobell 1974). These initial experiments validated the brain as a device that could produce music and art, usually through the specific mental states of focus and meditation measured by an alpha or beta wave signal. These signals are the one artists employ throughout most of their presentations. When more complex environments and more sophisticated brain EEG readers are used, additional mental states can be accessed, opening up new spheres of inquiry in the performance environment.

## Brain Performance As Surveillance

Watching a subject's brainwaves live time can mimic the performance theater of a surveillance state, whether it is simulated in the proscenium or observed by faceless, anonymous monitors during surreptitious interrogations. Performance itself has a long tradition of spectatorship and voyeurism, and of revealing hidden motives and intentions. Now brainwave readings are beginning to be stored in private data banks and scattered throughout the computing cloud (Leborgne 2015) (Syntrogi/Qusp 2016). Smoothing algorithms about various biometric states can currently quantifiably categorize that information. When personal data expands to include brain states, the ability to classify and sort information according to desirable outcomes implies a new type of control and discrimination. Imprints of our actions can wind up in the hands of the wrong people (McGrath 2004). This categorization facilitates tiers of privilege and access that could be selectively doled out to different individuals and groups. This new landscape or 'surveillance space' also mimics the control a theater director has over a play, or the control authorities have over designing and implementing surveillance scenarios.

As BCIs become affordable and hackable, the investigation of that internal cognitive space also becomes accessible to artists. Artists have created works using surveillance-related technology to disrupt normal audience responses allowing everyone, including subjects and audience, to view normally hidden processes. This provokes the 'possibility of agency' of the person, artist or audience member used as a test subject. A newly adaptive theater of surveillance driven by BCI devices is arriving allowing this same type of environment to make brain processes visible for the audience members, either through monitoring performers, or by accessing the brains of willing audience volunteers. Through an agency of excess, such as the intimacy of looking at people's live time brain feeds while they are sitting right in front of you, the emotional impact of what one is looking at subverts the plane of symbolic representation being played out on the stage. When the performative surveillant space incorporates brain sensors, the disruption and reversal of traditional audience scenarios changes. The audience impacts the lived space between themselves and the performers in unavoidable, but authentic ways.

The research from using medical brain devices to aid people with disabilities is also opening up new vistas into the capacity to use the brain in ways that echoes advances in strategic military combat. Researchers at the University of Washington (Rao, Stocca, Bryan et al. 2014) produced the first non-invasive human-to-brain interface by asking, 'Can information that is available in the brain be transferred directly in the form of the neural code, bypassing language altogether?' EEGs can now decode motor intentions from a 'sender' brain, and Transcranial Magnetic Stimulation (TMS) can deliver an equivalent motor command to the motor cortex of a 'receiver' brain. This is extremely important as eventually remote, magnetic or other types of stimulus could be used to convey information brain to brain, or surveil different brain states in captive populations like prisons or mental hospitals. Now drones and planes can be remotely activated through thoughts picked up by EEG braincaps (Brainflight, European Union 2012–2014), (Woollaston 2015) (Tekever 2015). These devices are also being deployed for aerial surveillance and ATLAS security test drills. Thus, a new 'theatre of war' and a 'theatre of surveillance' driven by the medical BCIs are developing almost in tandem. Formerly inaccessible states of subjectivity like cognition, analysis and decisions without neuromuscular follow-though can be encoded to specifically launch weapons of destruction. It can be argued that intentionality, and therefore actions have always created this situation. The difference, however, is this can be now be accomplished purely through the use of a cognitive interface.

The Emotiv headset, a portable consumer and professional grade EEG device reads changes in electrical activity in the brain (Emotiv.com 2014). Those changes are mapped to various emotions, facial movements, eye, eyelid and eyebrow positions, smiles, laughter, clenched teeth, smirks, and even virtual avatars. The device tracks six specific directions in a screen display; left, right, up, down, forward and 'zoom' or depth, as well as six rotations; counter clockwise, left and right, backward and forward and one interesting one referred to as 'disappear'. Billions of neurons are constantly interacting with one another, emitting tiny electrical impulses. It takes only eight seconds using Emotiv's software to calibrate the specific contours and fold patterns of any one individual's brain, a process so unique it is akin to a human fingerprint. Both conscious and non-conscious content has been mapped for accuracy into the software's algorithm to account for variations in the brain's multiple folding patterns. What scientists at Emotiv did was remap those signals back to their source in a specific area of the brain. The Emotiv reads and translates these electrical impulses with a latency of about 150 milliseconds, though depending on what interface software artists use, that timeframe can vary.

It is becoming important for artists who are technologically savvy and astute to address what can only be called 'the decade of the brain', and to explore the implications of these issues through their various art practices. My current practice focuses on developing a creative "brain opera" performance using an Emotiv EEG brain sensor to indirectly address these issues. The opera, called "Noor" which translates in Arabic as 'light', asks one very simple question – " Is there a place in human consciousness where surveillance cannot go? My reason for creating this opera is that what you can say in an academic paper, and what you can discuss in an artistic performance are two different things. Within the confines of this nascent technological landscape, a sense of self, or private self, is going to be exposed and potentially violated in a surfeit of overt and covert ways most of us have never imagined or experienced. Within the confines of a short performance, metaphor and allegory, sound and words, and interactivity suggests, but does not name these concerns.

## Noor – A Brain Opera

“Noor- A Brain Opera” is loosely based on the true story of Noor Inayat Khan, a Russian born, European raised Sufi Muslim Princess whose father Hazarat Inayat Khan brought Sufism to the West. During WWII Noor volunteered as a covert wireless operator for British Intelligence by parachuting deep inside occupied Vichy ruled France. For a period of three months Noor (code named “Nora”) was the only communications link transmitting critical information back to the Allies. Caught by the Gestapo, who were unable to break her to find out any information concerning her transmission cell, Noor was shot inside the infamous Dachau prison shortly before the end of the war. Noor is used as metaphor to work with issues of surveillance, privacy, and faith.

Databanks of video, audio and a spoken word libretto correlating to four basic mental states most accessible to the Emotiv headset are used: interest, excitement, meditation, and frustration. The algorithms and machine learning capabilities of the headset pre-determine the range of emotions reflected by the brainwave states. These databanks, which loosely contain information relating both to the theme of the story and to different emotional states are launched in tandem when the performer attains a specified threshold of a brainwave. The brainwave threshold is determined by careful measurement of the individual performer’s response over time, and in a variety of situations, as each person’s readings are unique. The data range is between 0 and 1. For example, the meditation threshold is set to launch when it is greater than .450, and the excitement threshold launches when it is greater than .650. There is an approximately ten second lag between the implementation of the brainwave state of the performer, and the launched databanks of sound, image and the libretto. I was unsuccessful in changing this lag since it is inherent to the combination of software, hardware and middleware deployed.

The triggered videos, with their accompanying sounds and libretto are projected through a series of MAX/Msp commands and ported over to Isadora, where they are projected onto a circular fifteen-foot high 360-degree immersive theatre screen. Sound and a spoken libretto are added through Ableton Live. For the actual performance, the ‘actor’ wearing the headset interacts directly with the audience members. There is no seating inside the theatre, just the ability to stand or sit on the carpeted floor. The actor’s brainwaves will also be projected live-time on one of the five screens for all to see.

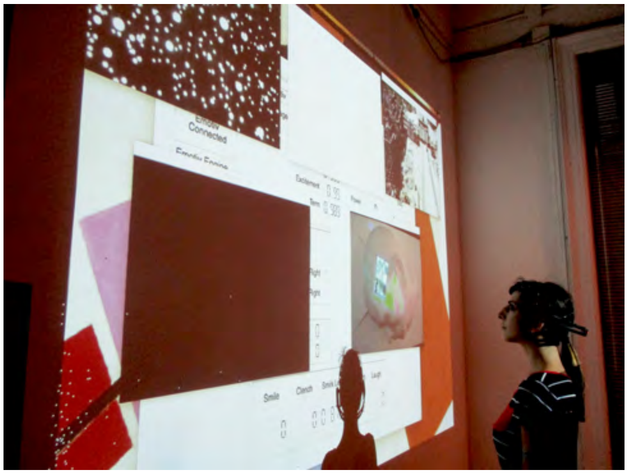

Figure 1. Testing very first iteration of “Noor – A Brain Opera” with Moon Rebas of the Cyborg Foundation on August 27, 2015 at Harvestworks, NY. Photo by Ellen Pearlman

Figure 2. Testing five screens triggered by performer (off camera). There are four emotions: interest, excitement, meditation and frustration. The fifth screen in the lower right is showing coloured bubbles of live time brain waves. Photo by Ellen Pearlman

Figure 3. Performer Saba Arat and choreographer David Leung training Saba, who is wearing the Emotiv headset under her hair, to interact with potential audience members. Photo taken at 360 Theatre, School of Creative Media, Hong Kong City University, January 6, 2016. Photo by Ellen Pearlman

Figure 4. Working on fixing resolution of 360 screen using Isadora

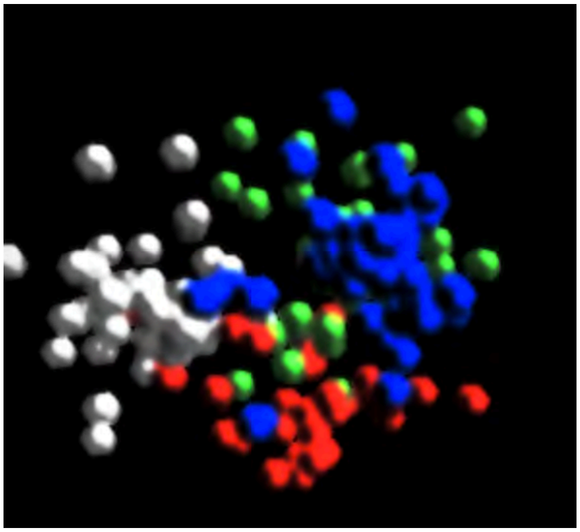

Figure 5 – Initial test image of four brainwave states: white, red, green, blue corresponding to four emotional states

## Conclusion

Government, coupled with private funding has increased research about the human brain. Banks of big data and the ability to mine that data for a variety of purposes have increased as well. Some of the technologies used to monitor the brain could conceivably lead to a type of 'brain fingerprinting', and introduce new ways to surveil and violate an individual's privacy. A new era of artists is exploring human computer interaction. "Noor – A Brain Opera" is a small contribution towards addressing the looming threat about brain surveillance, and contributing to the growing body of work on brain computer interaction in the performative sphere.

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# The Application of Established Gestural Languages in the Control Mappings of Free-hand Gestural Musical Instruments

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**Abstract.** The "mapping problem" is a long standing issue in the development of digital musical instruments, and occurs when an instrument's musical response fails to reflect the performer's gestural actions. This paper describes ongoing doctoral research that seeks to address this issue by studying the existing gestural languages of Soundpainting and American Sign Language in order to influence the control mappings of free-hand gestural musical instruments. The research seeks to contribute a framework of mapping strategies influenced by these gestural languages, as well as developments in the field of gesture recognition algorithms and novel evaluation methods for free-hand gestural musical instruments.

**Keywords:** Doctoral Colloquium, Digital Musical Instruments, Gesture Recognition, Gesture Communication, Sign Language, Soundpainting, Mapping.

## Introduction

While traditional musical instruments generate a musical response that is entirely dependent on the interaction between the musician, the instrument and the laws of physics, digital musical instruments are entirely freed from these restraints, and can instead map any conceivable input to any conceivable sonic output. However, without limitations these instruments lack cohesion and definition, which, once their initial novelty has waned, can disengage and frustrate audiences and performers alike. This doctoral research seeks to define a framework for free-hand gestural instruments by studying and learning from the sign languages American Sign Language and Soundpainting.

The research will expand on the latest research on gestural interactive music systems by studying and learning from long-established gestural languages for music improvisation and performance. The work will unite these gestural languages designed for human-human communication with novel developments in machine learning to enable fluid and transparent human-computer interaction for music. The research will contribute to the rapidly emerging and exciting field of computational gestural interaction with an overarching goal to develop a comprehensive system for musical interaction that incorporates an effective, nuanced gestural vocabulary that is inspired by pre-existing gestural languages.

The work will focus on asking: What can be learnt from drawing influence from gestural sign languages in the design of mapping strategies for gestural digital musical instruments?

This question can be further expanded as:

- What can be drawn from gestural language systems to achieve sophisticated musical expression and virtuosic performance?
- How can sign languages influence the encoding of musical meaning in gestural control?
- What methods of evaluating approaches and mappings of gestural interaction should be used, and what are the human factors that need to be considered?

The research will work to use gestural language systems that have been subject to decades of development and refinement to explore the issue of mapping freehand gestures to musical output, a long-standing issue in the development of novel digital musical instruments, and otherwise known as the “mapping problem”. The research will take an empirical approach, with novel methods of analysis determining the effectiveness of the application of gestural languages to music. The research will focus on the languages of Soundpainting and American Sign Language, and will work towards developing a framework for effective gestural mapping for digital musical instruments.

## Background

Gestural human-computer interaction is becoming increasingly prominent, with the development of low cost sensor technologies alongside the abundance of computational technology that enables the real-time execution of sophisticated gesture recognition algorithms. This has enabled the development of Virtual Musical Instruments (VMIs) (Mulder 1994) or Digital Musical Instruments (DMIs) (Miranda and Wanderley 2006), allowing musicians to interact with computers in novel ways, creating entirely new methods of composing and performing music.

Digital musical instruments provide the valuable opportunity to separate the site of physical interaction from the sound producing parts of a musical instrument (Winkler 1995). This process allows a musician using such a device to be able to harness a greater and more varied degree of sonic expression than that of acoustic instruments, as sound production relies not on physical but on virtual constraints. However, this decoupling of a musician’s input and a musical instrument’s output is unnatural for both musicians and their audiences, and can leave both parties feeling frustrated if the computer’s musical output does not appear to relate to the musician’s gestural input, resulting in what has been called perceptual disconnection (Nakra 2002) or “the mapping problem” (Wessel and Wright 2002).

Digital Musical Instrument mapping strategies are usually categorised via the relationship between input and output parameters, such as “one to one”, where individual inputs are mapped to individual outputs, with no inter-parameter relationships; “one to many”, where one input will be used to control multiple outputs; “many to one”, in which multiple inputs will have varying effects on a single output; and “many to many”, in which multiple input parameters will have varying degrees of control on a variety of outputs (Rovan et al. 1997) (Hunt and Kirk 2000). Studies have been conducted (Hunt, Wanderley, and Paradis 2003) (Hunt, Wanderley, and Kirk 2000) that show that multi-parametric interfaces with “many to many” mapping strategies provide the most engaging experiences for users. The key to intuitive expression in a gestural interface lies in its mapping (Dobrian and Koppelman 2006) and creating complex, nuanced controls that allow a musician to interact with a computer with the same level of detail and sophistication as they would interact with an acoustic instrument. However, complex mappings have the potential to fall into the mapping issues previously discussed.

The issues with devising a sophisticated mapping that retains its sense of embodiment has been previously addressed; Fels et al. (Fels, Gadd, and Mulder 2002) refer to this quality as the “transparency” of the instrument’s mapping, and they describe how deriving the mapping of a new instrument from that of an existing instrument, or more succinctly, using a metaphor of an existing instrument, can increase the transparency of the instrument’s mapping, enabling both the performer and the audience to understand the expressive qualities of the instrument. Wessel and Wright (Wessel and Wright 2002) also explore the application of metaphor in designing mapping strategies, drawing on the linguistic work of Lakoff and Johnson (Lakoff and Johnson 1980) and common human-computer interaction metaphors such as Drag and Drop.

However, those that wish to explore beyond the limitations of existing instruments are faced with new problems, especially systems that use spatial gestures to control musical output. With no standardised guidelines for designing mappings, the connection between gestural actions and musical responses often represent entirely arbitrary choices on the part of the designer (Nakra 2002). While this may result in a perfectly usable instrument, it requires players to learn the specific gestures for that system, and the designer is often unaware as to whether they have made suitable choices. Also, audiences that have no prior experience with a new DMI can struggle to perceive the connection between the performer’s actions and the resulting sonic response. An audience’s perception of a musical instrument is of as vital importance as that of the performer, and their understanding of intention and error in performance is a crucial factor for assessing a performer's skill and success (Fyans, Gurevich, and Stapleton 2010).

The field of recognising gesture in computing systems is dominated by machine learning techniques, most notably Hidden Markov Models (Yamato, Ohya, and Ishii 1992) and Neural Networks (Modler 2000). These techniques have been adapted and improved upon for recognising gestures, notably with the application of Dynamic Time Warping, which analyses a gesture as a series of successive states, capturing the repeatability and variability of a given gesture. This technique then "time-collapses" a prototype curve so that the velocity of a gesture becomes irrelevant in its recognition (Bobick and Wilson 1997).

The recognition of a gesture usually results in a discrete result: which gesture was performed and whether it was performed successfully. While this is fine for computer systems that only require specific triggering of events, it does not often suit the continuous nature of music performance. Existing music systems, such as SoundGrasp (Mitchell and Heap 2011), use this discrete technique to trigger one-shot events while tracking motion to control continuous parameters.

## Research

This research seeks to address the issue of perceptually disconnected control mapping by learning and drawing influence from the established gestural language of American Sign Language, and apply these strategies in a gesturally controlled musical instruments using computational gesture recognition techniques.

Soundpainting (Thompson 2006) is intended to be used by conductors to control the musical performances of an ensemble, yet the languages instructional gestures share many similarities with how one would control the parameters of a synthesizer or sequencer, including directions and gestures for controlling pitch, dynamics, timbre and note triggering.

As well as using language systems that are designed specifically for musical interaction, musical contexts can be drawn from more generic sign languages by using the meaning that already exists within them (for example, signs for big and small in American Sign Language could be used to manipulate amplitude). These gesture languages have been developed over many decades, with (in some cases) many generations of speakers refining and shaping the languages into meaningful, ergonomic systems designed to convey their meaning effectively and efficiently. Using and deriving from these languages and systems could provide a much more effective means of gestural control than other more arbitrary methods employed in digital musical instruments.

Both Soundpainting and ASL raise concerns about expressive control. Both languages use gestures to convey discrete meanings, of which variation plays little part. However, there are exceptions; in ASL, certain adjectives are intensified with the speed of performance. This is highly apparent in the gesture "slowly", in which the dominant hand is slid from the palm to the elbow of the non-dominant arm. If the sign is performed quickly, the sign, slightly paradoxically, becomes "very slowly".

Instead of using the exact meaning encoded in ASL, the methods used to encode that meaning can be used to design mapping strategies. For example, meaning can be encoded in ASL's gestural signs either arbitrarily or iconically (Taub 2001). In semiotics, an arbitrary sign is one that has no perceived connection to the concept it signifies, while an iconic sign resembles the concept it represents (Chandler 2007). ASL signs that encode meaning through iconicity have a physical resemblance to their concepts, and can often be recognised by non-signers (Lieberth and Gamble 1991). The language also uses iconicity to encode conceptual metaphors (Taub 2001), and this research intends to apply this technique to encode musical conceptual metaphors, such as the spatial metaphor MORE IS UP, which is often associated with pitch (Wong 2011).

This research will make use of continuous real time gesture following, building on recent work (Bevilacqua et al. 2010) (Caramiaux et al. 2014) that uses probabilistic methods to estimate which gesture a user is exercising as it is being performed. Using continuous gesture following as opposed to motion tracking allows computer systems to differentiate between when a performer is using a performance gesture and when they are not, and refrain from interpreting trivial movements (such as itching one's nose) as musical interaction.

## Methodology

Various frameworks exist for evaluating digital musical instruments (O'Modhrain 2011), most notably the method proposed by Wanderley and Orio (Wanderley and Orio 2002), which takes methodologies for evaluating human computer interaction and applies them to a musical context. Although the framework was designed to analyse devices and interfaces, their basic principles apply to many aspects of the digital musical instrument design process and can be adapted to evaluate freehand control mappings. They emphasise a set of contexts to aid in the analysis of different devices, five of which apply to hand-based gestural control of music: Note-level control (directly manipulating synthesiser parameters); Score-level control (controlling features of sequencers); Sound processing control (manipulating audio effects or spatialisation); Traditional HCI Contexts (drag and drop, scrubbing, navigation); and Interaction with Multimedia Installations (triggering audio without needing prior musical skill). Each context reflects a level of extraction between the user's actions and the computer's response. Wanderley and Orio stress that they do not represent fixed classifications, but it will be important to define the contexts in which the gestural mapping will be used when studying their effectiveness.

Wanderley and Orio also provide guidelines for developing musical tasks, which work as a benchmark to analyse the capabilities and usability of a controller in a musical context. The main features of these tasks are: "Learnability"; "Explorability"; Feature Controllability; and Timing Controllability.

Jordà also suggests criteria for the evaluation of digital musical instruments (Jordà 2004). He proposes that there are three areas of diversity (macro, mid and micro) that determine the nature of a newly developed instrument. His framework could be useful for analysing the characteristics that a gestural system would give to a digital musical instrument.

There are also many evaluation methods intended to analyse DMIs from the perceptions of spectators. Barbosa et al. outline five aspects of comprehension that can be tested for: cause, effect, mapping, intention and error (Barbosa et al. 2012). Similarly, Fyans et al. (Fyans, Gurevich, and Stapleton 2009) explore a method for evaluating a spectator's perception of error in performance, highlighting five issues raised by Bellotti et al. in general human-computer interaction (Bellotti et al. 2002): address, attention, action, alignment and accident; and re-contextualising them for digital musical instruments.

As well as making use of these methods, this research seeks to develop new methods of evaluation to analyse the efficacy of the application of techniques derived from gestural language in music control. This will draw from a broad spectrum of methods, such as adapting traditional human-computer interaction evaluation methods (Wanderley and Orio 2002) and those designed for digital musical instrument analysis (O'Modhrain 2011). These will cover both audience and performer perspectives, and range from qualitative studies, such as discourse analysis (Stowell, Plumbley, and Bryan-Kinns 2008) and heuristic evaluation methods (Nielsen 1994), to more quantitative methods, such as using reproductive musical tasks to compare the accuracy of a user's performance over time (Hunt and Kirk 2000).

## Contributions

The contributions this doctoral research intends to make includes a framework of mapping methods to be used in free-hand gestural digital musical instruments, as well as a series of rules and strategies for designing new mappings, influenced by what can be learnt from gestural languages. It also seeks to contribute further developments in the field of gestural recognition algorithms, as well as a new in depth analysis method for evaluating free-hand gestural digital musical instruments.

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# A Theatre Wind Machine as Interactive Sounding Object

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**Abstract.** This paper introduces the sounding objects used for producing late nineteenth and early twentieth century theatre sound effects as a potential resource for Sonic Interaction Design (SID). A specific example (a wind machine) is constructed and analysed as an interactive sounding object, before being fitted with a sensor system in order to control a physical modelling synthesis version of the same in software (the Sound Designer's Toolkit (SDT) in MaxMSP). The methodology used to recreate the sound-action coupling of the original acoustic device as a software/controller system is detailed, along with suggestions for further work. A demonstration of the in-progress software wind machine will also be given as part of this paper presentation.

**Keywords:** Sonic Interaction Design, sound-action couplings, everyday sounds, The Acoustic and the Digital, Interface Design Processes

## Introduction: Sound and Action

This work expands on previous research into the contribution the theatre space can make to the field of Sonic Interaction Design (Pauletto et al. 2009) through an exploration of the historical technique of theatre sound effects design and performance in the late nineteenth and early twentieth century. It is proposed that the methodology behind the design and performance of sound with acoustic materials is a potential resource for the field of Sonic Interaction Design (SID). Sonic Interaction Design (SID) is an interdisciplinary design approach that focuses on how sound can be used to give meaning to our interactions with electronic devices or digital systems, by giving information, guiding behaviour, or influencing how a user feels about a certain object. SID research falls within a diverse range of emerging disciplines and approaches researching tactile, performative and multisensory aspects of sonic experience (Franinović and Serafin 2013, vii). These approaches all aim to capitalise on everyday human perceptual experience in order to design more fluid and intuitive encounters with digital technologies (Dourish 2001, 99).

The relationship between sound and action has been highlighted as an important field of study when investigating the potential of sonic interactions (Hug 2008, 15). Analysing the actions inherent in the use of everyday objects (e.g. mechanical kitchen tools) has already proven to be a useful resource for composing experiences linking the sonic, tactile and kinaesthetic together (Franinović 2009). Similarly, the manipulation of everyday objects as part of the sound design process for film, the art of Foley (Ament 2009), allows sound designers to develop a tacit knowledge of the sonic possibilities of materials and the actions needed to exploit these. Franinović (2013, 20) has already suggested that the tacit knowledge accumulated by Foley practitioners is an invaluable resource for SID work, and it has not yet been fully explored by designers.

Research into the design of digital musical instruments (DMIs) has also explored the connections between sounds and actions. Designers and musicians have proposed several strategies to resolve these issues and introduce a more 'real-world' sensory experience and real possibilities for articulation to the digital musician. These include the introduction of constraints (Magnusson 2010), augmentation with haptic technology to provide tactual feedback (Hayes 2013), and the development of new strategies for mapping control signals to the software system in a more complex and meaningful way to create a perceived difficulty in playing (Hunt and Kirk 2000). Some DMI designs have also explored methods relevant to the performance of theatre sound effects, including the use of tangible acoustic materials (Crevoisier and Polotti 2005), mechanical systems (Sinyor and Wanderley (2005), and Shone (2008)), constraining movement (Ward and Torre 2014), increasing effort (Bennett et al. 2007) and creating simple single-gesture interfaces (Weinberg and Gan 2001).

Sounds produced for theatre in the late nineteenth and early twentieth century predate the audio recording technology that developed alongside Foley techniques, and as such were created with specific devices and object arrangements designed for performance. They therefore offer a unique opportunity to investigate sound-action couplings and tactile/sonic feedback. Unlike musical instruments, theatre sound effects are operated with very simple gestures, but produce reliable sonic feedback in the form of "everyday sounds" (Gaver 1993, 24). They offer a natural sound-action "coupling" to the operator rather than a "relationship" designed through digital means (Jensenius 2007, 29). This offers a unique opportunity to test and challenge a sound-action coupling without focusing on a musical instrument and participants with musical ability.

Serafin and de Götzen (2009) have already undertaken some research in this area with Luigi Russolo's intonarumori family, a series of mechanical noise intoners produced for Futurist noise performances in the early twentieth century[1] (Brown 1981). Through an analysis of the soundmaking elements of Russolo's noise intoners (Serafin and Nordahl 2005), and their operation in performance, a replica of the device as a user interface (controlling a digital synthesis engine) was built. This represents an enactive recreation of the workings of the original instrument (Serafin and De Götzen 2009). This work also aims to extend Serafin and de Götzen's research to the area of historical theatre sound, with an analysis of the operation and soundmaking capabilities of various sounding objects undertaken to produce software and hardware replicas in order to fully investigate their enactive properties.

As such, this research began with the collation and categorization of various designs and descriptions of late nineteenth and early twentieth century theatre sound effects in an effort to understand more about the way each method links human action with a resulting sound. This provided a useful overview of the design methodology as a whole. However, in order to fully understand the affordances of these sounding objects and the multisensory experience they offer an operator in performance, it is necessary to go beyond textual sources. Remaking has already been proposed as a way to investigate the tacit knowledge involved in the creation of historical objects and technologies (Elliott, MacDougall, and Turkel 2012, 124). This is a particularly useful method when investigating a sensory history, enabling sounds to be heard and materials to be touched and manipulated.

## The Acoustic Wind Machine as Interactive Sounding Object

A wind machine was chosen as the focus for an initial investigation into the process of remaking a historical design and adapting it to create an interactive sounding object with sensors and software. A wind machine consists of a cylindrical slatted structure rotated on a central axle, rubbing against a piece of cloth as it is turned. The friction of the wood against the cloth produces the sound of wind. It was chosen for several reasons:

1. It couples a simple continuous gesture (rotation) to a continuous sound (friction of wood on cloth), rather than a gesture of shorter duration to a shorter sound like an impact. This allows for the study of a more subtle control gesture linked to a continuously varying sound.
2. The rotational control offers a familiar control metaphor to users of audio control surfaces for musical performance, that of a continuous rotary encoder (digital potentiometer). The gesture involves the whole hand turning a crank handle rather than fingers and thumb turning a small dial, and so requires more effort on the part of the operator. This may lead to a more interesting and effortful sounding object design for sound performance in a theatre setting.
3. The wind machine can be rotated while silent by separating its cloth from the wooden cylinder, allowing the same wooden structure to be used as the basis for a digital controller. This preserves the same gestural shape,

[1] The core design of Russolo's 'noise intoner' consisted of a crank mechanism and rotator, which turned against a catgut string threaded through a drumskin. The mechanism was housed in a large wooden box resonator, complete with a metal cone flared around the drumhead (Russolo, 1986, p.12). The key sound-producing element of the intonarumori family is in fact a 'bull-roarer,' in use as a theatre sound effect from Elizabethan times. This device did not use a rotator, but the catgut string was manipulated by hand with a rosined cloth.

which will facilitate accurate data mapping and sound parameter evaluation when designing a sound synthesis model, which will replace the sound produced by the cloth.

4. The rotation gesture is also responsible for some other 'machine' effect designs, and so can be adapted to control other sound models as required – crashes (ratchet or impacts of masonry) or rain, for example.

This method of creating a wind sound appears in several historical manuals, each version slightly adjusted or refined according to the observations of the individual practitioner. This continual process of adaptation means that there is therefore no single version of a wind machine, but many implementations of the design. Rather than attempt to faithfully reproduce a particular historical example of a wind machine design, which might fail due to incomplete information, four particular versions (by Moynet (1976, 135), Browne (1913, 50), Leverton (1936, 50) and Napier (1936, 51)) were chosen to inform a new sketch for a wind machine based on a synthesis of their observations and implementations.

The wind machine example built for this research is challenging to operate for long periods of time, as it enforces a static position on the operator and requires a repetitive rotation movement to produce sound (going against ergonomic principles to some extent – see Nielsen et al. (2004)). The operator does have some choice over the way they grasp the crank handle, which allows for a neutral or supine grasp (Saffer 2008, 36). From initial observations of my own interactions with this wind machine, the following conclusions can be drawn about it as an interactive sounding object:

1. The crank handle control is highly discoverable (Norman 2013) and offers an obvious affordance to the beginner.
2. The rotation action, while repetitive, nevertheless can produce a continuous variation in the wind sound. This is accomplished by subtly shifting the speed of rotation during play.
3. The wind machine, when heard as recorded audio, produces a very convincing wind sound. This can sound repetitive and 'machine-like' if the operator has not managed to vary the speed of the crank handle during play.

In order to re-create the acoustic wind machine in software, an entity-action model was first produced to deconstruct its stages of sound production (Farnell 2010, 36). The workings of the acoustic wind machine could then be detailed as follows:

1. It translates a composed gesture of embracing pressure (hold handle) and rotation (turn handle) into the continuous friction of a wooden slatted cylinder against a tensioned rough hemp cloth.
2. This gesture is directly coupled to the resulting sound, which rises in pitch as the speed of rotation increases.
3. As the gesture slows to a stop, so the pitch of the wind machine decreases and stops.
4. At higher speeds, the rotation of the handle creates some momentum, so with an increase in speed the handle becomes easier to rotate.

While at first glance the sound appears to be produced by two objects causing friction when in contact (one cloth, one cylinder), the sound is in fact produced by a number of individual slats in contact with the cloth at once. In the case of this particular wind machine, seven slats touch the cloth at any one time. As the central cylinder rotates, each slat in turn rubs the cloth at its own particular pressure level depending on where it is situated. Rather than one cause of sound (one rubbing cylinder), there are in fact twelve 'rubbers' (slats) on the cloth, with seven of those active at once.

## A Digital Interactive Wind Machine

To recreate the acoustic wind machine as a digital interactive sounding object, a 10-DOF IMU sensor (Townsend 2013) was first installed at its axle to capture the speed of rotation as data. These kinds of sensor have already been used in Digital Musical Instrument (DMI) applications to create a controller based on rotational movement for digital sound production (Sinyor and Wanderley 2005). The data was extracted with an Arduino prototyping board, and to ensure that this setup would not impede the normal operation of the wind machine, a wireless XBee shield (Sparkfun 2015), was configured to transmit to a computer running Cycling 74's MaxMSP software without any cabling.

The Sound Designer's Toolkit (SDT) (Monache, Polotti, and Rocchesso 2010) was used to create a physical model of the wind machine. The SDT suite of MaxMSP objects mathematically model various interactions between two objects in contact, offering algorithms for both impacts and friction. Control data can be used to vary the properties of each object, as well as the nature of their contact (Delle Monache et al. 2007, 5). A sound model of the wind machine was implemented in MaxMSP using a configuration of the friction objects *sdt.friction~* and *sdt.scraping~*. Twelve instances of this model were created, each representing one wooden slat of the cylinder.

A single stream of gyroscope data from the IMU was then mapped to control the twelve digital 'slats' at once. The mapping strategy centred around the creation of a geometric model of the circular side of the wind machine, with each slat representing a 'particle' rotating around it. This was achieved by tracking the speed of the top slat of the wind machine in a 360° rotation from its origin, and positioning the other slats relative to this by placing them out of phase with the main data stream.

By giving a distinct degree value for each slat, their irregular placement around the wooden circle was transferred to the software. It was calculated that each slat would be silent in the lower section of the circle, which never makes contact with the cloth during operation. This range of values was used to trigger an *adsr~* envelope to silence each slat as it passed through this area.

## Evaluation and Future Work

The acoustic wind machine and its software counterpart were simultaneously recorded in performance, allowing an initial analysis to be undertaken.

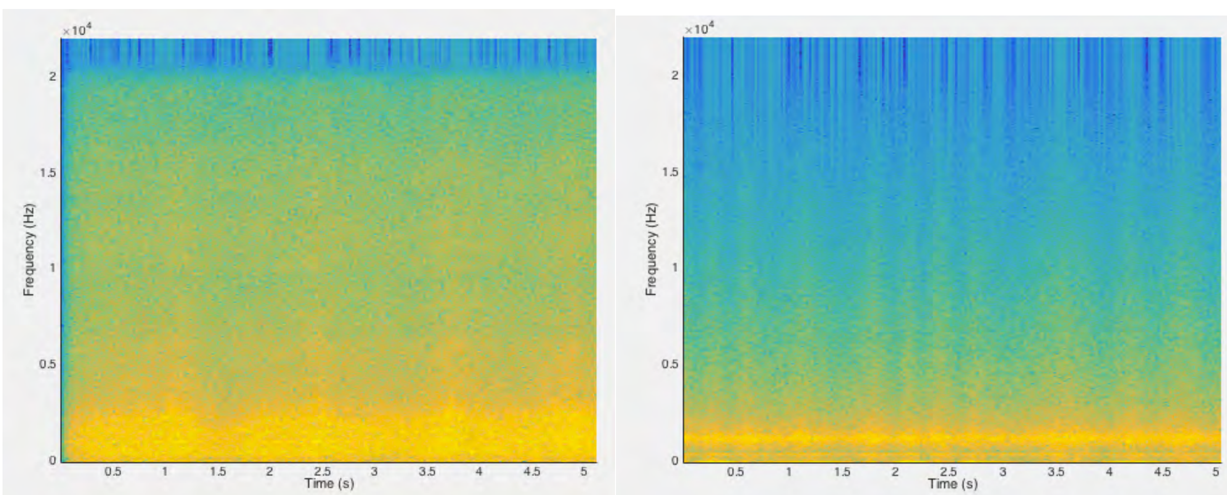


Figure 1. A spectrogram in Matlab of the acoustic wind machine (left) and its digital counterpart (right) during the same 5 seconds of performance.

Following a comparison of the two, it is clear that the rhythmic and repetitive elements of the wind machine's motion have transferred quite well to its digital version, but further adjustments are required. Work is currently ongoing to refine the digital synthesis engine, using its acoustic counterpart to help with calibration. For example, high frequencies generated by the acoustic wind machine are closely linked to its acceleration; so careful mapping of the accelerometer data to the sound model should introduce the same relationship and improve its resulting sound. Further parameters to *sdt.friction~* and *sdt.scraping~* will be examined as necessary.

Once the synthesis engine has improved, a more formal study will be undertaken to document and evaluate users' experiences of operating the acoustic and software wind machines, as well as a listening experiment to evaluate recordings of the acoustic wind machine, synthesised wind machine, and natural wind.

Work will also be undertaken to investigate how a gesture of rotation can be facilitated through an interactive sounding object. This will initially involve the testing of HUI devices as controllers for the synthesised wind machine, in order to examine how different data streams can be mapped to the geometric circle model, what material resistances offer the most comparable experience to that of the acoustic wind machine's crank handle, and how effective a gesture of rotation is when controlling continuous sounds. This could potentially culminate in a further study of a HUI or adapted HUI controller in use as a wind machine interface.

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# FoxDot
# Live Coding with Python and SuperCollider

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**Abstract.** Live Coding is an electronic musical movement that is growing in popularity as an interface for musical expression where laptop performers program in front audiences; executing, editing, and re-executing blocks of code to generate music. The languages used in Live Coding are usually designed specifically for the purpose of creating music and distance themselves from the traditional paradigms of more general-purpose languages such as Java or Python. FoxDot is an application that bridges this gap to bring the art of performance programming and the science of software engineering together to create music in a way that is accessible to coders or composers; novices and experts alike.

**Keywords:** Live coding, laptop performance, interactive programming.

## Introduction

When I first encountered Live Coding, a method of using programming languages to make music, I had just begun a Master of Arts degree in Computer Music at the University of Leeds. It wasn't long after I had completed my bachelor's in Computer Science and I considered myself a good programmer and, having played music outside of academia for most of my life, a novice in musical composition. However, my first encounter with SuperCollider (McCartney 2002) made me feel like I couldn't do either of these things. Over the course of my master's I was fortunate enough to be taught by Alex McLean, of Live Coding acts Canute (McLean 2015) and Slub (Collins et al. 2003), and starting scouring the web for anything Live Coding related. It didn't take long before I was getting to grips with Tidal (McLean 2014) and SuperCollider, among other languages, but I still couldn't express the musical ideas I wanted to with their capabilities. Furthermore, Live Coding languages tend to be domain-specific (or at least domain-specific implementations of more general-purpose languages) (Guzdial 2014) and structured in a way that didn't fit with the Object-Orientated Programming (OOP) paradigm I had become accustomed to during my undergraduate studies. For example, Tidal is embedded in the language Haskell, which utilises a functional programming paradigm, and the Ruby-based Live Coding language, SonicPi (Aaron and Blackwell 2013), uses a form of procedural programming. OOP is used to represent complex and real-world systems (Kindler and Krivy 2011) and I argue that music making can be as complex as any system found in the real world.

With FoxDot I wanted to create an application that bridged the gap between software engineering and Live Coding so that users who were entry level to programming, composition, or both would still be able to grasp the concepts and make music, while being able to apply the theory to both fields. This article begins by outlining the goals that I wanted to achieve and the purpose for creating FoxDot, and its Interactive Development Editor (IDE), before discussing the implementation of key features and their syntax. It is then concluded with a short discussion about possible future directions for this work.

## Design

Before development could begin the technical requirements for the project were outlined; the system should:

- Create music-playing objects that have a state that changes over time (i.e. the note being played) and this state can be accessed by any other object at any point

- Make use of time-dependent variables that, when accessed, return a specific value depending on the time in a metronome
- Utilise a global and dynamic variable system: an object's default values should be accessible via the alteration of a global variable e.g. changing a default scale variable should update all objects using that scale
- Be written in, and derive its syntax from, an existing high-level language that has a large user community and in-depth documentation but also inherit common syntax from other Live Coding languages

# Development

## Choice of Language

Of the three most popular programming languages in the world (Java, Python, and PHP)[1], Python (http://python.org) is the language that fits the FoxDot requirements best. The rationale for choosing Python for a Live Coding environment is that the combination of its heavy use of OOP and class customisation allows for a flexible design model, and its focus on code readability makes it ideal for use in a performance context.

Alongside Python, SuperCollider will be used to synthesise sounds using Open Sound Control (OSC) (Wright, Freed, and others 1997) in a similar vein to the live coding language "ixilang" (Magnusson 2011). While "ixilang" has a similar implementation design to FoxDot, it is written in the programming language used to write SuperCollider, SCLang, and does not have the established popularity and support that is offered by a language like Python. Another language, SuperDirt (Rohrhuber 2016), is currently being developed that acts as interface between Tidal and SuperCollider, but it is still in an early and experimental phase of development and, as mentioned earlier, does not adhere to the OOP paradigm that is central to the principles of FoxDot.

## Interface

FoxDot uses a custom IDE written in its base language, Python, that can execute the 'block' of code (consecutive lines of text with no empty lines) that the text cursor is in by pressing 'Ctrl+Return'. It shares many similarities to the interactive interpreter that comes packaged with the standard installation of Python but allows for the user to easily edit and re-execute code instead of executing each line as it is typed in. The editor also features a console output that displays the Python code executed and any printed output from it, allowing users to program in Python in a much more interactive way than previously available.

## Player Objects

In FoxDot, music is performed by creating Player Objects (POs) that take several keyword arguments. Instead of defining a new PO for each sound the user wants to create we define one main class that takes a SuperCollider SynthDef as an argument and sends OSC messages to SuperCollider to create a sound. The first argument is a string that refers to the name of the SuperCollider SynthDef to be used and the second argument is the degree (the index of the note of the scale, which is 0 by default). The duration of each note can also be specified and this value is used in the scheduling process (see TempoClock for more information). Other keywords can be specified that correlate to the keyword arguments used in the specified SynthDef. To create a PO that uses a SynthDef named "pads" that plays the first 8 notes of the default scale using 1/2 beats, the following syntax can be used:

```
p >> pads(range(8), dur=1/2)
p = Player('pads', range(8), dur=1/2)
```

[1] Source: http://pypl.github.io/PYPL.html, Accessed: 13-02-16

These lines are equivalent but the first line has a much cleaner syntax and implies that “pads” is a Python object itself when, in reality, it is not. FoxDot examines each block of code before it is executed and detects when special FoxDot syntax is used (the >> assignment syntax in this case). When creating a PO, the first argument is always the degree(s) of the PO’s scale (a globally defined default scale is used unless specified with a keyword argument), which is followed by keyword arguments such as note length (’dur’) or sustain (’sus’). Player Objects can play simultaneous notes (useful if you want to play chords, for example) by grouping multiple degree values using a tuple by enclosing values in round brackets ‘()’. For example:

```
p >> pads([0,2,4,(0,2,4)])
```

This snippet of code creates a new PO that plays the first, third, and fifth note of the scale[2] and then all three of these notes simultaneously. FoxDot automatically laces any nested lists in Player Objects such that the nested list [[0,1,2,3],7] would be equivalent to the list [0,7,1,7,2,7,3,7].

A special PO, known as a SamplePlayer Object (SPO), can be used to play back samples and is created using a $ sign and a string of characters (in a similar syntax to Tidal). The following line of code plays a kick drum (’x’), closed hi-hat (’-’), snare drum (’o’), and another closed hi-hat and repeats:

```
beat $ “x-o-"
```

Each character in the string is mapped to a buffer id used in SuperCollider to play using a SynthDef called “sample_player” and represents one 1/2 beat. A character’s duration can be halved by putting them in square brackets. Round brackets are used to lace patterns, similar to nested lists in regular POs, such that the following two lines of code are equivalent:

```
beat $ “x-o-[xx]-o(-[-o])"
beat $ “x-o-[xx]-o-x-o-[xx]-o[-o]"
```

POs are designed to be flexible and accessible. Two POs can be connected by using a PO’s “follow()” method, taking another PO as an argument. Attributes, such as the panning or the durations of a PO, are not altered by following a different PO, but when it comes to calculating the note value to send to SuperCollider, note data is retrieved from the source PO and a different frequency is calculated instead. Basic algorithmic composition can be done by using traditional mathematical operators in combination with POs. Adding or subtracting a list of numbers creates a PO expression and modifies its note degree by the value in the list at the index of the current event. A simple way to demonstrate this is with the example below where the PO ’p’ will play the same note as ’b’ but every third note will be a fifth higher, even when the degree of ’b’ is changed.

```
b >> bass([0,2,5,3], dur=1, sus=1/2).stutter(4)
p >> pads(dur=1/4).follow(b) + [0,0,4]
```

## TempoClock

A dedicated time-keeping object, known as a TempoClock, is instantiated at runtime that contains an empty queue. POs are added to this queue with a corresponding time value that denotes when they should next be played. The TempoClock plays the PO’s next note by calling them as if they were a programmatic function, which means any Python function can also be scheduled to be executed in the future. By default these are scheduled at the start of the next bar as calculated by the TempoClock’s time signature attribute.

[2] Python, like most programming languages, used zero-based numbering for its arrays whereas musical scales use a one-based numbering system. Consequently, the 1st, 3rd, and 5th notes of a scale are accessed with the indices 0, 2, and 4, respectively.

While running, the clock continually increments its internal counter at the rate of its specified beats-per-minute (BPM). Once this counter is equal to the scheduled time of the first item in its queue, them item is ’popped’ from the queue and then called. If the item is a PO, it creates an OSC message based on its current state and sends it to SuperCollider to generate a sound before re-scheduling itself into the TempoClock’s queue again. This means notes can be any duration and complex polyrhythms can be created easily by scheduling multiple POs with uneven durations. The code snippet below shows two POs playing the same note but player ’a’ plays it three times over the course of two beats and player ’b’ plays it four times:

```
a >> pads(dur=2/3)
b >> pads(dur=1/2)
```

## Scale Objects

Without the use of the keyword argument “scale” POs use a default scale found in the Scale module (accessed as “Scale.default” from the FoxDot IDE). At start-up it is set to the major scale but can be changed easily (see below). When Scale.default is updated, any Player Object that is using it is also updated (which makes for incredibly easy key changes etc.). The default scale can be changed in a number of ways and can include floating point numbers (as seen in “Scale.justMajor” for example). The following lines of code are equivalent to each other and set the default scale to the natural minor:

```
Scale.default('minor')
Scale.default(Scale.minor)
Scale.default([0,2,3,5,7,8,10])
```

Accessing an element in an array (referred to as lists in Python) is usually done by specifying the index of the item you want to retrieve as a whole integer. FoxDot Scale objects can take floating point values when being accessed in order to return a value between two elements in a Scale. For example; when a Scale object is defined as S=[0,2,4], then S[1.5] will return the midpoint value of the numbers at indices 1 and 2 (in this case, 3). This means that values used for a PO’s degree attribute can be floating point numbers and emulate micro-tonal systems quickly and easily.

## Time-Dependent Variables

A time dependent variable (it will be referred to as a ‘Var’ from here on in) is a variable that, when accessed by a PO or user, returns a value derived from the current state of the global TempoClock. These variables are created using the following syntax:

```
a = Var([0,3,4],[8,4,4])
```

The Var above, ’a’, returns the values 0 for 8 beats, then 3 for 4 beats, and finally 4 for 4 beats before starting over. This can be very useful for creating multiple Player Objects that share the same underlying music based on chord sequences, like so:

```
a = Var([0,4,5,3],8)
p >> pads(a, dur=1).offbeat() + (0,2,4)
b >> bass(a, dur=1/4, sus=1)
```

Calling the update method on a Var will change the values for all POs that are accessing it, which means patterns can be shared very easily between POs. Vars can be used for any keyword argument, e.g. setting a PO’s amplitude to be loud for 8 beats and then silent for 24, and used in PO expressions. Figure 1 is the passage of music equivalent to what would be produced on repeat with three simple lines of code such that both players are following the common chord sequence I V VI IV with ’p’ oscillating around the fifth and third notes of the chord, and ’v’ playing sustained notes with alternating harmonies.

```
a = Var([0,4,5,3],4)
p >> pads(a + var([4,[2,0],1] [2,1,1]), dur=[1/2,1/4,1/4]) + [0,[-1,1]]
v >> viola(a, dur=4) + (0,var([[9,2],4],4))
```

Figure 1: Nominal score representation of output from FoxDot code

## When Statements

A common component of any programming language are conditional statements (commonly known as "if" statements), which execute a block of code only if a certain condition is satisfied. FoxDot implements a "when" statement that evaluates this condition at regular points in the TempoClock's cycle and executes any code assigned to that condition when it is evaluated to be true. Some useful applications of this feature include allowing POs to change their state based on the state of other POs over time, and changing multiple POs' states based on a variable that may, or may not, be affected by POs. Below is an example of an implementation of two 'parts' of a piece of music that can be alternated by changing the value of the variable 'val' to 0 or 1:

```
val = 0
a = Var()
when val == 0:
    a.update([0,-3,-4],[4,4,8])
    p >> pads([0,2,4], dur=[1/2,1/4,1/4])
    b >> bass(a, dur=[1.5,0.5,2], sus=0.5) + Var([0,2],4)
else:
    a.update([7,4,5,3],4)
    p >> pads(a, dur=[1.5,1.5,1], sus=2) + var([2,4],4)
    b >> bass(a, dur=1/4, sus=1) + [0,0,(0,9)]
```

# Further Work

## Expanding Content

The basic concepts and functionality for FoxDot have already been programmed but there is still a lot of work to be done. The library of samples is very small and needs to be expanded to incorporate more "interesting" sounds in addition to those of a basic drum kit. FoxDot currently comes with a SuperCollider .scd file that contains several SynthDefs already written but, like the sample library, needs to be expanded. FoxDot is designed to be flexible and customisable; both the collections of samples and SynthDefs should be accessible by the user and changeable at their choosing through the use of an easily edited configuration file. Similarly, the types of musical patterns available to the user will also be expanded upon, drawing inspiration from existing definitions (Spiegel 1981).

## User Testing

FoxDot is currently in its alpha stage of development and it will be quite some time before a stable release version exists, but between now and that time the collection of user feedback would be useful for adding ideas to, and furthering the development of, FoxDot. If you would like try FoxDot for yourself, the most up-to-date version is available at https://github.com/Qirky/FoxDot and any feedback will be more than welcome.

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# Interfacing with questions: The unpredictability of live queries in the work of 'Thousand Questions'

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**Abstract.** This article discusses an artistic project entitled *If I wrote you a love letter would you write back (and thousands of other questions)*: a piece of software that utilizes Twitter web API to query questions, drawing unpredictable questions in real-time from the distributed database of Twitter. It undergoes the process of data query and manipulation: requesting data and receiving responses in a standardized format through mathematical operators. This article discusses the role of operators in which they constitute the unpredictability of queries. By understanding the operational and cultural logic of live queries, the article explores the live and unpredictable processes of query execution.

**Keywords:** queries, API, unpredictability, operators

## Introduction

*Loveletters* (1952), allegedly the first digital literary artwork was built using the Ferranti Mark I computer by Christopher Strachey at the University of Manchester. It is a computer program that employed Alan Turing's early developed algorithm for generating random numbers. Together with random choices of sentences structures, the love letters were generated through a combination of grammatical rules[1] that included adjectives, nouns, adverbs and verbs. The resulting love letter, as Noah Wardrip-Fruin argues (2011, 306), is an unpredictable manifestation of two hidden elements: data and processes. Wardrip-Fruin is not interested in the resulted letters as semiotic and poetic representations, but is more focused on the generative processes (ibid., 306). This article examines the notion of unpredictability inherent in examples such as this. It takes its cue from how Wardrip-Fruin analyzes computational processes that move beyond the meaning of their representational output. My collaborative artistic project *If I wrote you a love letter would you write back (and thousand of other questions)*[2] (from hereon referred to as *Thousand Questions*) is inspired by the multiple variations generated through the application of simple rules. Instead of generating love letters, the work *Thousand Questions* takes 'questions' from the Internet as text and 'voices' them.

## Query in Thousand Questions

*Thousand Questions* drew thousands of questions based on the key symbol —a question mark—from the Twitter network, translating questions in text form to speech. The project employs query, following the standard and official Twitter API[3] format (using 'REST Search API') that offers programmable access to search and extract Twitter data.

[1]Noah Wardrip-Fruin draws reference from Strachey's work to indicate the grammar logic as: "My—(adj.)—(noun)—(adv.)—(verb) your—(adj.)—(noun)" (Wardrip-Fruin, 2011, 309).
[2] The project was developed in 2012 by Winnie Soon and Helen Pritchard, see the artwork's documentation: http://siusoon.net/home/?p=900
[3] See: https://dev.twitter.com/rest/reference/get/search/tweets

Query is most commonly understood as a language. Structured Query Language (SQL) is one of the most popular query languages. For mainstream relational databases, such as Oracle and MySQL, SQL is used to communicate with a database. SQL can be executed, meaning that it provides instructions for storing, querying, and manipulating data. Ashok K. Chandra and David Harel define this: “[a] query language is a well-defined linguistic tool, the expressions of which correspond to requests one might want to make a data base. With each request, or query, there is associated a response, or answer” (1980, 156). Therefore, the execution of a query is a two-way communication, both a request and a response.

The use of the term *live queries* in this article does not focus on any database models or their technical structures behind. Live queries include all kinds of ways that inquire data from a database / structured document through a technological and distributed network. It is a structured format, allowing data exchange between sites, platforms and applications in real-time. Data can be specifically selected, filtered, generated, sent and collected from an enormous databank that is operated continuously and across continents. Taking Twitter as an example, it uses a relational database such as MySQL and gradually moves to a NoSQL database, such as Cassandra and Gizzard, because NoSQL can handle massive data and support better for a time-critical query (Metz 2014). Technically speaking, a query can interface with a relational database system or NoSQL database system.

Running a web Application Programming Interface (API) is regarded as one of the query forms. It is widely understood that a web API is an interface. It is a technical standard and specification that is used for communication between applications or programs (Cramer & Fuller, 2008). In my project, *Thousand Questions* for instance, the use of Twitter API is an interface between the artwork and the Twitter platform.

With the “rising values of APIs” and with many big and small companies providing APIs that extract value out of the available data, it is claimed that offering an API creates “new business opportunities”, enhances “existing products, systems, and operations”, and develops “innovative business models” (Mason & Mckendrick 2015). In parallel, the critiques of APIs in journal articles have been increasing seen in academia. For example, together with Carolin Gerllitz, Anne Helmond analyzes the “likes economy” in Facebook via their Facebook API (2013). Helmond, in another publication, argues that the politics of data flows in web platforms have been transformed from open standards to proprietary APIs (2015, 22). Likewise, Taina Bucher suggests that APIs exhibit control and freedom through her examination of the Twitter API (2012, 2013). In additional to the widely available web APIs mentioned so far, David Berry discusses how the use of specialized and private APIs expose some of the relations between companies like Microsoft and the political economy of software development (2011, 70-1). An investigation of these APIs suggests that they exist “as data sources and as objects of study that can be historicized, analyzed, critique, etc.” (Helmond 2012, n.p). In other words, studying API queries enables a better understanding of different platforms and the politics of data circulation associated with contemporary computational culture.

By using the Twitter API, *Thousand Questions* was written with various criteria and conditions of data extraction as part of the larger query request. This includes content search that comprises of a question mark (?) and where tweets must be in English language. In addition, the returned query output only incudes 50 results (tweets) per request and they are regarded as ‘recent tweets’ by the program. A query statement, like this, consists of multiple parameters.

For the latest development of *Thousand Questions* (2016), the newly added visual component includes the returned questions and a screen displays only one character per frame until all the remaining characters are shown (See Figure 1). Using Apple’s text to speech feature, an Australian woman’s voice is heard, speaking all 50 tweets one after the other. The program repeatedly poses questions, alongside other parameters, to Twitter’s social media platform once the artwork finishes displaying and speaking all the pending tweets. Therefore, the experience of such live queries results from interactions between different machines[4] - an ongoing request and response that is both operational, cultural and social. The work makes apparent query processing by showing the latency and the temporal aspect of getting questioned tweets and speaking unanswered questions through an audio-visual experience. The project is meant to be

[4] The use of machines here refers to the machine that runs *Thousand Questions,* Twitter’s machines, and also those social machines that in contact with the Twitter platform.

an endless process of query processing, in which temporality is expressed through the display of the underscore symbol (_), indicating the waiting of the program for the next query execution. This experience of waiting is unpredictable in two dimensions: indicating both the time of query processing and the content of “unanswered queries” (ELC3 2016).


Figure 1. A screen grab of the visual part of *Thousand Questions*

## Mathematical operators

The unpredictability of query can be examined through computer execution: what it does and means when a query is being executed? My analysis here is oriented towards a more systemic and materialist approach to understand the operational aspect of how queries interact with the Twitter platform using the example of *Thousand Questions*.

At the material level, a query employs set-like operations to link or to group data together. In this way, the query is about bringing their relation to the fore. I discuss how data bring things into relation using the case of live queries in *Thousand Questions*. The operation is mainly focused on data selection and retrieval, but not on data update or deletion through code. Such operations and relations are necessary to understand how data is returned differently, and hence further unfolding the unpredictability of data relations through live queries.

A query is based on various mathematical operators that specify a request. Figure 2 to Figure 5 show the requested query (from *Thousand Questions* to Twitter) and the excerpt of the returned query (from Twitter to *Thousand Questions*) that was executed on March 16, 2016 at 10.45 a.m. In addition, Figure 4 to Figure 5 show the two queries that had erased the semantic aspect of data so as to emphasize the operators that are involved in query execution.

To explain, most of the frequent operators found are ‘=’, ‘+’ and ‘-‘, with the occasional operator ‘&’ in the returned query. The ‘=’ operator refers to the list of specified words that are used to construct the query. In Figure 2, the list is more than just a question mark (this is indicated as %3F – the URL encoding character[5]), but a combination of words and characters that request Twitter to filter specific words and characters out[6] from its database search. ‘-RT’ indicates the removal of retweets. In other words, the mathematical operators play an important role to make inclusion and exclusion of data, identifying what data should be grouped together or otherwise. By having the mandatory parameter of ‘query’ or ‘q’ (as indicated in Figure 2-3) and the ‘=’ operator, parameters, operators and list of values (the words and characters) constitute an instruction to Twitter: the list of words and characters belong to the ‘query’ parameter.

[5] See: https://en.wikipedia.org/wiki/Percent-encoding
[6] The blurred parts of Figure 3 and 4 are the words about racial slurs, incitements of racism and sexual violence. In the work of *Thousand Questions*, we have filtered out a list of these words.

Additionally, by having the '+' and '-' operators, complexity increases by adding more than one word or characters for data processing. The operator '+' refers to adding different words while the operator '-' refers to removing certain words. The two seem to contradict each other but function quite differently. The operator '+' is also used to separate different words, while the operator '-' is used instead to signal the function of removal such that Twitter knows what are the words that it has to pay attention. These are all complying with the query operators that are specified in the Twitter specification[7]. To put simply, a query, such as '?+hello+-world' means to search for tweets with a question mark and the word 'hello', but remove the word 'world'. The query parameter and the corresponding values are fixed, meaning that the query is executed with the same requirement and request logic every time. Although the condition is the same, the result of the query execution events is unpredictable- results are different and are subjected to what data is available at both the current moment and over the past seven days[8].

```
Query{query=%3F+-      +-      +-       +-     +-    +-   +-       +-    +-     +-       +-RT+-%40',
lang='en', locale='null', maxId=-1, count=50, since='null', sinceId=-1, geocode='null',
until='null', resultType='Query.RECENT', nextPageQuery='null'}
```

Figure 2. A requested query in *Thousand Questions*

```
QueryResultJSONImpl{sinceId=0, maxId=710038706049122304, refreshUrl='?
since_id=710038706049122304&q=%3F+-      +-      +-       +-     +-    +-    +-       +-    +-     +-
        +-RT+-%40&lang=en&result_type=Query.RECENT&include_entities=1', count=50, completedIn=0.07,
query='? -       -       -       -      -    -    -       -     -      -        -RT -@' …}
```

Figure 3. An excerpt of the returned query in *Thousand Questions*

```
Query{      =   +-      +-      +-       +-     +-    +-   +-       +-    +-     +-       +-   +-    ',
='   ',        ='      ',       = ,       = ,        ='      ',        = ,         ='     ',       ='      ',
='                 ',                 ='     '}
```

Figure 4 The erasure of the data content of the requested query in Figure 1

```
QueryResultJSONImpl{          = ,       =                    ,          ='          =
& =   +-     +-     +-      +-    +-    +-    +-       +-    +-     +-        +-  +-    &     =  &
=              &               = ',      = ,                 =     ,      ='  -       -       -       -
-    -    -        -    -      -         -   - ' …}
```

Figure 5. The erasure of the data content of the returned query in Figure 2

There are other logics that also constitute the indexing algorithm and sorting of Twitter's database. Although Twitter does not publish this information or its implementation logic, it is important because the operators contribute to the relation and grouping of data for almost every logic. For example, the previously mentioned condition – the past seven days of the recent tweet, the 'day' criteria is part of the algorithmic logic that filters out which data is stored beyond seven days. To implement 'the past seven days', the machine has no idea what the past seven days means logically and mathematically unless an instruction states to subtract the current date. Such subtracted data defines the scope of the time, thereby the date parameter is within a specific range for query processing on Twitter. As such, other mathematical operators might also use specified criteria. A case in point is relational operators, including '==', '>', '<', '!=', '>=', '<=' that stand for "equality", "greater than", "less than", "inequality", "greater than or equal to", "less than or equal to", respectively. They are called relational operators[9] because there is always a relation—a comparison—between two entities (Meysenburg 2014, 44-5). By using different operators, the algorithm is able to act—exclude, specify and sort

[7] See https://dev.twitter.com/rest/public/search

[8] According to Twitter web API specification, Twitter will return current and the past seven days data by using REST API to search for specific data. See https://dev.twitter.com/rest/public/search.

[9] See https://en.wikipedia.org/wiki/Relational_operator

data—in a variety of ways, bringing the relation to the fore, and hence to directly impact what data to process. Therefore, live queries comprise of operators that act, in which a data relation is established through query execution. The combination of data and their relations are only specific to a particular query at a particular time. The next execution produces different data relationships due to the dynamics of the Twitter platform. The results of live queries thus are something that cannot repeatedly be generated.

Indeed, the logic of the ‘past seven days’ is just part of many other blackboxed criteria that remain unknown to the public. But for any criteria in a query, using different operators for data selection are inevitable. More importantly, same operators bring different data into relation for every query execution as in the case of *Thousand Questions*. While running the software, the same query is executed to fetch new data that matches the stated criteria. Thus, the output data is presented as just a snapshot of the Twitter database. Although the query parameters are fixed for every codeiteration, there is a “constant injection” of new data into the Twitter database that changes the system dynamics (Hayles 1990, 159-60).

N. Katherine Hayles observes that expansion of information is increasingly common in contemporary culture where information is interwoven with technologies and social landscapes (Hayles, 1990, xiii). By drawing upon Robert Shaw, Hayles discusses a chaotic model in which data is added from external inputs as “information”. In physical systems, such external inputs could be thought of heat – something that produces “random fluctuation” (ibid., 159-169). In live queries in Twitter, tweets can be understood as “random fluctuations” too, in which fluctuations/events exist at the “microscopic” level that leads to “macroscopic chaos” (ibid., 160). Adding up all the microscopic events—by “constant injection of new information”—into the macroscopic system, such amplifying fluctuations reconfigure the processing of data, resulting in the macroscopic chaos of output data, in which the “chaotic celebrates unpredictability, seeing it as a source of new information” (Hayles 1991, 8).

One of the important concepts about a chaotic system is scaling, yet retaining the same properties at all levels. Fractal geometry in mathematics, for example, demonstrates the complex relationship between microscopic parts and the whole, sharing the same algorithms that generate fractals. The “complex forms characterized by multiple or infinite levels of self-similarity” (Hayles 1990, 288). This scaling level demonstrates the incremental difference that “shifts the focus to complex irregular forms” (ibid., 210). Each level is inter-related that together shape the form.

Considering how live queries are conceived in terms of fractal geometry, each iteration of query execution shares the same deterministic properties. Operators bring data together by restricting and specifying criteria; hence, a new set of returned data would form a new relation. Such a new relation can be understood both from a system and cultural perspectives. Yet scaling in contemporary computational culture does not mean exactly the same as fractal geometry in physical science, but rather to expand and take into the consideration of the world on how it is represented at multiple scales. As Hayles too explains, the world “is rich in unpredictable evolutions, full of complex forms and turbulent flows, characterized by nonlinear relations between cause and effects, and fractured into multiple-length scales” (1999, 8). The temporal relation of data is the result of contemporary computational culture, which is dynamically changing and unpredictable. Such a temporal relation is derived from a set of deterministic operators that generate relations in both technical and cultural senses. Live queries are not only observed in artistic practices of course, but also in many daily situations, such as searching things on the Internet. The relation is temporal because every execution generates a different set of data from its database that is being updated and data is being stored, and that is subjected to the real-time and contemporary conditions. In physical science, fractal geometry for example, we understood the relationship between chaos and unpredictability where simple deterministic systems can possibly produce unpredictable results.

By drawing upon the notion of macroscopic chaos, I hereby further extend the notion of unpredictability by drawing attention to the agency of operators that produce unpredictable relations as output data. In summary, operators act upon, and beyond, a chaotic system that includes the process of specifying, sorting and excluding data. Furthermore, executing queries require the operators that bring data into a temporal relation that share similar fluctuations. I argue that query generates a temporal relation in the context of live queries execution. All the selected data meet certain pre-programmed criteria but brought together in a mutating relation that entails deterministic but also unpredictable matters for every query execution.

## Notes

The artwork *Thousand Questions* was a collaboration with Helen Pritchard. It was first exhibited as part of the Microwave International New Media Festival in Hong Kong (2012), as part of *Digital Futures*, at the Victoria and Albert Museum (2013), presented in the research workshop *Artistic Research* at Kunsthal Aarhus (2015), and most recently published in the Electronic Literature Collection, Vol. 3 (2016). The website of the work can be found at http://siusoon.net/home/?p=900.

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# Music-making for the Deaf: Exploring new ways of enhancing musical experience with visual and haptic feedback systems.

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**Abstract.** Musicians with hearing-impairment are able to exploit multi-sensory feedback produced by acoustic instruments, allowing them to perform to the highest of professional standards. However, Digital Musical Instruments (DMIs) generally fail to provide the same types of feedback, which limits their usability for the deaf. My research will build on related work to steer development of new haptic and visual feedback systems. These feedback systems will aim to represent the components of sounds produced by DMIs, delivering a multi-sensory experience similar to that provided by acoustic instruments. I intend to investigate how the senses of sight and touch are stimulated, build prototype hardware and software systems to replicate the missing feedback and test the resultant systems for efficacy. The overall aim of my research is to enhance the musical experience for deaf musicians who wish to play virtual instruments and expand their range of live performance opportunities.

**Keywords:** Human-Computer Interaction, Haptic and Visual interfaces, Ethnographic approach to interface design, Perceptual and cognitive issues.

## Introduction

There has been relatively little research on how to optimise musical experience for deaf people (Nanayakkara et al. 2013) and the majority of existing research has concentrated on enhancing the passive activity of listening to recorded music. Where research concerning active music-making for deaf musicians exists, it tends to concentrate on enabling technologies, for example, providing haptic pulses to help musicians play together in time (Fulford 2013). There would seem to be an, as yet, unexploited opportunity to develop haptic and/or visual feedback systems that accurately represent or describe sound to enhance the playability of virtual instruments for deaf musicians.

There are a number of hearing impaired virtuoso musicians, such as Evelyn Glennie, who have mastered acoustic instruments, often describing a multi-sensory experience whilst performing (Glennie 1993). Of course, hearing players experience the same sensations but may perhaps, not rely on them to the same extent. However, it is generally accepted that players of computer-based, virtual instruments do not enjoy the same visual and tactile sensations as those experienced by acoustic musicians. In discussing the relationship between performer and instrument, Rebelo (2006) describes how haptic sensation allows a performer to “negotiate subtlety” and “recognise threshold conditions”, enabling the player to master the instrument. When playing DMIs, the musician is denied this “haptic space” and while the hearing player is less able to reach the highest levels of performance standards, the deaf player may be unable to play the instrument at all.

The objective of my research is, therefore, to explore new ways of providing meaningful multi-sensory musical feedback. This will be achieved by designing a system that provides an immersive experience for players of a wide range of Digital Musical Instruments (DMIs). An ethnographic study of the specific requirements and expectations of deaf musicians will be carried out to inform the development of innovative visual and haptic feedback systems taking into account their needs. This research should introduce a new level of inclusivity in the field of Human-Computer Interaction, while advancing knowledge in sensory replacement.

# Related Research

## Haptics

The majority of existing work on haptic feedback for software instruments focuses on issues not directly associated with hearing impairment; the haptic drum kit (Holland et al. 2010), designed to be a teaching aid, provides a guide to playing technique but does not attempt to convey any information about the sounds being played. Eagleman (2015) has devised a sensory replacement system designed to help the deaf hear the human voice with the aid of a dynamic haptic vest. By using an array of actuators activated by audio input, the vest provides real-time brail-type stimulation to the user's torso. It may be possible to adopt some of the techniques utilised in these types of system to physicalise audio data for digital instruments. Other systems, such as the Viblotar (Marshall 2005), seek to deliver a more immersive musical experience by providing vibro-tactile feedback, which is driven by the amplitude of the source waveform. The efficacy of this approach will be evaluated and be used to inform design decisions in the construction of resonant chambers or bodies. Drawing together elements from the systems described above will facilitate the development of a haptic display capable of describing both synthesised sounds and controller parameters. If successful, this type of display will empower deaf musicians, providing real opportunities for live performance using a whole range of virtual instruments.

## Visuals

In discussing the appreciation of 'music alone', Kivy (1996) examines the subject of 'visual music', asserting that visual perceptual complexity is far superior to auditory perception. He describes how the brain attempts to make sense of what the eye sees, rather than merely seeing lines or shapes. Bruce, Green and Georgeson (2003) support this viewpoint and propose that the apparent superiority of the visual sense is an evolutionary response directly related to human survival. It should be possible to exploit this inherent natural ability to quickly assess visual cues when designing visual displays. Principles of abstraction, where complex images may be reduced to a few significant features, as observed by McCloud (2011), will inform the development of simple but meaningful pictographic icons, which could be used to represent various elements of sound.

# Research Questions

**How do deaf musicians interact with acoustic instruments?** This will be addressed by researching how sensory information is exploited by virtuoso players, who are most likely to understand and be able to accurately convey this information. It is clear that the senses of sight and touch play a vital role in conveying the fine detail and components of sound. However, it will be necessary to examine in great detail how these senses are stimulated to reveal the subtle cues that expert players are able to resolve and interpret.

**What types of visual and haptic feedback provide the most positive user experience?** A review of relevant literature has revealed a wide range of research into haptic feedback with an equally wide discourse on the subject of visuals, albeit located mostly in adjacent fields. Principles and ideas will be incorporated into prototype systems and will need to be tested extensively in user trials. It will be important to consider all cognitive effects derived from the sense of sight to understand if additional or augmented feedback, such as lighting, may be useful. Care will be taken to ensure feedback is meaningful, rather than merely pleasing.

**What physical limitations are necessary to ensure a good user experience?** The overriding aim of the project is to develop an enjoyable and widely accessible system. Factors such as affordability, comfort, ease of use and physical size, amongst others, will need to be considered.

## Aims and Objectives

The primary aim of this research is to address the needs of deaf musicians and afford them a better performance experience when using DMIs. In order to do this, it will be necessary to understand the visual and tactile elements missing from the musical experience of deaf people when playing electronic instruments. Deaf musicians exploit a combination of senses in cross-modal interaction in order to play acoustic instruments successfully. Observation of this phenomenon will inform the design of a multi-sensory feedback system that will enhance the overall performance experience but avoid the introduction of confusing or mis-judged feedback.

It would make sense to integrate any potential new system with existing systems that provide ease-of-use allowing the user to concentrate on creating music rather than complex software manipulation. The Birmingham Conservatoire Integra Lab have already developed musician-centred interfaces for live electronics; a logical further step would be in developing additional modules to provide enhanced capabilities for deaf musicians.

This research will be structured into three distinct phases:

1. Gathering of quantitative and qualitative data on the experiential elements considered to be missing when playing an electronic or digital musical instrument.
2. Investigate how new systems may provide the missing elements.
3. Carry out real-world evaluation of prototype systems.

The second and third phases will by cyclic in order to refine the systems based on user feedback.

The differences between acoustic instruments and DMIs, such as lack of expressivity in the latter, will be central concerns when considering how to reintroduce visual and tactile cues for those who are unable to hear the unusual sounds produced in modern synthesisers. Accurate representation of the sound will be vitally important if a deaf musician is to be confident in virtual instrument performance.

## Research Methodology

This research will be conducted, using mixed methods. A series of questionnaires and interviews with virtuoso and high-level deaf musicians will generate qualitative data on sensory perception and exploitation. An extensive interview with Evelyn Glennie has recently been conducted, which revealed a wealth of information that will inform design direction. A mix of qualitative and quantitative methods will be used to gather data on how a much larger set of users, both hearing and deaf, react to the subsequent prototype system; the charity *Music and the Deaf*, were approached and have agreed to help identify suitable participants. Evaluation of the data will help determine the success, or otherwise, of the project.

Haptic and visual displays will be designed using a combination of hardware and software systems. The nature of these displays will be based on detailed research, development and testing. Ethnographic field studies will form a large part of the research with cyclic development based on interpretation of the user experience of individual musicians involved in testing. Participants will be asked to evaluate the prototype displays to determine how well they describe particular sounds; the subjective opinion of users are likely to produce variable results as they evaluate how well the visual and haptic feedback represents the sounds that they are playing. Creswell (2012) suggests that qualitative researchers should conduct their study with the intent of reporting the multiple realities of those individuals taking part. When compiling a phenomenology, it will be important to take a distilled view of the most popular experiences as described by the majority of people who evaluate the system, while also reporting on the differing views of individual users.

The focus of research will be on development of novel feedback systems exclusively; there is no intention to explore the development of new input devices or instruments. The aim is to increase accessibility to virtual instruments for hearing-impaired players using standard controller keyboards and commercially available software, such as Apple Logic Pro.

## Impact

It is expected that this research will greatly enhance the experience of deaf musicians enabling them to enjoy the act of making live music with software and other electronic instruments. This will provide a similar degree of confidence and enjoyment as that experienced when playing acoustic instruments, which provide predictable haptic and visual feedback. The research will also add to the body of knowledge in the field of Human Computer Interaction (HCI) revealing a previously neglected area of how HCI can benefit hearing impaired musicians. The desire to reintroduce feeling in a DMI has been widely discussed and successfully implemented in a number of cases, however, very few systems have been directly concerned with sensory replacement. It is this gap in knowledge that this research also seeks to address.

By focussing on the needs of the deaf this research will conform with Inclusive Design principles, however the benefits of an immersive musical experience may be enjoyed by all and so the research will also conform to the principles of Universal Design as defined by the National Disability Authority.

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# Augmented Space in Artistic Production: The Relationship Between Moving Image and Physical Environments

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**Abstract.** In this paper we establish a relationship between virtual elements and physical environments (both in the private as in the urban context). We review both theoretical and empirical works on which we base our methodology of performative-led research. The outputs are works that promote Augmented Space experiences in the artistic context with the purpose of creating new readings and experiences of the place through audiovisual installations and live performances.

**Keywords:** Augmented Space, Art, Moving image, Physical environment, Place

## Introduction

The urban space is the starting point and the context for the development of this project. The reconfiguration of the city is more and more frequent, not only due to the constant use of mobile devices in the physical space, but also to the increasingly frequent presence of artistic projects in the urban context. The deep changes that, in the last years, have reshaped the ways in which we address and manipulate the image in the urban space, are fundamental to understand our object of study. In a society in which people are increasingly "stuck" on their individual screens, how do we enhance the gaze towards the physical space through new projection techniques in the public space? As we will show, the concept of Augmented Space can have different definitions and research paths. We analyze theoretical works and artistic practices, with a perspective based on artistic production and its technical and conceptual possibilities. Projects will be developed and subsequently analyzed in order to move towards new approaches in artistic creation. The works, presented as installations in public spaces, build a connection between the moving image and physical spaces.  Thereby, we consider ourselves able to answer to our research question.

## Theoretical context

We can describe Augmented Space as a convergent reality, which establishes a relationship between virtual and physical world.

According to Lev Manovich:

> ...derived the term 'augmented space' from the already established term 'augmented reality' (AR).10 Coined around 1990, the concept of 'augmented reality' is normally opposed to 'virtual reality' (VR).11 In the case of VR, the user works on a virtual simulation; in the case of AR, the user works on actual things in actual space. Because of this, a typical VR system presents a user with a virtual space that has nothing to

> do with that user's immediate physical space. In contrast, a typical AR system adds information that is directly related to the user's immediate physical space.(2005, 224)

Manovich in *The Poetics of Augmented Space*, defend the evolution of this concept starting from the idea of the history of art itself, that is to say, in the sense of the evolution of the gallery, passing from a 2-dimension character, in the exhibition of paintings, to a 3-dimensional use of the gallery space, in which the observer has a dynamic interactive experience: "is the physical space overlaid with dynamically changing information" (Manovich. 2005: 1).

According to Manovich, Augmented Space rises as an architectural issue, because of the direct relation between virtual layers of information and the physical environment. In this way, we observe a change in contemporary practices; "To put it in another way, the layering of dynamic and contextual data over physical space is a particular case of a general aesthetic paradigm: how to combine different spaces together" (Manovich. 2005: 226).

Also authors such as Oliver Bimber and Ramesh Raskar, suggest hypothesis that could represent a development of Augmented Space. They refer to the concept of Augmented Space, like Augmented Reality Space, in fact, they foster the use of projection techniques in the physical space, like the *video-mapping*. They consider this technique to be fundamental to attain an Augmented Space experience through the immersion and interaction in the artistic context, "spacial displays detach the display technology from the user and integrate it into the environment" (Bimber, Raskar, 2005: 18).

In his article *The Politics of Public Space in the Media City* (2006), and specifically in the chapter *The Post-Broadcast Digital Era,* Scott McQuire tries to understand the changes in a *post-broadcast digital* culture, where we see the screens coming back to the public space, becoming an integral part of our everyday life and of urban infrastructures. McQuire argues that the first aim of screens and their most conventional use in public places is the broadcast of sport events or live concerts as well as news and advertisement.

If we think of the first cities that have used large size screens in public space we can affirm that they suffered from alterations regarding the way in which we inhabit public spaces, both on a social and an artistic point of view. The *media event* comes back to the public space through screens. In this sense, it is fundamental to mention the concept of *Media Building,* developed by Paul Virilio, in which he establishes a relationship with Middle Age cathedrals that work as information channels.

The relation between moving image and the urban space focuses mainly in questions of space and time matters, through the relation between cinema and architecture. Therefore, the video projection in urban space is a necessity of creating spaces of collective reflection e Segundo Holly Willis "...a series of interventions that allow people to participate not only in the interrogation of the stability of that power, but to imagine more open, engaged and mutable forms of public intervention and connection." (Willis, 2005, 93)

Nicholas Bourriaud uses the term *Relational Aesthetics* within an artistic perspective that represents a new way of thinking, defining it as a construction through social relationships.  For him, three events were fundamental: a new socio-political context after the fall of the Berlin Wall in 1989; the technological development through the democratization of the access to mobile technology (portable computers and mobile phones) and permanent Internet access.

Bourriaud builds, then, a connection between art pieces from the beginning of the 1990s and the idea of the work of art in open space, with digital art increasingly rising and interactive (Bourriaud. 2009: 23). In his book *Relational Aesthetics*, he develops this idea and argues that art is organized as the sharing among objects, images and people, and also as a laboratory of living forms that anyone can appropriate of. As a consequence, a urban culture rises, where social exchange increases, together with the mobility of individuals and a strong development of infrastructures of communication (Bourriaud. 2009: 20).

Therefore, the artistic experience is linked to the interaction and participation of the user and we pass from the idea of an object that we only contemplate, to an experience in which the user completes the meaning of the piece through his/her actions: "an art that has as a theoretical horizon the sphere of human interactions and their social context more than the affirmation of a symbolic space, autonomous and private" (Bourriaud. 2009: 19). In this sense, McQuire identifies some projects where we can see various examples of Relational Aesthetics, that is to say, the possibility of relation between architecture and public, turning urban space in a place for "public" discussion.

Nowadays, with the ever increasing quantity and development of screens in public spaces, we believe that, through artistic interventions, we can achieve a significant role in increasing consciousness to the social issues, and in our relationship with others, as well as with the notion of place in public space. Currently, due to the excessive use of mobile phones in urban spaces, we believe that we are loosing our relationship with others as well as with the physical environments that surrounds us.

Maurice Benayoun in is article Overscale Art in Public Space: from Play to *Dysplay* in Gigantic: Mediation Beyond Surface states the following: "Street art has reminded us again of the power of media when artists practice outside of the white box. For centuries the frame separated the art from the "real" world, a boundary which was questioned by the introduction of screen technologies. More recently the screen has expanded, invading the walls, the façades and now the very skin of the building itself. Light and image are covering entire buildings in a way that, beyond any previous definition of screen, the urban architectural complex has become a medium."(Benayoun, 2016: 381)

## Practical References

To better understand the evolution of this concept we need to mention authors that deal with the issues that we have previously introduced. Even before the concept of Relational Aesthetics was established, authors such as Jenny Holzer and Krzysztof Wodiczko already made use of images in public places.

Jenny Holzer – creative interventions of a social criticism nature, characterized by ephemerality in public space. She seizes upon large-scale screens and buildings in public places and uses them as a physical medium for her interventions. In her work, she usually employs words to beget critical thinking, considering this kind of structure in the public space as a traditional form of media: control, access, content.

Krzysztof Wodiczko – projections in public space, through the first devices for image projection as slide projectors and later, video projectors. Wodiczko acts in several cities in the world and approaches questions essentially linked to immigration and its implication on themes such as the identity and the territory.

Segundo Wodiczko "it must critically explore and reveals often painful life experience rather than camouflage such experience by administering the painkillers of optimistic design fantasies". (Wodiczko, 1995: 29)

To establish the concept of Relational Aesthetics, McQuire takes, as a basis, the work of these authors:

Rafael Lozano-Hemmer – according to McQuire, he works on the main characteristics of the concept of Relational Aesthetics, among which, the relationship between real and virtual, involving the body in an interactive experience. The user can explore, in public places, the relationship with others, using the body as a vehicle of the experience, in collective or individual performances. This author allows us to understand the way in which we can use Interactive Digital Systems (IDS) in physical environments, enhancing the Augmented Space experience through participation.

Janet Cardiff - sound paths where we can move in space following a narration and audio instructions. Through the combination of fragments of narratives and sound effects, the artist succeeds in adding a new virtual layer to reality, attaining an Augmented Space experience. Following the conceptual work developed by McQuire, several authors have explored art in the public space:

Christopher Baker - discusses the lack of privacy that telephones and social networks have brought to the contemporary world. His purpose is to show that the opposite happens with mobile phones. Instead of being used to send a piece of information information to a specific receptor, they are used to send it to one or a group of unknown people.

Nordic Outbreak - This project integrates several different artists and reflects an open exhibition structure for the open museum and the contemporary ways of engaging with cities through moving image integrated with landscape. It reflects movement, memories and transition. It's a fundamental case study to understand the way the projects in public places may increase the physical interaction between people and the city.

## Research Question

How can we enhance the experience of Augmented Space in artistic production, through the relationship between moving images and physical environments?

### Sub-questions

In this experience, how can we increase the user's awareness on the use of the body in the urban space?

How can we establish a relationship between the user and the idea of place?

## Research Methodology

"It not only expresses the research, but in that expression becomes the research itself" (Haseman 2006: 6).

*Performative-led research* will be our main methodology: with the article *A Manifesto for Performative Research* (2006), Brad Haseman, suggests that performative research should be developed through practice, being this activity central in the research, a pre-requisite. The already established qualitative and quantitative research methodologies present limitations when referring to practice-led research, particularly in the artistic context.

We want, then, to define our methodology through artistic practice as performative-led research suggests. The aim will be the exploration by practice that, according to Carole Gray's proposal, suggests that the research should be adjusted by practice, the context in which problems and challenges arise, elements that motivate the progress of the research itself. The author suggests, then, methods for acquiring data that we are familiar with (Gray, 1996). A *performative-led research* has its origins in qualitative methodologies, but intends to present the result in a performative way, that is to say, through the artistic process, or through the implementation of the projects with the consequent data analysis. The main difference between qualitative and quantitative methodologies is in the way conclusions are expressed. The results are presented not only in a symbolic way, that is to say numbers or words, but also through the artistic practice itself. Haseman questions: "how can presentational forms be understood as research? What makes a dance, a novel, a contemporary performance, the outcome of research?" and mentions the notion of performativity by John Langshaw Austin as a starting point. Austin affirms that "performative speech acts are utterances that accomplish, by their very enunciation, an action that generates effects".

Therefore, starting from the development of artistic projects, we will create a model to establish a relation between moving image and physical environments. The output of this work will then be the development of artistic projects that will be subsequently critically analyzed, and that will originate new perspectives on artistic practice. The results will be presented in the form of exhibitions in public spaces, for that audiences are able to actively participate. On the other hand we also aim at creating knowledge by producing and sharing texts and scientific papers in order to bring a contribution to the community.

Based on this study, we divide our methodology in 3 stages that constantly interact and influence each other, fostering the acquisition of data and new questions during the practice. We then try to establish a cyclic and continuous relation between artistic and scientific practice. The different steps that we will explain below, will not be static nor linear in time, but happening in parallel:

**Stage 1 – Theoretical plan:** as presented above, we begin from a definition of the concepts proposed in this project: analysis of the evolution of the key concepts: detailed review of the different practical projects.

**Stage 2 – Practical exploratory plan in studio:** the practical development of the research that started in 2014, began with the building of a cube-shaped metal structure, that has allowed us to test surfaces, projection techniques, video and interactive digital systems. To enhance the practice, we have used the cube with an experimental perspective to arise questions that will originate during the development of the projects. The cube is tested with different formats and ways of interaction that allow us to understand the better strategy of building a connection between moving image, the performer and physical environments, finding new experience models that we present shortly:

*InBetweenTheBox* (Figures 1 and 2) is an audiovisual performance that creates an immersive environment and explores the relationship between virtual and physical space. We challenge the border between these spaces promoting awareness of our body and its dislocation in physical environments.

*braINbox* (Figure 3) is an interactive audiovisual performance created with Muarts, Sininho and Tiago Salazar for the MIRA Forum artistic residency. The box is a medium between the physical world and the digital realm. In this case in particular, the physical world is physiological and is represented by the electromagnetic brain activity of the writer and the digital world is it´s translation into the digital realm. Technically, we have used an EEG Emotiv Epoc headset and a Max7 patch to acquire and translate the brain data into an audio-visual projection of his thoughts into a translucid cube (Figure 4)

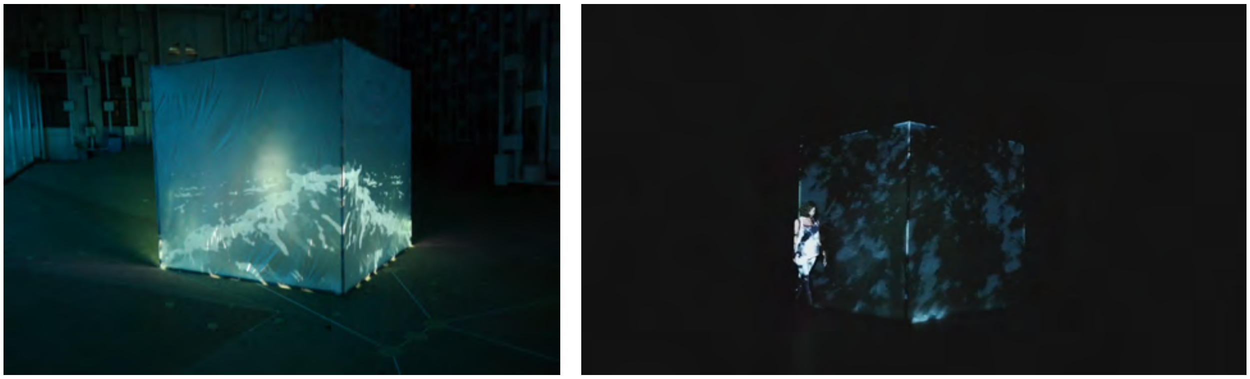

Figure 1 and 2: Performance *InBetweenTheBox*


Figure 3. Performance brainbox

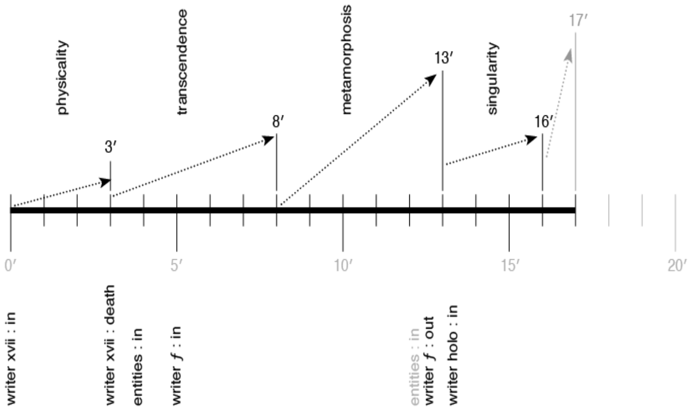


Figure 4. Conceptual narrative flow

*Serralves 40 horas* (Figures 5 and 6) - A interactive collaborative construction of a narrative that combines the online world with the experience of the event, in order to conserve memory of the event. So through the application developed for this event (Max/MSP), they will be accumulated in the same projection, a unique visual history and the individual contribution of those who want to participate.

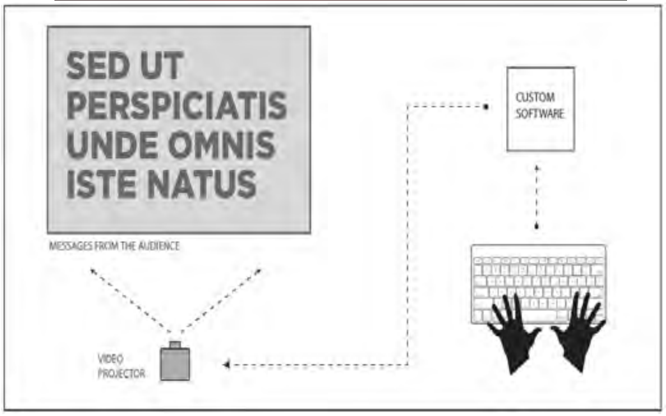


Figure 5 and 6. Installation Serralves 40 horas, technical details

*Kobayashi 2001* (Figures 7 and 8) is a live audiovisual performance composed by live coding sound and audio-reactive visuals. It consists in the exploration of a non-linear narrative using images and sounds captured in the physical world. Searching for their artistic potential and expressiveness, we use these digital recordings from our daily experiences as raw material for the performance. We explore a dialogue between Supercollider and Ixilang for music composition and VDMX and Resolume for video editing.


Figure 7 and 8. Peformance *Kobayashi 2001*

*SINØ* (Figures 9 and 10) is a live audiovisual performance composed by sound elements and audio-reactive visuals. The installation consists in a box made by a rectangular structure with multiple layers of transparent fabrics. We explore the relationship between the retro-projection and the body of the performer, creating a augmented space (between projected elements and the physical body) trough this mixed reality.


Figure 9 and 10. Audiovisual Performance *SINØ*

**Stage 3 – Practical exploratory plan in the public space** (Figures 11 and 12): After the tests of the stage above, we will approach the public space. We assume that the projects implemented in this phase, as far as technical aspects are concerned, will be already complete with the related data– such as robustness of the system, interactive digital systems design, modes of interaction, technical and physical characteristics in the implementation - to be able, in this stage, to exclusively work to promote the relationship between moving image and Public Space.

This practice-led research aims at establishing a constant and direct relation among the three steps of the project. Starting from these premises, we develop this project through the relationship between theoretical plan, artistic practice and its consequent reflection of results, with the purpose of finding innovative methodologies to enhance the experience in Augmented Space in the context of audiovisual interactive installations and in live performances (private and public space).


Figure 11 and 12. Testing video projection at Public Space

## Future work

Based on stage 3 we aim to create Media events in Public Space. Trough the exploration of site-specific installations we want to promote the relation with the urban space and the idea of the place.  We want to understand the methodologies and technologies that suit best for the work we propose. As such, we have as principal objective to understand how we are able to enable the relationship between people and the sense of place in urban space, through a number of artistic interventions. Thusly, during the next year, we will create two fixed places of projection in urban space, which will remain during a month as a way to understand if we have achieved the formerly mentioned objectives. It will be through our *in situ* experience that we will be able to extract data and will be able to reflect on future projects.

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# Sonic Ghosting: developing an interface between space/place/memory and sound/music/noise.

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**Abstract.** This presentation explores how 'sonic ghosting' works seek to offer an interface between sound/music/noise and space/place/memory. It offers a brief outline of the sonic ghosting concept, along with an overview of how creative fracture and multimodal presentation are used to explore the multiple intersecting temporalities of the present soundscape. In our everyday experience of place, there are occasions when we are reminded of the pasts or unfulfilled potential futures of the spaces that we occupy. This presentation suggests how a sonic ghosting practice might address the problematic nature of relating a visual experience – seeing the ruined shell of a factory in the post industrial landscape – with the fact that what we hear is the present soundscape, and provide an interface by which the listener can experience the multiple sonic temporalities of space/place/memory. Finally it briefly outlines an example of how the work has developed by giving an overview of the installation work 'Ghosting the Periphery'.

**Keywords:** sonic ghosting, soundscape, temporality, multimodal, installation, performance, memory, space, place.

## Conjuring the Sonic Ghosts

In our everyday experience of place - whether that is walking through the city, the gallery, the ruined and repurposed spaces of the post industrial landscape, or sitting in the concert hall - there are occasions when we are reminded of the pasts or unfulfilled potential futures of the spaces that we occupy. Often, this is by encountering the remnants of previous inhabitants, functions, owners or objects. A pair of discarded boots, a painted sign from a forgotten business on the side of a wall, rusted and overgrown machinery – these things allow us to see the juxtaposed layerings of pasts, presents, and futures that could have been. However, if we close our eyes and listen, what we hear is the present soundscape, regardless of how we might experience it. In the fleeting moment of our visual or tactile encounter with this temporal fracture, we might recognise, at least temporarily, how the multiple simultaneous "intersecting temporalities" (Edensor 2005: 126) point to the fact that "[t]here is no place that is not haunted by many different spirits hidden there in silence" (de Certeau 1984: 108). It also challenges the singular narrative that we might otherwise presume, given the illusory completeness of the current soundscape – whether in our experience of it, our memory of it, or a recording. Though we might observe some of the "intersecting temporalities" within the visual or haptic space, there are others that remain hidden, and those we do see, in their defunct or 'past' status, often remain inactive. Without action they are 'mute objects' that stand "beyond the horizon of sound" and "yet the mute object is silently *present*" (Ihde 1974: 51).

The development of a 'sonic ghosting' practice seeks to offer a way to interrogate the relationship between space/place/memory and sound/music/noise by fracturing the soundscape of the present with the echoes, phantoms and potentialities of the soundscapes of the past/future. In doing so, it explores the space in-between "presence and non-presence" (Derrida 1994: 13), exploding out the moment where the present "unexpectedly betrays us" (Jameson 1999: 39) and we catch a glimpse of the multiple "intersecting temporalities" (Edensor 2005: 126) that haunt it. In one sense, it is ventriloquizing the material/space/landscape that it engages with, extending it beyond the bounds of its normal sonic existence, and blurring the horizon between what is "hidden there in silence" and what is actually present. The shadowy apparition that is conjured up within the present soundscape reveals something about itself or, perhaps, the listener/composer/performer's relationship with it, as "listening makes the invisible *present* in a similar way to the presence of the mute in vision" (Ihde 1974: 51). Sonic ghosting hopes to offer an invitation to listen out for one's own sonic ghosts, and a potential interface by which it might be possible to hear them.

To achieve this, there is a creative and compositional employment of fracture, degradation and performance interruption – both temporally and spatially. Where sonic material is gleaned from on-site field recordings it is manipulated, cut-up, processed, delayed, moved in time and space. The resulting work may also be presented in-situ alongside the soundscape of the place/space about which the work is made, where it is presented, or contextualized with text/image/materials. It may also fold the spaces of presentation, and actions of the listener, into the work by incorporating real-time processing driven by movement/presence sensors, ambient sound level metering, footfall sensors or the pitch tracking of environmental sound in and around the exhibition/installation/performance space. This process creates layers within the fabric of the work, between the memory of sound on-site, the recordings, their fractured remains, electronic and acoustic instrumentation, and the multiple modes of presentation and iteration: performance, installation, documentation, image, text. The deliberate juxtaposition of the present soundscape and the warped and processed conception of the creative work - which, in itself, may incorporate various shades of obfuscation of the source material - presents the listener with a combined soundscape that simultaneously disrupts and suggests both causal and reduced listening. As such it emphasises that "the question of listening with the ear is inseparable from that of listening with the mind" (Chion 1994: 33) and through doing so, hopes to develop one possible interface between a sonic memory - of space, place, inhabitants - the listener, and the multiple "intersecting temporalities" (Edensor 2005: 126) of the present soundscape and its spectres.

## Developing work

To illustrate how the processes, practices and modalities of a sonic ghosting work might manifest more specifically, I will briefly outline one of the works developed during the research project: 'Ghosting the Periphery' (Bright 2015).

'Ghosting the Periphery' was a sonic ghosting work reflecting on the histories and spaces of the Hatton Gallery in Newcastle-upon-Tyne, prior to it closing down for a major refurbishment. It comprised a four channel sound work composed from manipulated, fractured and processed site recordings made in the gallery spaces – both the public spaces, and the store rooms, archive, and mezzanine not usually seen; a footfall/presence responsive layer of real-time processing which samples and alters granular fragments of the soundscape composition according to the number of people in the gallery space and their movement; and a printed text assemblage linking the experience of researching and composing the work to fragmented, cut-up remnants of the gallery archive materials.


Figure 1. The main gallery space on entrance to the exhibit.

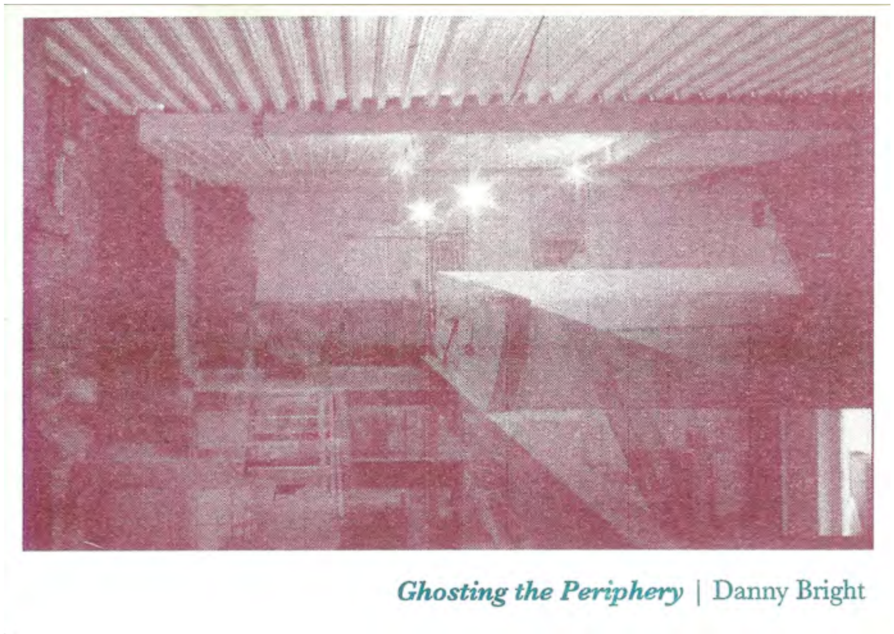
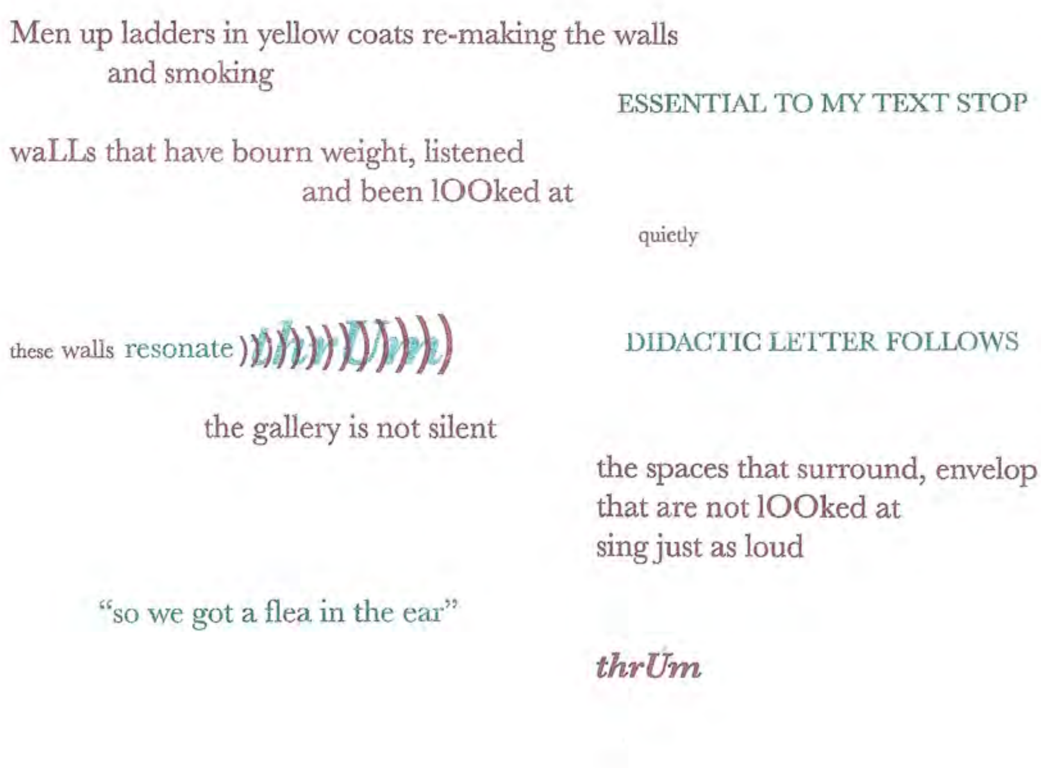



Figure 2. The front of the printed card incorporating an image assemblage of a gallery archive photo and a photo taken during the making of the work



Men up ladders in yellow coats re-making the walls
and smoking

ESSENTIAL TO MY TEXT STOP

waLLs that have bourn weight, listened
and been lOOked at

quietly

these walls resonate

DIDACTIC LETTER FOLLOWS

the gallery is not silent

the spaces that surround, envelop
that are not lOOked at
sing just as loud

"so we got a flea in the ear"

***thrUm***

Figure 3. The rear of the printed card with an assemblage of sound-text and words from the gallery's archive collection of exhibition documents and correspondence.

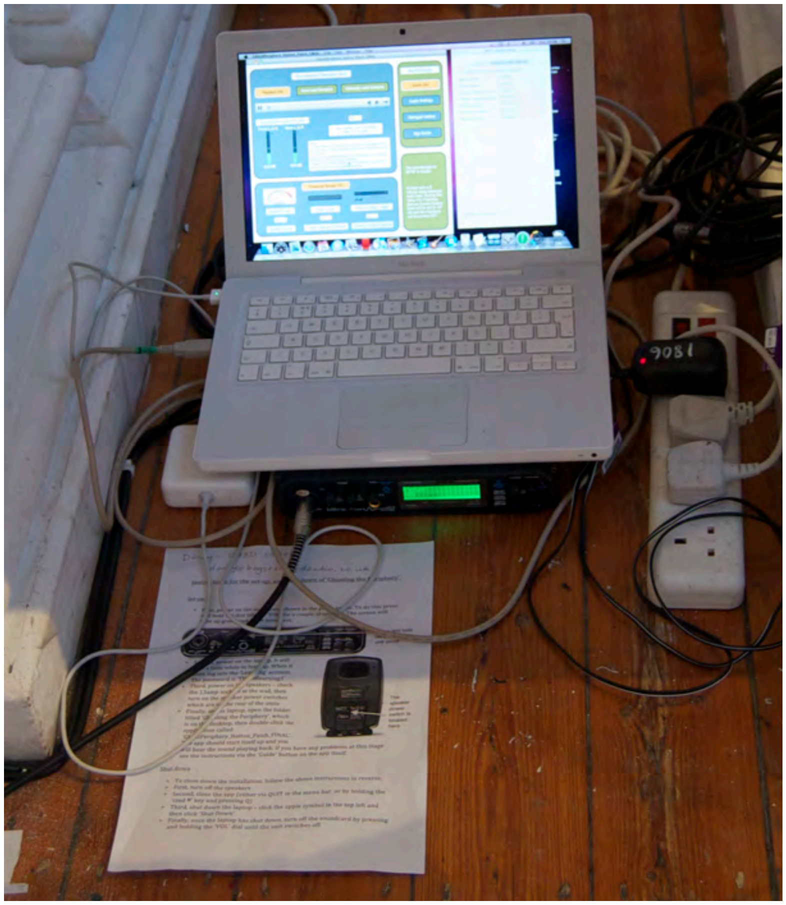



Figure 4. The computer system running the Max patch with soundscape playback, footfall monitoring and live processing/spatialisation.

The work sought to provide an opportunity for the gallery visitors to engage with the various spaces of the gallery, the people who have inhabited it, and the soundscapes that have accompanied them, the works that have been exhibited, and the various functions of the building since it was constructed. It also sought to offer an interface for them to engage with the importance of the sonic histories and heritages of a place almost entirely devoted to the visual arts. It did this by creating a number of layers – constructed from field recordings made in various spaces during the 'quiet' of open gallery hours and the noise of frantic work during exhibition changeover – that blurred the line between the present soundscape in which the work was heard (it was mixed at a level that would mix with the natural soundscape of the gallery) and the fractured and warped soundscapes of the work itself. It also used the space and movement of people within it – by using noise thresholds and the resonance of the wooden floor through a contact microphone – to drive an extra layer of processing and spatialisation. This extra layer created a situation where the work could continue to tune to the sounds of the gallery and the movement of the people within it over the course of its three week installation – syphoning off a stream from the pre-composed soundscape, processing it granularly, and re-spatialising it randomly across the four speaker diffusion system.

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# Brain affordances: an approach to design for performers with locked-in syndrome

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**Abstract.** Locked-in syndrome is a condition where a person is unable to move but has preserved cognition. While it is not common, the existence of potential performers with this condition questions the very nature of performing. Most of the time it depends on moving the body: a musician playing her instrument, a dancer swirling through the stage, a live coder typing on the keyboard. What happens then when the performer cannot move? Can he perform? How is flow affected? Can it be considered live performance? How does the relationship with the audience change? These are a few questions raised by the existence of performers with severe motor impairments. This article proposes the concept of *brain affordances* as a starting point for the discussion about the design of live interfaces for performers with locked-in syndrome.

**Keywords:** disability, locked-in syndrome (LIS), interface design, brain-computer interface (BCI), affordances.

## Introduction

The artist was present. The artist was motionless. The artist was performing. But her stillness was by choice, by design. In *The Artist is Present*, Marina Abramović (2010) represents one end of a spectrum: a performer that chooses to be still as part of her performance. At the other end sits a performer that is forced to be still, one that did not choose to be there, motionless. It can be argued that such a performer might replicate Abramović's work by communicating his desire to do so to his caregivers but the nature of the performance will be changed by the nature of the choice. It can also be argued that such a performance should not be the only expressive possibility of an artist that cannot move. Then, what choice does this artist have?

To answer the question, we must understand the cause of stillness. Severe motor impairments (SMI) are a set of conditions where the ability to perform voluntary movements is compromised. The most restrictive SMI is Locked-in Syndrome (LIS), a condition where the person cannot voluntarily move his body but keeps his cognition intact; sometimes, voluntary eye movement is preserved (Laureys et al. 2005). No voluntary motion means the person cannot use a typical musical instrument, move through a stage or sing, for example. While there are design approaches that take into account disability (Dalgleish 2014) and assistive technologies, such as eye-gaze tracking, to support people with SMI (Majaranta and Räihä 2002; Riveros et al. 2014), they may not be enough to cater to the specific needs of these users. Preserved cognition and no possibility of voluntary movement means a focus on the brain may yield better solutions.

Brain-computer interfaces (BCI) offer the possibility of giving control over expressive tools to users with LIS. Previous experiences include tools for communication (Chaudhary and Birbaumer 2015; Käthner, Kübler, and Halder 2015), robot navigation (Choi and Jo 2013), drawing and painting (Muenssinger et al. 2010), performing music (Cádiz and de la Cuadra 2014; Eaton, Williams, and Miranda 2015), and performance (Tomé-Marques, Carvalhais, and Pennycook 2014). There is also previous work on conceptual models regarding the use of BCI in the performing arts (Zioga et al. 2014; Aparicio 2015). What seems to be lacking is a common conceptual model to frame research into the specific needs of users with LIS in the context of live performance and live interfaces. This paper introduces the concept of *brain affordances* as a starting point for the development of such a model.

## Brain affordances

Affordances are the potential actions that an agent may perform upon an object (Gibson 1977). They depend on the relationship between what the agent can do, its abilities, and the object's properties. The body of the agent, and its structure, defines and constrains the set of the agent's abilities. In other words, "affordances are defined in relation to an agent's body" (Dawson 2014). Building upon the original definition, Smith (2009) introduces the notion of *structural affordances*: a range of abilities and constraints in mobility afforded by the specific embodiment of an agent. In this case, the relationship that defines the affordance is internal to the agent, between its brain and its body, and it is used to determine the set of possible movements a given body part may afford. That is, *bodily affordances* (de Vignemont 2014).

The concept of bodily affordances has been used to inform design loops that strive to find a fit between the affordances of an object (a musical instrument, for example) and the bodily affordances of a performer with a disability (Dalgleish 2014). In the case of users with LIS, however, one of the basic assumptions behind bodily affordances is not met as no body part affords movement. While the constraint upon movement is imposed by damage to the efferent connections the intention of action may be preserved. By this I only mean that the user may perform voluntary mental actions including, maybe, imagining the motion of a body part.

These actions have neural correlates that can be measured using several techniques and, in turn, we can interpret those measurements according to different paradigms to extract information. We can then map that information to a set of actions in a given system. Two examples: (1) we could use EEG to measure the mu wave of the user in a base state versus visualizing moving his hand and, from this measure, extract two states and map them to a toggle (Pfurtscheller et al. 2006; Höhne et al. 2014); or (2) we could use EEG and the classic P300 speller to map selection of a menu option to its corresponding action (Käthner, Kübler, and Halder 2015; Jijun et al. 2015).

We will call the combination of measurement technique and interpretation paradigm a *control paradigm*. We can say that each control paradigm yields a set of potential actions for any given signal. In other words, each control paradigm affords a set of actions. Then, by analogy to the definition of bodily affordances, we may define *brain affordances* as the set of actions a control paradigm may afford. In this case, the relationship that defines the affordances is between brain and brain.

What is the usefulness of this concept? First, it let us decouple each control paradigm from specific actions in the interface by abstracting them into potential actions which may not exist beyond the abstraction itself; following our previous example, the light switch with its particular actions of turning on or off the light bulb can be replaced by an abstract switch with two possible states.

Second, by abstracting the actions we implicitly abstract the control paradigm; this means that, during the design process, we may concern ourselves only in identifying the minimum number of potential actions required to control a given interface and then identifying which control paradigms may supply them. In other words, we are decoupling the control modules from the action modules of any given interface.

Finally, this decoupling allows for modularity both in the design process and the implementation of a specific interface as any given control paradigm that provides a set of potential actions may be replaced by another control paradigm that provides a set of the same or greater cardinality. For example, User A is able to use a control paradigm with two potential actions but User B cannot use it because it depends on certain qualities of the signal that are not present for her; in this case, the design process should identify alternative control paradigms that provide two or more potential actions, test them with User B and then replace the original context with a better option.

## Future work

This article introduced the concept of brain affordances and argued its usefulness during the design of live interfaces for performers with LIS. It becomes useful by providing three key characteristics to the design process: (1) decoupling of the technical implementation of BCI from the design of the interface, (2) decoupling of control modules from action modules and (3) modularity in both design and implementation. These characteristics should enable more formal exploration of solution spaces by explaining designs under the same conceptual model, comparing them to identify the best initial fit to the specific requirements of a performer/performance and iteratively modify them to reach an optimal design. To accomplish this, the next step will be the creation of a formal framework that uses brain affordances to support the design of interfaces for performers with LIS.

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# 'Vivisecting' tempo-spatial semantics in immersive environments and hybrid events: few methodologies for '3D VJs' and 'VR conductors'

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**Abstract.** This research (doctoral project in its beginning phase) investigates potentials of live staging of immersive multimedia productions with self-adopting interface elements for author(s) and participants. The aim is to propose novel concepts for a hybrid interaction system that can enhance artistic expression within complex scenarios, and also function as a part of embedded infrastructures for adapted venues. While focusing on interfaces controlling spatial dynamics of 3D/stereoscopic visuals and multi-channel audio, research would propose few guidelines for more comprehensive metadata and signal exchange framework, which would comprise not only formal structure of multimedia event, but also include spatial arrangements and signal feedback within e.g. exhibition or performance locations. The framework is envisioned as a hybrid interaction system, consisting of networked hardware specifications and custom developed software modules for adapted venues; participation and involvement roles, and conventions (dynamic set of protocols) for real-time improvisation and collaboration among authors, co-developers, producers and audience.

**Keywords:** immersive, stereoscopic, synaesthesia, VR

## Introduction

The (working) title refers to the traditions of orchestra/choral conductor role, the more recent phenomenon of VJ (Visual Jockey) movement in audio-guided audio-visual performance, and uses a metaphor of the historic medical term for cutting on living tissue (coined by anti-vivisectionists in the 19th century). It also poetically hints to existence of specific, 'metaphysic' tempo-spatial qualities, characteristic to several time-based genres and event types, where illusory and physical spaces are merging, transforming and, sometimes, colliding.

Having my own educational background and creative practice path that made evolution from classical arts and music, to immersive 3D environments, my motivation is to combine some accumulated tacit knowledge with survey of relevant technological outlooks (e.g. in field of augmented reality, real-time structure scanning, gesture capture) and critical reviews as well as recent theories (e.g. concept of *ideasthesia*), in order to propose novel formats of staging immersive time-based creative practices.

The vision (hypothesis) of this research is, that function-adopting interfaces, constructed in Virtual and Augmented Reality can enhance 'overview': ranging from traditional fixed score, to representation of an aleatoric, generative audio-visual composition, or other type of sequential or non-linear dramaturgy and 'control' – efficient manipulation of elements and their relationships in multi-modal performance by pre-defined and improvised mapping of parameters, dynamically located in illusory perceivable spaces.

## Brief description of the practical research topics

The aim is to investigate, propose and design and evaluate number of methods and tool prototypes for artistic and creative projects, to create and perform original artworks and also to use the system as more generic interaction or even exhibition platform. It would focus on capacities of affection on the user and the variety of interaction with particular communities. The research topics focus on practical discourse and technological application and use their proactive interconnection for potential new outcomes.

Following topics will be investigated practically:

- combined characteristics of interactive installation prototypes that can be:
    - improvised (performed live) by artist (author) as ‘artist's signature style’ expression
    - self-running, autonomous (permanent or temporary) structure within exhibition, stage (or other type) of venue, processing data from external or simulated processes, explored by visitors
    - extended for other alternative presentation formats, adding various additional contexts within larger exhibition or event - potentially creating link with other artworks or events

- concepts of ‘tempo-spatial objects’ (e.g. unity of spatial, time-based audio-visual elements) - both as artistic metaphor and authoring interface that leads to efficient control of powerful immersive (hybrid reality) experiences - also as ‘artificial synaesthesia’

- individual and collaborative authoring interface concepts, that can involve gesture, body, brain- or other type of bio-feedback, that enhances live control of complex ‘tempo-spatial objects’

One of the aspects is to propose a ‘meta-framework’, comprising pre-categorised and live-extracted artwork structure, exhibition space sensor readings and audience response. Thus, the framework would describe not only artwork’s parameters (content, formal structure and unlimited abstract data), but might include also e.g. spatial arrangements within exhibition/performance venue and participation/involvement roles. The framework is envisioned as self-updating environment installations (software and networked hardware and architectural elements), for adapted venues; and conventions (dynamic set of protocols) for real-time improvisation and collaboration among authors, co-developers, producers and audiences. In addition, exploration of potential future organizational and business models for such events would be investigated and proposed.

## Brief description of the research methodology

A series of experimental modules would be developed, to test aspects of the system for roles of artwork author, active participant and passive spectator. They will explore perceptual potentials of panoramic technologies and look at the role of sound and motion in these particular environments. This will implicate experimental strategies with uncertain capacities in the effectiveness of interaction, quality of public response and impact of audio-visual language. These factors will be handled with usability and likability testing when particular system structures might be set up and tested for public response. I will use audience research in both qualitative (specific groups and e.g. test teams) and quantitative mode – analysis of anonymous interaction statistics on site (within large event) and through online interfaces. During the research project time I will create at least two different, specific artworks that would illustrate the findings the researched concepts.

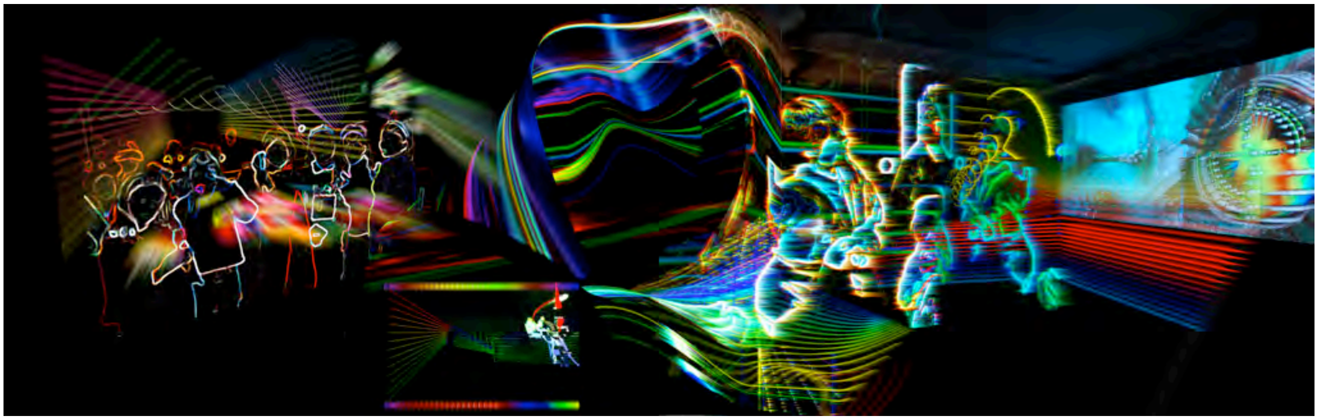

Figure 1. Interface study

## Few metaphoric concepts

Following are few metaphors, from my recent and upcoming artworks – planned for the practical research sessions:

### 'Spatial subversion'

Setup uses multiple view representation of interior and visitor presence, captured by stereoscopic cameras, structure and depth sensors, with applied spatial depth extraction, edge-detect filters, 'point cloud', etc. - that allow illusory swapping the solid objects by their 'hollow versions' – to be superimposed with additionally mapped, 'solid' 3D objects.

### 'Vivisection' (from Latin, meaning – *vivus*: alive and *sectio*: cutting)

In this case is 'virtual manipulation' – an imagined 'surgery' on abstracted multiple layers of audio-visual illusion, represented by 3D stereoscopic image (Augmented Reality HMD or 3D projection) and spatial sound (binaural simulation or multichannel setup). In addition to 'spatial subversion' elements, tapping into signal circuits of equipment displaying audio-visual material (e.g. specific artwork) and 'augmenting' the scene with layers of extracted features, and establishing alternative circuits (echos, delays of various value, feedback loops, reverberation, filtering, etc.) The aesthetic aim is to create 'dense artificial atmosphere', that is superimposed with abstract, graphically visible interface that visually divides, cuts, mixes, recombines space, exaggerated by stereoscopic imaging and immersive audio effects. The 'surgery' is manipulated by a pair of XYZ/6-DOF sensors (e.g. Razor/Hydra or Sixense/STEM), coupled with laser-pointers (to track and map projected elements in exhibition space). In the process, the interface to the object/space (used by the subjects: author and viewer) becomes part of the observed object.

### 'VR Conductor'

In many musical genres, the conductor provides tempo, dynamics, articulation, phrasing and cueing to other performers by specific gestures and even by mimics and gaze. From mid-19th century conducting technique became increasingly standardised. In the recent decades, there has been a number of experimental projects to track conductor's arm, hand and baton movements (by wide range of technologies), to extract various aspects of expression and convert it to code, than can be passed further to control some parameters of electro-mechanic or digital instruments. The most recent advances in popular live tracking technologies (e.g. Kinect Sensor, Leap Motion etc.) allow automated calibration, whole-body-, arm-, hand- and finger tracking, and 'smarter' parameter mapping to adopt to individual, unique gesture styles (not related to the classical conductor tradition). For this research, these or similar technologies will be integrated with real-time 3D graphics engine, which generates interface elements that can control tempo, flow, movement direction, picking elements, adjusting parameters in 3D space.

### ‘3D VJ’

The concept of VJ-ing– as accompanying visual entertainment, characterised by short video-loops, live-cut and mixed to rhythmical music – has grown into a specific art form, which is merging with genres of stage-design, performance and live cinema. Some of the synesthetic methodologies and technologies will be used - including algorithmic music, beat, pitch, volume, frequency spectrum detection, MIDI/DMX/OSC synced equipment and software, 2D and 3D projections (using 3D stereoscopic source material and rendering) mapped on almost any kind of surface.

## Conclusion

The research will particularly examine creative interface solutions that can engage broader audiences by proposing new authoring methods to solve the complex requirements of content management. A proof of concept would be arranging a specific cultural event (incl. performance, exhibition, conference), connecting at least two venues by the designed system and original artwork – using the system modules. After evaluation and adaptation, the system prototype should have a scalable capability to function as progressing, temporary (or partially sustained) ‘infrastructure’ for more cultural events and venues. This research will produce a critically informed practice in which theory and practice build a balanced part in the final outcome.

# Algorithmic Interfaces for Collaborative Improvisation

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**Abstract.** The paper explores three different systems designed by the author which take critical approaches to algorithmically mediating collaborative improvised performance taking place between (i) co-located performers interacting with a graphical interface, (ii) performers with diverse musical practices performing together telematically, and (iii) co-located live coding performers. The three performances have different approaches to algorithmic mediation. In (i) performers work directly with the same sound sources via a GUI which is mediating each performer's input individually through restricting interface resources, in (ii) 'musical consensus' is deduced through machine analysis of the inputs assuming that the 'musical average' is the point of consensus, and in (iii) algorithmic agents with pre-defined musical preferences direct the mediation. The paper describes the initial considerations, design and implementation, and evaluation of the three systems, as well as a discussion of the issues raised by the use of such systems.

**Keywords:** collaboration, improvisation, algorithmic, generative, machine listening.

## Introduction

Network music systems have been concerned with social organisation of performances since the late 1970s when network music pioneers The League of Automatic Music Composers (later became The Hub) began experimenting with building their own network structures for passing musical information and directions (Bischoff et al 1978). The ability to exchange and repurpose multi-modal data between performers and open new communication channels has driven network music system designers to imagine new structures for the temporary community of the musical ensemble.

Cross (2003) points towards music making as a “safe” domain for testing cultural theory. We might consider then, that network music systems, which utilise technology integral to contemporary social interaction and community formation, may interrogate the nature of these interactions and structure the exchange of available communication channels – audio, visuals, text, data – in ways that reflect and critique the nature of online interaction.

With the development of social networking, interface design and algorithms have become integral to our social interplay with data collection, content personalisation, and behaviour prediction, mediating the potential interactions we have and e.g. character limits, 'like' buttons, and even Instagram filters informing the content of our interactions. Algorithmic mediation and content creation, and interface design in network music systems are central topics explored through the systems discussed in this paper.

The section which follows describes briefly the design of *Controller*, *Union* and *Flock* and the specific aesthetic and technical considerations which impacted the development of each system.

## The Projects

### Controller

*Controller* is a GUI based project which aimed to design an interface for group improvisation, where performers’ actions are mediated by a central control mechanism which modifies their ability to contribute to a group performance. To facilitate this interaction a simple interface was designed with which to control both a shared sound space and the social structures within the group, thereby requiring the players to act both as performers in modifying the sound, and as conductors in changing the contribution of other players to the modification of sound. This group action is subverted by the mediating control mechanism which modifies throughout the piece the performers' abilities to contribute to both the sound and social aspects of the piece.

## Interface Design

*Controller* consists of a simple interface on each performer's laptop. The interface is used to send control values over the network to set parameter values of a shared sound space. The interfaces are linked over the network in such a way that changing the setting of an interface element on one laptop changes the setting accordingly on all other laptops.

The interface itself consists of three basic types of control: sliders which can be used to control elements of the shared sound space; buttons which switch on and off the sliders of other performers; and knobs which effect the number of control data messages per second sent from a player's slider to control the shared sound space.

## Structure

The structure of the performance is shaped by algorithmically setting the visibility of interface elements for each of the performers through a combination of 'random' allocation and 'special events'. Any one performance always follows the same basic structure of beginning with allocating each player just a small number of sliders, to increasing the number of sliders and rate of change of the allocation of interface elements. Buttons and knobs allowing performers to interact with the visibility of other performers' controls and therefor the social structures of the piece appear in the second half of a performance.

## Aesthetic Design Considerations

There were several aesthetic considerations in play in the design of the performance interface relating to how the player interacts with the performance and enforcing particular social structures, some of which are discussed below.

The choice of interface elements was designed to make it easier to interact with the sound space than to interact with the social space. Therefore small buttons and knobs were used to control the social space and larger sliders were used for controlling the sound space thus asserting that the primary role of the performer is that of interacting with the sound and perhaps reinforcing social changes as subversive behaviour.

The status of other performers (i.e., how many controls they have relevant to other players) and therefore the overall social hierarchy is not revealed to performers. Neither is any indication given as to whether changes to the availability of elements on the performers' interface are the result of computer or performer action. However an audience graphic has been developed which gives audience members an overview of all performers' interactions with their interfaces.

The level of difficulty of performing with the interface should vary over the course of the piece, in essence, providing another way of controlling the interaction of players with the interface.

## Conclusions

Laptop ensemble composition provides many possibilities for facilitating democratic interactions among performers and many network music pieces deal with shared sound spaces or shared controllers in order to facilitate collective action. *Controller* comments on this democratic potential by providing an interface which varies during performance to change the level of control participants have. Further, the work brings to the foreground for performers and audience the complex underlying group dynamics of interaction, with an ongoing negotiation of 'who controls what'. The piece extends the notion of 'composing democratically' for laptop ensemble (Knotts 2015) into the arena of 'composing democracy', that is, creating a musical structure out of shifting group dynamics, with political action at the forefront of the compositional design.

## Union

The development of *Union* was the result of working with two different female-only laptop ensembles in 2015. The author worked with FLO (Female Laptop Orchestra) from 2014 to October 2015, and later co-initiated OFFAL (Orchestra For Females And Laptops), as a specifically telematic ensemble. Knotts (2014) surveyed the general characteristics of laptop ensembles and found only one female-only group, whereas many groups were male-only. *Union*'s development and the later formation of OFFAL arose out of the desire to form a large ensemble of improvising laptop musicians who are women[1]. Strategically the most practical way to develop a large ensemble of female performers was to develop a system for telematic collaboration. This facilitated the inclusion of many more women without the need for large funding grants to rehearse and perform. Further considerations were that in order to be inclusive to as wide a range of participants as possible the system needed to use free and open-source software, allow performers to collaborate with minimal intervention to their normal performance setup, and should work on non-institutional and low-speed and -bandwidth internet connections. These technical considerations defined many of the starting points of the project. Additionally the author had experience of audio streaming setups through several performances as part of GIASO (Grande Internationale Audio Streaming Orchestra).

While co-located network music systems offer the opportunity to develop alternative ensemble structures through designing the structure of additional information exchange (musical data and textual), telematic systems can provide interesting structural challenges due to the dislocation of performers from the site of the performance and from each other. In addition, inherent network delay may create varying levels temporal asynchronicity – depending on the technology and quality of network used. These issues can lead to social and musical disconnect as temporal asynchronicity and lack of visual feedback means performers can less easily perceive the actions of the other performers in relation to their own actions. In telematic scenarios chat clients can provide a site of social cohesion, a means to describe the remote locations, performance site, and audience interaction, and to give textual feedback and discuss creative aims.

### Basic Setup

The audio from all participating performers is sent using streaming software to an Icecast server where all eight streams are then accessed by the system laptop. SuperCollider's SCMIR library is used to analyse the spectral content of the streams and mix according to similarity. The mixed version of the audio streams is sent directly out to the loudspeakers in the concert space in 8 channels and back to Icecast as a stereo mix, where online audiences can listen to the performance using software such as VLC, and performers can also monitor the final mix. Some basic testing revealed that this setup results in ca. 5-20 seconds delay between the individual performers sending their sound to Icecast server and hearing the same sound back as part of the final mix.

### Developing the Algorithm

When performing with GIASO, there is always a performer in the performance space who is responsible for the final mix of the incoming streams. This solves many issues of asynchronous performance as there is a final 'gatekeeper' who can curate which streams currently sound most coherent together. However this raises some interesting considerations as clearly this act of mixing mediates the musical flow of the performance by picking and choosing whose sound gets heard by the other performers. Many different potential versions of the same performance are never realised due to the mixing decisions of this key performer, as their curation impacts not only the current moment, but the future decision of performers in how to react to the current sound mix. Additionally, the human mixer is not free from bias, and memory limits mean the ability of the mixer to mix 'fairly', i.e., so that all performers have a relatively equal amount of participation in the performance, is limited. Therefore we can clearly see that a performance hierarchy exists whereby the mixing performer has a large amount of power to shape the structure and musical narrative of the performance. This analysis served as the basis for designing an algorithmic mixer, with 3 distinct tasks: (i) to ensure a sound musical

[1] Including any female-identifying, or gender non-binary persons.

structure at the macro-level of the performance; (ii) to ensure equality of participation among performers; (iii) to use musical 'consensus' as a basis for shifting the power balance of the mixing task back towards the performers.

The *Union* algorithm uses machine listening techniques to detect similarity between the streams and attempts to balance 'consensus' against 'fairness'. The basic algorithm mixes the stream with the most 'average' audio features the loudest, scaling the other stream's amplitudes between 1 (most average) and 0 (least average). A higher level algorithm tries to ensure musical flow by moderating the density of the performance – every section has *n* streams which will be audible and every stream after the first *n* most average streams has an amplitude of 0 for that section. Each section has one more or one less stream than the last, with a slight tendency towards building up the density. Section breaks are made when the system switches to giving the *least* average stream the loudest amplitude. A final step in the algorithm balances the above with trying to ensure that all players get approximately the same amount of time 'on air'.

In performances with the system, a projection is used to show the online chat interactions between performers, giving audience members an insight into the musical decisions of the players, and their reactions to the algorithmic intervention, revealing to audience members the humanising elements of the musical interaction. In addition a visual aspect was developed which shows a (highly processed) photo of the currently audible performers. This seems to be relatively successful in showing how the algorithm is functioning to audience members and linking sound to specific performers.

## Flock

*Flock* explores flocking mechanisms in network structures as a means of managing collaboration in a live coding performance. Loosely modelling the behaviour of bureaucrats in their interactions with self-regulating political systems, the three performers engage in a live coding election battleground, hoping to win votes from an artificial population. The more votes a performer wins, the more prominent in the final mix that performer's audio signal will be.

*Flock* is a system of voting agents who each have musical preferences. In a similar way to Union the audio of several performers is analysed using machine listening techniques and at regular intervals the agents vote for whichever stream has the closest audio feature values to their preference. The audio is mixed accordingly, i.e., if a performer gains 40% of the votes their audio level is set to 0.4. In an attempt to more closely model real world electioneering, the agents are connected via a bi-partite network and their preferences are influenced by the outcome of each round of voting and the preferences of other agents they are connected to. The performance uses live coding as an analogy for political rhetoric and policy writing with the updating of a running process to get closer to AI preferences as similar to the way that politicians rescript their policy proposals in response to opinion polling.

SuperCollider's JITlib was chosen as the language of algorithmic politics as SuperCollider is a reasonably neutral language, which places relatively few stylistic limits on performers, allowing them to form their own musical manifestos. Performers will develop their framework code in rehearsals beforehand, allowing them to form individual musical election strategies, before making their policy proposals (in musical form) to the artificial population in performance.

The voting mechanism itself is based on Rosen's work on flocking in bi-partite decentralized networks (Rosen 2010). Rosen proposes that the most efficient and successful means of managing large group collaborations is through decentralised self-regulating networks. He suggests that these networks can maintain their decentralised non-hierarchical organisations through flocking mechanisms.

In *Flock* the network is made up of two types of node: feature trackers (using the SCMIR library in SuperCollider); and AI agents (who have preferences and voting rights). The feature tracker nodes hold information relating to the current feature states of the input audio from the performers (one node per feature). The agent nodes each have a profile, which includes ideal state preferences for each feature which is being tracked, and values denoting how autonomous they are – i.e., how strongly they are influenced by neighbour nodes. These features combined define the position of the node in the network and how it moves within the flock.

Performer feedback on the system includes that the system exerts a pressure to perform all the time in order to win votes, and that musical choices are influenced by the voting of the agents, i.e., a good strategy to win votes is to play similar sounds to whichever performer is currently leading. However, the flocking of the agents means that it's not possible to predict exactly how agents will react or move within the network and preferences change radically over the course of the piece, so the performers must also react to changing tastes of the agent population.

## Conclusion

The systems described explore possible synergies between the dynamics of improvisation in music ensembles which use network technology to exchange musical and social data, and the dynamics of online social networking which is fundamentally mediated by algorithms and interface design. The three pieces discussed each explore the dynamics of human interaction when data collection and algorithms are used to modify or moderate this interaction, and algorithms subvert or enable particular power-dynamics within the group.

Magnusson (2009) points to the political, ethical and aesthetic nature of technology and how technology design structures human action and interaction, particularly software technologies, which are capable of reflecting the thought structures of their designers, necessitating a reflective responsibility from the ethical programmer. This is of prime concern in designing socially-aware systems which mediate performer interaction, and requires critical reflection and active acknowledgement that a value system is percolating through to the performance system. The impact of the system on performer agency should always be at the forefront of the design choices.

Relating to deliberative democratic ideals which resist consensus and the desire to avoid traditional composer-performer hierarchies, an important goal in my research into interface design was to not impose strict musical choices on performers, and therefore to have somewhat musically neutral design choices, which focus on performer interaction rather than content and musical structure.

Consensus is also an interesting avenue of exploration in relation to improvised performances, particularly in telematic contexts. The temporal nature of improvisation and the imperfect communication channels of audio and visual mean that immediate action and reaction without conferral is the standard route available to the unfolding of the performance in free improvisation. Musical dialogue, harmonious or antagonistic, directly drives the collaboration. Network music systems with the ability to collect data and provide text based communication in-performance, as well as the possibly controversial ability to restrict access to technical resources, allows us to investigate consensus in the context of musical interaction. Obvious arising questions which are actively explored through the design process include, how can we determine musical consensus and is consensus always desirable. The approach taken in the systems above was to develop algorithmic methods of deducing a form of consensus, while acknowledging the system designers' non-neutrality and the impact they therefore have on the group dynamic.

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# INSTALLATIONS

## Introduction

Cecile Chevalier

We were pleased to present a series of installation work by artists and researchers that thought about live interfaces from reappropriation of obsolete technologies and of junk instruments, to tracking technologies, and the body itself, whilst questioning ways in which the live interface experience expands thinking around synesthesia, ecosystems, ludic experiences and politics. These installations were a wonderful addition to 2016 ICLI conference.

# Signal to Noise: A Live Interface based on Analog Radio Interference

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**Abstract.** "Signal to Noise" is a sound installation using radio transmissions and mobile radio receivers as an interface for audience-based performance. Carrying radio receivers, the audience moves through the space created by two overlapping radio transmissions that broadcast on the same frequency, creating a volatile acoustic space of radio interference that changes with each motion of every participant. The result is an embodied and interactive creation of a soundscape which is shaped by the unpredictability of interference and noise in analog radio. The installation deals with the battleground of ideological discourses, broadcasting archived radio programs of the Cold War era. Listeners move through the space in which transmissions from the East and West jam and disrupt each other and with every motion enact an ever-changing soundscape. The resulting choreography technologically reenacts the "fight over hearts and minds" at the border between East and West, recalling the technological and ideological mechanisms used during the Cold War, where Western propaganda radio was jammed by Eastern authorities.

**Keywords:** Interference, Analog Interfaces, Installation, Audience Interaction, Technological Reenactment

## Description of the Work

"Signal to Noise" is a sound installation using FM radio transmissions and mobile radio receivers as a lo-fi live interface for audience-based performance. Carrying radio receivers, the audience moves through the space created by two overlapping radio transmissions that broadcast on the same frequency resulting in a volatile acoustic space of radio interference that changes with each motion of every participant. The outcome is an embodied and interactive creation of a collective non-musical soundscape which is shaped by the unpredictability of interference and noise in analog radio. Using radio transmissions as a medium of interaction, the installation exhibits highly sensitive and lag-free interactivity, facilitating a spontaneous choreography of the audience. As a live interface, the installation demonstrates the "post-digital" use of seemingly outdated technologies in combination with digital devices to achieve a responsive environment that does not presuppose advance gesture recognition or tracking technologies but instead engages the human body in a system whose reactivity results from analog devices alone, and their uncontrollable yet fascinating interaction.

Thematically, "Signal to Noise" deals with the concreteness of ideological discourses and the imaginary of the "Other" by technologically reenacting the interference strategies used during the Cold War period. The volatile acoustic space spanned by the two radio transmitters becomes a space in which two concurring voices compete. These two voices consist of archived material of the Cold War era from (Western) Radio Free Europe and (Socialist) Radio Romania. Carrying mobile radios, listeners move through the space in which both transmissions jam and disrupt each other. It is only when they will come across the middle line formed by the two transmissions, that listeners will break the neutral point and it will become possible to hear fragments from of one of the two broadcasts. It is like being cached between two Logos (or two ideological positions), where beyond words, the ideological and media wars embody beings.

The resulting choreography re-enacts the “fight over hearts and minds”[1] between East and West and recalls the technological and ideological mechanisms used during the Cold War – when CIA-funded Radio Free Europe was meant to counter Socialist ideology and in turn was jammed by eastern authorities. The radio space in that era was considered an “invisible battleground” of broadcasting, jamming and complex technological counter-jamming strategies. Radio Free Europe is considered unique in the annals of international broadcasting because of acting as surrogate domestic broadcaster for the nations under Communism. It also relied on local official media and informal news in order to broadcast what was considered “objective” information. By doing so, it also gave shape to an inaccessible public, instantiated as the “East”.

By using lo-fi and DIY-methods, the project also recalls the bricolage strategies used to circumvent state propaganda that are reflected in today’s technologies for activism. Far from being historical and contextual dated, the fluidity of radio (or “Hertzian”) space continues to be relevant today, in the age of wireless communication and coded information.

“Signal to Noise” is part of the project “Repertories of (in)discreetness” – an art research project that has its starting point in the archives of Radio Free Europe from the Open Society Archives in Budapest, considered one of the most important archives of the Cold War period. The project questions the act and mechanisms of archiving the “Other”, with a focus on the European East. It discusses the ways in which information is collected and transferred, the ways in which the East has gained an epistemic body through refraction, as well as the ways in which this body is reiterated today.

# Additional Information

## Biographies

Following Visual Arts and Cultural Anthropology studies in Cluj (Romania), **Tincuta Heinzel** completed her PhD in aesthetics and arts sciences at Paris 1 University (France) in 2012. She is interested in the relationship between art and technoscience, with a special focus on smart materials and wearable technologies. She curated and coordinated several projects, such as “Areas of Conflu(x)ence” (Luxembourg, Sibiu/Romania, 2007), “Artists in Industry” (Bucharest/Romania, 2011-2013) and “Haptosonics” (Oslo/ Norway, 2013). As an editor, she published “Art, Space and Memory in the Digital Era” (2010) and coordinated Studia Philosophia‘s issue on the “Phenomenology of Digital Technology” (2010). Tincuta is member of 2580 Association Cluj (Romania) and of Paidia Institute Köln (Germany) and is currently research fellow at Nottingham Trent University (UK) and visiting professor at “Ion Mincu” Architecture and Urbanism University Bucharest (RO).

**Lasse Scherffig** is an assistant professor for art and technology at San Francisco Art Institute. His work explores the relationship of humans, machines and society, technological infrastructures of communication and control, and the cultures and aesthetics of computation and interaction. He recently defended a doctoral dissertation on Cybernetics and Human-Computer Interaction at KHM, Academy of Media Arts Cologne. He co-founded the trans-disciplinary artist group Paidia Institute and has been a visiting professor at Bauhaus University Weimar. He has published on a variety of subjects, such as locative arts, Cybernetics and the development of Brain-Computer Interfaces. His art projects have been shown at Tranzit Bucharest, Science Gallery Dublin, Transmediale, ISEA, National Art Museum of China, and the ZKM.

**Acknowledgements.** The research for “Repertories of (in)discreetness” project was possible due to a Visegrad Scholarship at the Open Society Archives in Budapest (HU) in 2015. For “Signal to Noise” we received technical support by Lab3, Laboratory for Experimental Computer Science of the Academy of Media Arts Cologne (KHM) (D) and we were able to make some preliminary tests at Opekta Ateliers in Cologne (D) in April 2014. The exhibition “Repertories of

[1] “fight over hearts and minds”. Expression used by the American propaganda during WWII.

(in)discreetness” was presented at Tranzit Bucharest in March 2015 with the support of Erste Foundation, Goethe Institute Bucharest, OSA Archives Budapest, 2580 Association Cluj, Radio Romania Archives, Fortepan Budapest and National Dance Centre Bucharest.

Figure 1. “Signal to Noise” installation view, Opekta Ateliers, Cologne, April 2014.

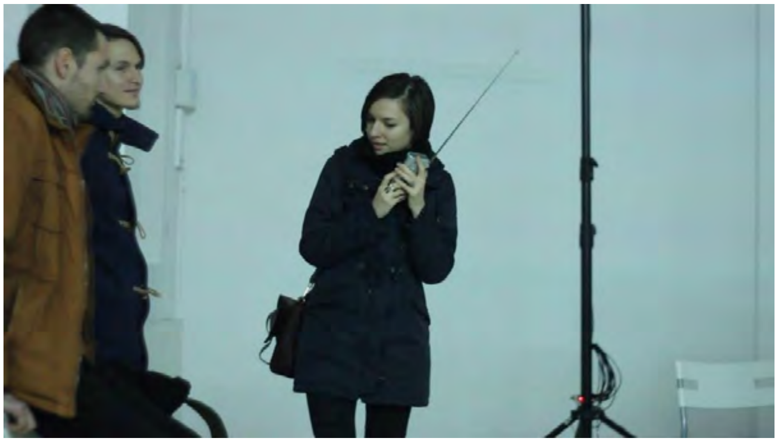

Figure 2. “Signal to Noise” installation view, Tranzit Bucharest, March 2015. Photo: Istvan Laszlo.

# A Sound and Puppet Archaeology of Vehicular Emissions and Other Excited Rotations A Holiday Snap

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**Abstract.** The performance mixes noise, object, theatre and puppetry in a semi-improvised burst of sound and image. Both Paul and Matt are exploring the world of 'Junk' in their respective fields, and this show builds soundscapes, instruments, puppets, objects and conceptual themes from the abandoned and the pollutive aspects of Transport and Travel. Junk Instruments are used for the acoustic qualities but are also transformed electronically to create new and idiosyncratic methods of sound performance. Abandoned objects are used as props and functional items in the show. Puppets, lighting, objects and other performative materials are constructed from the detritus of society.

**Keywords:** junk music, puppetry, performance, improvisation.

## Introduction

This performance explores new interfaces for musical expression using sonic waste and ludic events to travel around found texts, for example – the Hayes motoring manuals. Haptic interfaces are interpreted live through the way media archaeology is brought to life in the use of visual and aural junk. This is developed through using broken projectors, redundant sound equipment and the guts of smashed technology. Puppetry and animation is used throughout to investigate the vibrant hum of objects and also performing objects in the form of found objects and puppets. The acoustic and the digital is represented through the way objects and analogue systems are played with in the space and how some machines are specifically animated sonically through the use of bespoke computer applications designed by Rogers. Multimodal and multisensory media is located in the mix of analogue, digital, junk and the performance of media archaeology. Audiovisual performance is represented ludically through the way objects and sounds are repurposed within the new poetics of the performance space. The performers use audience interaction and comedy in the performance throughout to develop an interactive and joyful exploration of the potential wonder that matter can provoke through performance and play.

## Figures

Figure 1. Matt Smith operating projectors.

Figure 2. Humphrey the puppet

Figure 3. Shadow figure in cine projector light



Figure 4. Paul Rogers playing junk.

Figure 5. Some of the objects of the stage set.

Figure 6. The dashboard instrument and projector screens with broken slides.

# Brighton Community Choir Does... Without You

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**Abstract.** 'Brighton Community Choir Does...' is a participatory choir project that utilises physical and conceptual objects to encourage the formation of an impromptu choir. Part of an ongoing series of 'Line-Making' works based around a common score, these interventions use lo-fi and everyday objects and materials – wood, chalk, mp3 players, paint, coins - to create unusual and unexpected events within the everyday. The film 'Brighton Community Choir Does...' documents the use of a painted wooded sign emblazoned with the words from a pop song to interface with the common experiences of the inhabitants of Brighton's clubbing district. The work "seems to be attacking the wrong audience with an over clever statement that will be lost on most of the participants".

**Keywords:** participation, autonomy, low-tech, Mariah Carey.

## Introduction

Brighton Community Choir Does...' explores the use of limited, recognisable 'low-tech' materials as a means of lowering the participatory barriers raised by the implementation of more complex technology. By focusing on a badly-taped sign decorated with simple hand-writing, the performance directly challenges the position of power often taken up by the performer in regard to their audience, and allows the simplicity of its tools to foster a dynamic in which the audience have no less control over the outcome than the performer. The use of an interface comprised of recognizable material – be they conceptual or physical – allows participants to engage with the work on a more autonomous level. There is no new skill to be learnt, no 'wrong' way of interacting with the work, and no hidden mechanisms.

The work involves a performer carrying a large wooden sign through the streets on a busy Saturday night, emblazoned with the chorus lyrics to the Mariah Carey hit 'Without You'. The performer is heckled throughout by the cities inhabitants, continuing to hold the sign aloft and stopping, without expression, to witness those who choose to engage with it. Given the inebriated nature of its potential participants, the work relies not on any explicit participatory model, but on the unknowability of the responses that it will illicit. With this in mind, the performer offers no additional information beyond the carrying of the sign, refusing to interact with the world except through that object. Rather than relying on any assumptions as to who might participate and how they might do so, the simple, identifiable nature of the works object and theme creates an open-ended event in which participants can interact – or not – in any way they see fit. Lacking any 'correct' way of interacting with the performance, participants retain the confidence to test out a variety of ways of being in the same shared space as the object – singing, dancing, shouting, protesting, fighting, and so forth. Part of the dynamic is that, given the nature of the environment, the performer is visibly afraid of his audience – and throughout the performance is subject to not only positive interactions – conversation, singing, applause – but also negative responses such as being shouted at, spat on, and physically abused. The idea, as demonstrated by the work and its accompanying film, is that the minimal materials of the interface in combination with their unique context, allow the audience to respond in a far stronger and far less predictable manner than otherwise might be the case.

**Photographs**


## Biography

Daniel Alexander Hignell-Tully is a participatory artist currently undertaking a PhD at Sussex University. His work focuses on a broad spectrum of sound-based practices, exploring the intersect between performer and audience within the confines of the art event. His work examines the implementation of music and art as a community practice, invoking numerous contemporary models of participation to avoid the tropes of 'community art'. His PhD work, 'As a Process of Line-Making', involved the creation of a 130-page score for performance upon a wide range of instruments and materials, including chalk, wooden signs, coins, drunk people, children's story books, cardboard boxes, tape measures, churches, harmoniums, cake, shopping centres, feet, carrots, and modular synthesizers.

# DOT, a videogame with no winner

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**Abstract.** 'Dot, a videogame with no winner' is an interactive installation with synchronized sounds and images, played with an audiovisual synthesizer in the form of a 'game console' built and programmed by the artist, and controlled by vintage videogame (Nintendo) joysticks. The instrument is completely autonomous and works without a computer, using only a projector and sound system to play its content.

**Keywords:** audiovisual synthesizer, generative, HOL, interactive installation, standalone instrument, videogame, visual music, abstract art.

## Introduction


Figure 1. Instrument

'Dot, a videogame with no winner' is an interactive installation with synchronized sounds and images, played with an audiovisual synthesizer in the form of a 'game console' built and programmed by the artist, and controlled by vintage videogame (Nintendo) joysticks. The standalone instrument works without a computer, using only a projector and sound system to play its content.

The project was created with the idea of criticizing some aspects of game logics, but using its own aesthetics, sounds and characteristic graphic elements. The work criticizes, through abstract images, themes linked to people's everyday life and games. All images and sounds were created and programmed by the artist and they are generated in real time as the visitors press each button on the joystick.

The piece has 5 parts, like the levels of a game. The visitors control all sound and image elements using two joysticks – as if they were playing a videogame at home. The difference is that there is never a winner.

The performance works as a game, and each part deals with a specific theme:

**– Level 1 – Shot**

Level 1 - a criticism of the high degree of violence in nowadays games – is represented by a red background is the scenery to the players actions. The latter consist in drawing red lines inside a blank red square. This square is an abstract shape that symbolizes a bullet hole, while the trickling lines resemble the blood coming from the injury. The players define the point where the drawing starts, while generative animations take part in the scene, in the form of branches that randomly come out of the main core. Thus, the players generate only part of the image, while the random lines have their own particular behaviours. Each sound is composed by a single frequency that follows the X and Y current position of the end of each line. Other sounds complete this composition: a continuous pattern resembling a heartbeat, and some noisy sounds that are triggered each time a player presses a button symbolizing a painful cut in the flesh.

**– Level 2 – Put you down**

Level 2 is a metaphor of human behaviour that uses the degradation of the other as a way of self-promotion. Each player controls an abstract shape that symbolizes a hammer that, once pressed, falls over the other participant's avatar, sinking him deeper into the ground. The guest is able to make melodies pressing the joysticks buttons. Each button generates a synthesized sound. I can play these melodies as well, and my joystick has extra functions used to add some patterns to the soundtrack and also change visual elements. The colours black and white were chosen to make more explicit the contrast between the players.

**– Level 3 – Capital**

Level 3 is called 'Capital'. Each player controls the vertical and horizontal position of falling elements. The position where each new element appears is a random variable, and the players don't know where the next one will appear. The sound is composed by some generative elements and the horizontal position of each shape changes the pitch of the two main voices. An invited player controls the end of this part, while the game enters a glitch aesthetic as all the gaps had been filled. As the entire screen is filled with the falling shapes, the instrument enters a glitch mode where non-programmable images appear randomly on the screen. Now players have no longer control over their actions. This part is a metaphor for the chaos created by the ultimate level of capitalism. The sound gets messy and everything gets deteriorated until the initial scenery is no longer recognizable. This happens because the counting variables enter into an overflow resulting in completely unexpected results in sound and image.

**– Level 4 – Mimesis**

The next level - Mimesis - is made up of a black and white graphic background that changes each time I press a specific button, and two red sprites that represent each player. Players can choose among different shapes in order to look equal (or not) to the background. If the player chooses a shape similar to the background he will almost disappear, whereas a different shape will distinguish him from the background. This type of programming approach criticizes the mass behavior of people that prefer to be lost in the crowd instead of standing up with their specific features. This level has a very rhythmic approach and the artist can turn on and off some audio patterns with random elements in their melodies.

**– Level 5 – To the Future**

The last level is called 'To the Future' as a metaphor for the decadence of culture in today's world. It resembles a continuous backward movement in the world's evolution. All the players can do is postpone their falling and disappearing at the bottom of the screen. The images refer to the idea of ski diving down a mountain, with trees passing through. Here the position of each player builds the main motif of the soundtrack, added to the sound of background elements passing through the screen. Other patterns are turned on and off by me in order to create a dynamic soundtrack. The rhythm is composed by generative elements, with random notes composing the melody and rhythm.

Figure 2. Example of image generated by the instrument

The instrument has an Arduino board, a Gameduino shield and two SNES controllers, enclosed into a plastic box. Arduino receives the information from the 2 joyticks and each button is assigned to a variable. The programming was made inside the Arduino enviroment, using the Gameduino library. Gameduino is a shield that can be linked to Arduino and has VGA (video) and a P2 plug (audio) stereo output.

Gameduino1  is the core of the circuit. It can generate color images and 64 synthesized independent voices. But this shield has many limitations. It can handle a 256 maximum number of sprites on the screen at the same time, each one with 16x16 pixels. It can display a small number of colors simultaneously, and also a limited processing amount. Video output has only 400x300 pixels and 512 colors.

A library2  was used to get the information from SNES controllers and convert them in variables that Arduino could understand. The joysticks control all the real time functions during the performance and each one controls different parameters according to the 'level' that is being played.

After building the circuit, all the components were put into a plastic case with a 'retro feeling' adhesive on top. A 12V power source was used for it to work standalone. For the live performance, the VGA output should be sent directly to the projector and the P2 connected to a stereo sound system.

[1] "Gameduino - a game adapter for microcontrollers", 2011, http://excamera.com/sphinx/gameduino/
[2] "nespad - NESpad Nintendo game pad library for Arduino", 2011, http://code.google.com/p/nespad/

## Links to Further Documentation

More information, photos and videos: http://hol.1mpar.com/?page_id=811

## Biography

Henrique Roscoe is a digital artist, musician and curator. Works in the audiovisual area since 2004. Is graduated in Social Communication (UFMG) and Electronic Engineering (PUC/MG) and has expertise in Art and Culture (FUMEC).Has a conceptual and generative project called 'HOL'. With this project had performed at the main live images festivals in Brazil like Sónar, FILE, ON_OFF, Live Cinema, Multiplicidade, KinoLounge, FAD and also abroad, in England (NIME, Encounters), Germany (Rencontres Internationales), Scotland (Sonica), Poland (WRO), USA (Gameplay), Greece (AVAF), Italy (LPM e roBOt), Mexico (Transitio) and Colombia (Festival de la Imágen). Participated of videoart festivals in many countries as Germany, France, Spain, Holand, USA with documentation of the performances.Is the curator of FAD – digital art festival - that happens in Belo Horizonte since 2007. Makes part of the audiovisual duo 'ligalingha'. Develops interactive installations, programming in Processing, vvvv and Max/Msp. Builds instruments and interactive interfaces using sensors and common day objects. Produces stage design for bands like Earth wind and Fire, Skank, Roberto Carlos and events in Brazil, Germany and USA. As a VJ participated of the festivals Skol Beats, Creamfields, Nokia Trends, Motomix, Eletronika among others. www.1mpar.com

# Synaesthetheatre: Sonification of Coloured Objects in Space

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**Abstract.** Vision and sound can interact in many ways. For synaesthetes, sounds can automatically and consistently elicit vivid colours (and vice versa). Could a device that converts vision into sound provide not only a window into synaesthetic experiences, but also be a way for the visually-impaired to 'see with synaesthesia?' Sensory substitution devices (SSDs) convert live video into sound so users can experience visual dimensions through changes in auditory feedback. SSDs allow the visually-impaired to 'visually' locate and recognise objects, as well as expand access in education and art. Drawing upon research exploring natural hearing mechanisms and synaesthetic associations, an SSD called the 'Synaesthetheatre' has been developed that replicates the experience of synaesthesia for use as a visual aid. The Synaesthetheatre turns 3D spatial and colour information into aesthetically pleasing sounds that vary in real-time. We encourage attendees to experience a new form of synaesthesia through an installation at ICLI 2016.

**Keywords:** Sensory substitution, seeing, hearing, vision, sound, depth, distance, colour, sonification, synaesthesia.

## Introduction

Visual content permeates nearly all aspects of human experience, from picking up a cup of coffee to exploring the natural world. However visual information is not inextricably linked to the eyes. By using sensory substitution devices (SSDs) that convert visual dimensions into auditory ones, it becomes possible to 'hear vision.' Here we explore how sonifying visual information has been previously done to improve access to science, art and the wider visual world for blind and visually-impaired persons (BVIPs). Furthermore we discuss how the use of the psychological associations between vision and sound, as found in synaesthesia and the wider population can not only optimise the design of these devices but also allow access into experiencing a new form of synaesthesia. We present a new SSD called the Synaesthetheatre that hopes to achieve these aims and will be demonstrated as part of an installation at ICLI 2016.

## A History of Sonifying Vision

Representing visual information through sound has a rich history. Galileo Galilei provides the first occurrence of this in 1586, who when needing to count the number of times a fine wire coiled around a bar for a scientific test, found the visual examination too difficult to count. Instead, Galileo ran a dagger down the bar and over the coiled wire, counting the auditory clicks that occurred. This way sonification provided access to the scientific data he required where vision fell short (Anstis, 2015). The sonification of scientific data remains to this day through providing access to graphs for the visually-impaired and in illustrating the temporal aspects of data where hearing provides a finer resolution than sight (Ebert, 2005; Guttman, Gilroy and Blake, 2005). Likewise, the sonification of paintings and performances, have also improved the accessibility of art for BVIPs (Cavaco et al., 2013a; 2013b; Mengucci, Medeiros and Amaral, 2014).

The sonification of sight itself has revealed fundamental processes on how our brains understand and process information as well as construct visual consciousness. In 1992, Peter Meijer designed the 'vOICe' (middle letters sounding out 'Oh I See!'), a device that typically converts one greyscale image into sound every second (Meijer, 1992). A single vertical column sweeps across the image, panning from the left ear to the right, turning the pixels under the column into sound. The vertical location of the pixels determines the pitches played (high locations play high pitched notes) while the brightness of the pixels determines their loudness (bright luminances play louder sounds). For an image such as this:  the user would hear a low pitched tone in the left ear, progress smoothly to a high pitched tone in the right ear. Users of such devices are able to locate and discriminate objects such as books and bottles from sound alone, furthermore, the processing of these auditory shapes takes place in regions of the brain previously thought to be 'sight-specific' for shape discrimination (Amedi et al., 2007). This new way of representing sight shows that the brain is not sense-specific but is able to extract meaningful data from potentially any sense and pass it on to the areas of the brain best suited to the task (Reich, Maidenbaum and Amedi, 2012). For blind users of such devices, the visual cortex becomes increasingly involved and necessary for the effective use of these devices (Merabet et al., 2009). Perhaps most stunningly is that long term users report conscious experiences of sight being generated by the auditory signals (Ward and Meijer, 2010). For those with previous experiences of sight this provides compelling evidence that the visual information provided through sound is enough for the brain to reconstruct a conscious visual world. Furthermore, while the SSDs provide some information, they often lack others, such as smooth motion, colour and depth. However over time, the brain is able to fill-in these gaps to create a smoother, more colourful 3D world (Ward and Meijer, 2010). Practically speaking, the mental construction of an accurate 3D world and identification of upcoming hazards is essential to safe and confident navigation of wider society for most BVIPs.

## Designing Sensory Substitution Devices

When designing devices that convert visual information into sound, several factors have to be considered. The first is purely informational capacity; the sheer quantity of information of can be received and resolved by the senses. Overall the eyes can discriminate many more bits of information than the ears (Jacobson, 1950; 1951). As a result visual information has to be simplified in order to fit through the sensory 'bottleneck' of the ears. Which information is best to keep or exclude remains an open question, some devices preserve a high spatial resolution through feeding information in a piecemeal fashion, while others prioritise fast feedback loops between visual and auditory changes over spatial precision. Recently, colour information has also been explored as providing practical benefits to scene and object recognition beyond what basic increases in spatial resolution can provide (Hamilton-Fletcher and Ward, 2013).

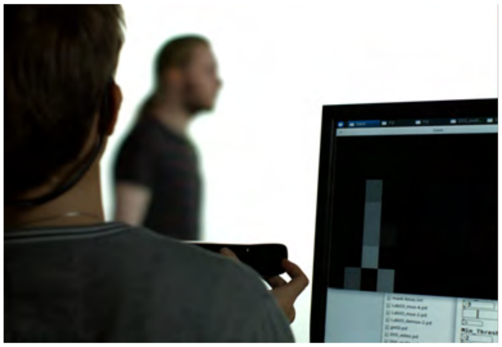
Beyond simply transmitting the information, is there an optimal way of representing visual information in sound for the end user or is any consistent pattern comparable to any other? The first optimisation that can be taken is to utilise our natural hearing mechanisms when appropriate, for instance, the horizontal location of an object could be communicated by replicating the experience of hearing a sound emitted from that location in space. This is done by creating a 'head-related transfer function' that describes the relative timing and intensity differences received from a single sound source for the left and right ears. For resolving the vertical location of objects, while the shape of the ear does actually attenuate certain frequencies based on height, this vertical discrimination skill is impaired for BVIPs (Lewald, 2002). Instead the more abstract mapping of pitch-height is a common approach in SSDs. This draws upon a body of psychological literature that finds that humans intuitively relate high pitches to high spatial locations, a tendency that is present from infancy (Walker et al., 2010). These intuitive associations are called 'cross-modal correspondences' and describe a wide variety of mappings between the senses (Spence, 2011). Recently evidence has been provided that sound-colour correspondences in SSDs results in superior colour discrimination and memorisation abilities for users (Hamilton-Fletcher, Wright and Ward, 2015). For those with previous experiences of vision, this may help reduce the difficulty in understanding one sense through another.

## Seeing with Synaesthesia?

A related condition to 'seeing with sound' is that of synaesthesia, a perceptual condition that affects approximately 4.4% of the population (Simner et al., 2006). For synaesthetes, stimulation in one sense creates an automatic, consistent and vivid experience in another sense (Simner, 2012), so that listening to music might create a cascade of colours that reflect the quality of sounds being heard. Interestingly, many of these synaesthetic mappings are found to be intuitively linked on an unconscious level in the wider population (Ward, Huckstep and Tsakanikos, 2006). As such, audiovisual media inspired by synaesthesia is rated as more aesthetically appealing by non-synaesthetes (Ward et al., 2008). By using these mappings in SSDs, not only are the intuitiveness and aesthetics of such devices likely to improve, but users could also experience a new synthetic synaesthesia. While there have been multiple attempts to train synaesthesia in non-synaesthetes, only studies with intensive training have reported any perceptual effects (Bor et al., 2014). SSDs are in a unique position to create effort-free synaesthetic experiences in day-to-day life.

## Introducing the Synaestheatre: Practical Synaesthetic Sight

In pursuit of a device that can convert vision into sound in a way that is practical, intuitive, aesthetically pleasing and speaks to the wider cross-sensory experience of human psychology, we present a new SSD called the 'Synaestheatre.'



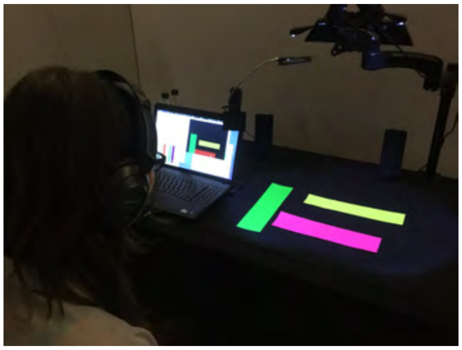


Figure 1. Demonstrations of the Synaestheatre by (left) a blind user detecting the motion of another person and (right) a sighted user listening to various colours. Users can add and move coloured objects while listening to changes in sound. Attendees will also have the option of experiencing both of these at ICLI 2016. See https://youtu.be/7t4NCse6_-w and https://vimeo.com/167031634.

This device turns the 3D location of colours into sounds using both natural hearing mechanisms and synaesthetic sound-colour associations in real time. In particular, a 13 by 7 grid of depth points are selected by a Kinect 3D sensing camera, with colour information in each of the 91 spatial locations categorised into one of seven colour categories (black, grey, white, red, green, blue and yellow). Each of these potential outcomes (91 depth points, 7 colours) has an associated sound that is played when there is the presence of an object in that location. The horizontal position of each pixel gives the sound its associated inter-ear timing and intensity differences. The vertical location specifies the sounds' pitch and the colour provides its timbral quality. The distance from the camera denotes each sound's loudness, with objects beyond the set maximum distance being silent. Furthermore, the device gives the end user a great deal of control over how the image is sonified. For example, pixels can either play independently from one another (mode 1), or can be time-locked together (mode 2). As a result mode 1 sounds similar to an orchestra testing their instruments prior to a concert, while mode 2 sounds like the orchestra playing in rhythmic unison. The timing of sounds can also be offset according to colour categories or spatial position to help users discriminate colour positions.

## User Experiences of the Synaestheatre

Experiences with the Synaestheatre by blind users have been documented previously (Hamilton-Fletcher et al., 2016). The fast temporal resolution and precise localisation of sounds was deemed important as it required minimal effort to distinguish the position of objects and allows immediate detection of changes in an object's position in any direction. The instant feedback was appreciated from moving the camera and sensing the immediate change of sound. The vertical pitch mapping also seemed to be well received, with some describing the experience as "turning the room into music." The Synaestheatre was seen as being the most useful in navigating unknown environments in order to detect obstacles like tree branches or scaffolding sets. Experiences of alternative modes by visually-able users found that while mode 1 was deemed to be "pleasing and challenging," mode 2 was seen as more informative. One user suggested that social events could incorporate this through sonifying the location, movement and colour of guests.

## Using the Synaesthеatre as an Installation


Figure 2. Synaestheatre installation, users can listen to sounds generated by various colours (left) or objects (right).

Attendees will be able to experience the Synaestheatre in a variety of typical use scenarios, from understanding the location of objects to how colour is translated into sound. Through using the 3D sensing camera as a surrogate pair of eyes and listening to the resulting sounds, attendees will be able to discriminate the location and movement of various coloured objects. We hope this installation will help us refine the Synaestheatre, open up discussions on how our senses interact and have attendees experience a unique fusion of sensory substitution and synaesthesia.

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# Lichen Beacons

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## Statement

Whereas digital activism often echoes the frenzied pace and proprietary algorithms of social media, this installation proposes a different, slower politics of interaction and reflection. The cyclical rapidity of digital activism is no match for the slow moving disaster of anthropogenic climate change and new modes of activism are necessary. Responding to the emerging cultural politics of the anthropocene, Lichen Beacons seeks to generate a symbiotic ecosystem in which the symbiosis is modeled on the environmental significance of lichens. Lichens have for some time been recognised as monitors of air pollution, environmental beacons of the anthropogenic shifts associated not just with climate change, but also with sulphur dioxide, nitrogen, oxidants and pesticides. More recently, digital photography and smart phone technology have deepened the global network of lichenologists and activists, revealing a new symbiosis between digital imaging and the non-human environmental scale of lichens. Digital culture is changing human awareness of lichens. The small-scale ecosystems of lichens are nevertheless highly sensitive to the environmental damage inflicted by humans. This installation explores what might be involved in an activist politics of solidarity with lichen ecosystems, by attempting to create a lichenised digital environment that offers a sympathetic symbiosis of text and sound.

Central to the collaborative research that has gone into making a self-sufficient, non-proprietary digital environment has been a new model for using Raspberry Pi technology and digital Bluetooth beacons. Site-responsive, rather than site-specific, the digital environment of Lichen Beacons invites participants to carry a do-it-yourself portable plastic box containing a battery-powered Raspberry Pi with a small screen and headphones (Fig. 1c). Moving around the physical environment of the installation triggers images on the hand-held screen and sound-files in the headphones in relation to proximity to one of the nine beacons. The images offer digital photographs with textual fragments (Fig. 1a), while the sound files offer a sequence of symbiotic combinations of music, field recordings and spoken word. Both the musical environment and its co-existence with the recording of spoken-word files are stacked against the outdoor environment in which the spoken-word files were recorded binaurally. Participants can experience the sequence of image and sound-file combinations in any order, exploring their own environmental relation to the dissonances suggested between indoor and outdoor environments, and between digital and non-digital lichens.

This sound-art installation proposes, then, a new model for what, in her discussion of Marcel Broodthaers, Rosalind Krauss calls the 'post-medium condition' of contemporary art. Rather than suggesting a synthesis of multi-modal immersion, the activism required of participants in this installation is more awkwardly symbiotic and site-responsive, and awkwardly 'contained' within the virtual, ‘individualised’ isolation of a digital sound environment experienced wearing headphones. Critical of the consumption or appreciation of 'nature' for human aesthetics, this awkwardness draws attention to the generative differences between different modes of attention, different kinds of environment and the complicity of the digital in the making of anthropogenic environments that threaten the shared ecosystem of lichens and humans. The photographs offer images of lichens in different ecologies, including cities, car parks and a nature reserve. The spoken word text articulates the conditions of its own possibility by sounding out the language of lichen ecology and digital perception.

One compositional parameter of the spoken text reconfigures relations between nouns and verbs, and between adjectives and adverbs, offering compositional lichenisation of grammatical conventions that would otherwise separate words into different genera and species. The sonic environment in turn juxtaposes field recordings with its own musical environment written using SuperCollider. Working symbiotically in and around the spoken-word text, the musical part is diatonic, using only the seven white notes of the piano keyboard, but resisting the conventional sonorities of triadic chords (Fig. 1b), instead using common-tones for musical continuities. As part of this, the constancy of the note D sounds as a drone and throughout the musical design, both in the headphones and the installation space. The music is harmonically constrained but rhythmically free in its symbiosis with the spoken words. The dialogue between word and music develops a supporting environmental mutualism rather than a parasitic rivalry, and this ecology of solidarity with lichen symbiosis extends into the detailed constraints and freedoms of the installation. A plurality of musical, visual, textual and acoustic digital environments are stacked into the work's physical environment, and this digital stacking is site-responsive, turning the experience of site-specific immersion into questions about the politics of environmental solidarity. Lichens have been canaries of the anthropocene for more than a century: Lichen Beacons offers a model for a new kind of digital activism that might hear and act in solidarity with lichens.

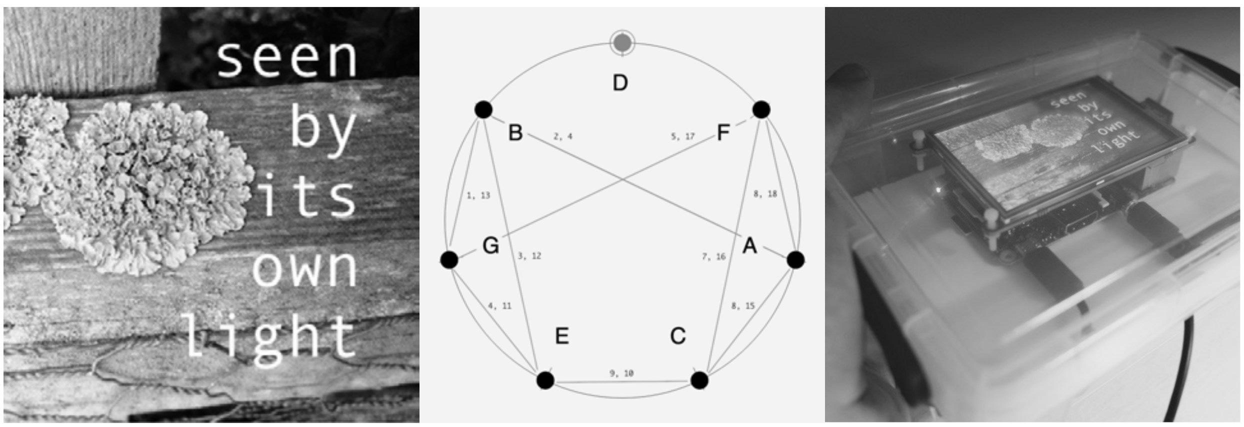


Figure 1. a) Lichen Beacons Section A screen image crop; b) music representation; c) Pi-in-a-box

## Additional Information

Project homepage: [www.ludions.com/projects/lichens/](www.ludions.com/projects/lichens/)

## Biographies

BARRY BYFORD has a background in electronics and creates software to automate electronic design. He is a STEM Ambassador and a regular participant at Raspberry Jams. He has run workshops on GPS and Bluetooth beacons and creates work using interactive physical systems across multiple platforms including the Raspberry Pi.

TOM HALL's music combines acoustic instruments with recordings and electronic sound, often in combination with composed, algorithmic and improvisatory elements. Much of his work uses multichannel sound sources or individually experienced mobile sound. Recent collaborative performances and installations share forms of digital notation with audiences and involve notions of flow and slowness. Tom is a lecturer in music technology at Anglia Ruskin University.

DREW MILNE's recent books of poetry include: equipollence (2012), the view from Royston cave (2012), Burnt Laconics Bloom (2013), and, with John Kinsella, Reactor Red Shoes (2013). Previous books include Sheet Mettle (1994), Bench Marks (1998), The Damage: new and selected poems (2001), Mars Disarmed (2002), and Go Figure (2003). Since 1997, he has been the Judith E Wilson Lecturer in Drama & Poetry in the Faculty of English, University of Cambridge.

# Limits To Growth

Martin Parker[1], Owen Green[2]

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**Abstract.** Limits to Growth is a sonic parasite. It feeds off its surrounding auditory environment in order to make itself heard. Over the course of its infestation, its relationship to the environment changes. Interventions from invited artists, gallery staff, passing traffic and its own voice see the work 'mature' in situ, establishing a niche. The piece develops from something closed to something structurally coupled to the environment, where behaviours and transformations of sound are themselves driven by what it 'hears'.

**Keywords**: sonic art, feedback systems, multi-channel audio, performance with installation

## Description

Limits to Growth (LTG) feeds off the sound of its surrounding environment via four miniature microphones positioned around the space. It records and stores sounds at intervals which are then used and transformed as the basis for its utterances. LTG is designed to exhibit changing behaviour over the course of its inhabitation of a space. Initially, it is a closed system—simply a piece that sounds periodically; over time it becomes more coupled to its surroundings, such that both the nature and timing of its soundfulness are environmentally driven.

As an embedded artwork, LTG aims to draw listeners' attention to the sounds that happen in the venue where it is installed. The sounds undergo this process in situ so automatically adapt themselves to the context in which they are found. This is not particularly interesting until you take into account the character of what has been heard and what is being played.

One the one hand, the piece makes an anarchic comment and intrusion into the environment it is in, regurgitating material based on what it has already heard. In this respect it could be argued that we 'hear' the voice of the machine, randomly exploring itself on its own terms. To some extent this is true, although this machine (like all machines) is not just algorithmically energised but also twisted toward the taste of the people who designed it.

There are two characteristics that impinge on one another. The characteristics of the sounds that occur in the space are integral to themselves and belong to the moment of their creation. As these are captured and played back, they begin to assume characteristics integral to these sounds being played back again in the space. The obvious links to these feedback and transduction processes align in some respects with Alvin Lucier's and Agostino Di Scipio's work.

What becomes important about this work is the way in which these comments on what has already been heard in the space are articulated and how they feed back in. The original content and context provide one characteristic shape, but these shapes are quantised and refashioned by the listening and playback tools we've designed and implemented.

## Biographies

### Martin Parker, 1975, UK

I think sound is at its best when you know what you're doing but you don't know what's going to happen. I explore this idea across my work in composition, improvisation and sonic art by experimenting with sound technologies, people and places. I teach a number of courses as Programme Director of the MSc Sound Design at the University of Edinburgh and am slowly developing a trilogy of pieces designed especially for performance in cinemas. I do a number of other things as well, have a look around this website to find out more http://tinpark.com. To learn about the MSc Sound Design, please go here: http://soundeducation.net. You can access some of my scores and music via online music publisher http://sumtone.com

## Owen Green, 1975, UK

I enjoy making soundful systems that breathe and try, playfully, to adapt to their surroundings. Much of what I do involves making such system-compositions as a territory / provocation / instrument for improvising players (usually me, plus chums). I work at the University of Edinburgh teaching on a number of sound and theory based courses on the MSc Sound Design, as well as working as a freelance composer, sound designer and recording engineer. Check out http://owengreen.net for a selection of projects, sounds, videos and publications.

# [CUE]APORIA: a Philosophy Game

Aaron Finbloom, Sara Zaltash

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**Abstract.** [CUE]APORIA is an experimental gaming interface which combines elements from Fluxus/Surrealist scores, John Zorn's Cobra, The Community of Philosophical Inquiry (Philosophy for Children) and Tino Sehgal's constructed situations. The game explores how contemporary scoring and choreographic techniques can create performative interfaces for philosophical practice which disrupt the technicity of the book, replacing it by that of the card and thereby injecting discursive practices with ludico-dramatic and embodied elements.

The game entails reading and discussing a short theoretical passage alongside Cue Cards which direct the verbal responses based on traditional philosophical structuring (for example: provide a definition), surrealist methods (for example, only speak in questions), and improvisatory frameworks (for example, users write their own conversational directive).

The game will be activated at ICLI as a 20 minute performance intervention for 3-10 audience participants.

**Keywords:** new interfaces of philosophical expression, paratextuality, philosophy games, fluxus, john zorn, tino sehgal, cue cards

## Introduction

How can contemporary scoring and choreographic techniques create performative interfaces for philosophical practice? What happens when the technicity of the book is replaced by that of the card; when a discursive practice is injected with a ludic-dramatic embodied practice?

[CUE]APORIA is an experimental gaming interface I have invented which combines elements from Fluxus/Surrealist scores, John Zorn's Cobra, The Community of Philosophical Inquiry (Philosophy for Children) and Tino Sehgal's constructed situations. The game begins with a chosen short textual passage (for ICLI a text from Interface theory will be selected). This text is read aloud and discussed; however, participants are forced to give verbal responses based on various cue cards. Some of the cards provide more traditional philosophical structuring: analogy, example, reason, definition, clarification, etc. Some of the cards display passages of text itself to be read aloud. Other cards deliberately break and play with language: only say one word at a time, only speak questions, think in silence. While some cards are left blank thereby giving users a chance to spontaneously create context-dependent conversation structures. [CUE]APORIA pushes the practice of philosophy away from the textual linearity predicated in the materiality of books and articles as well as the discursive practice of philosophy aimed at achieving material-independent understanding or semantic meaning. With [CUE]APORIA philosophy's temporality moves along the kairotic temporality and ludic physicality of the cue card interface, which allows for alterations in bodily movement, rhizomatic thinking and word play.

This 20 minute performance intervention requires 3-10 audience participants.

## Prior Iterations

[CUE]APORIA developed out of a series of structured philosophical conversation experiments pioneered by Aaron Finbloom in Montreal during 2015 which were attempts to score John Zorn's Cobra without instruments and rather using intellectual dialogical interlocutors. Cobra is an improvisational musical score or game developed by John Zorn in in the 1980s in New York City. The game's rules were never codified by Zorn and instead one learns the rules through experience or verbal explication. As one who personally witnessed the piece performed multiple times in the past 10 years, I have come to understands that the game works as a conductor uses a complicated system of Cue Cards to initiate particular musical cues. John Brackett describes this process:

> Nineteen different cues are included on the left-hand column of this page. These particular cues—associated with "Operation 1"—describe an event or action that can be called by a player ("caller") through a specific bodily motion (e.g., hand signals, pointing) that is relayed to the prompter who can either accept or decline the cue. If the event suggested by the caller is accepted, the prompter holds up a color coded, rectangular card with the relevant cue and shows it to the entire ensemble (the prompter may also initiate cues). The cue is activated when the prompter lowers the card, an action constituting a "downbeat." (Brackett 2010)

I was interested in attempting to translate the improvisational dimension of this piece into a philosophical and conversation dimension which occurred by across a series of performative experiments. This series was called the "Cobra Philosophy Experiment Series" and had 2 major iterations. The first was at Concordia's matralab in October of 2015. The second was held at Concordia's Topological Media Lab in December of 2015.

Iteration #1 (figure 1) involved giving participants Cue Cards with the letters N, Y, Q, C, D which were abbreviations for: No, Yes, Question, Clarification, Definition. In order to give a verbal response a participant had to raise a card indicating the kind of response intended and then the conductor would call on a number of persons to initiate responses. In addition I also attempted to track the conversation using a secondary conductor role (figure 2) who would write questions, key terms and quotes and project the contents for the conversation interlocutors to implement.

Iteration #2 saw a radical change of direction as we experimented more with writing dramatic and conversational directives on Cue Cards within the context of a developing conversation. Two persons would begin talking as a third person would write a directive for the conversation (figure 3). These directives involved bodily movement, gesture, alteration of tone, shiting of conversation content, and more. Once written, the writer of the directive would display the card in front of the two conversation partners thereby instructing them to perform the given action or prompt (figure 4).

From this experimental series I have taken various successful components from each iteration to create [CUE]APORIA. The game retains the ludic, improvisatory and structured philosophical elements and brings them into a cohesive whole while retaining a rhizomatic fluidity which allows the game to explode or implode given the participants' directives.

## Author Bios

Aaron Finbloom is a philosopher, performance artist, musician and co--founder of The School of Making Thinking (SMT)- an artist/thinker residency program and experimental college. Much of his work involves rekindling the connection between the philosophical and the performative by creating quasi--structured conversations through games, improvisational scores, booklets, audio guides, dance maps, theatrical lectures, existential therapy and philosophic rituals. Finbloom has taught philosophy at Suffolk County Community College, and has curated dozens interdisciplinary immersive courses for SMT. Finbloom holds an M.A. in Philosophy and Art from SUNY Stony Brook and currently he is housed within Concordia University's Interdisciplinary Humanities PhD program.

Sara Zaltash is a live performance artist creating bold contemporary projects that enact an evolving engagement with political, philosophical and spiritual realities. Her work is disarmingly personable, enchantingly direct and prone to radicalism. Out of popular movements, digital lives and ancient practices, Sara seeks frontiers, pioneers and revolutions. Sara is a Fellow of the Schumacher Institute. Sara holds a BA Theatre, Film and Television (Bristol, 2008), a Postgraduate Language Certificate in Persian Language and Literature (Tehran, 2010), an MA Performance, Culture, Context (Leeds, 2012), and a Graduate Diploma in Law (BPP).

Figure 1. Cobra Philosophy Experiment #1 w/ Cue Cards

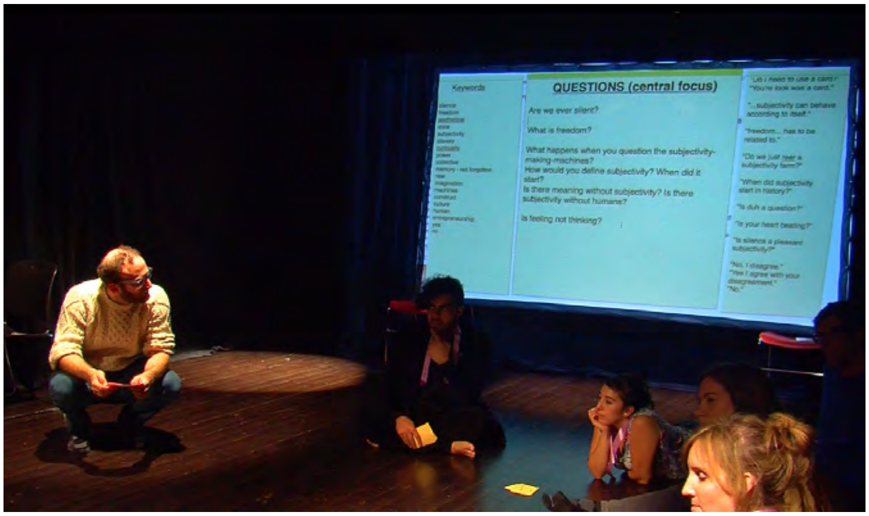


Figure 2. Cobra Philosophy Experiment #1 w/ Cue Cards and Projections

Figure 3. Cobra Philosophy Experiment #2 - Improvised Card Writing

Figure 4. Cobra Philosophy Experiment #2 - Improvised Card Writing Delivery

## References

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# FAUX PAS

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**Abstract.** Over recent years' mobile communication technologies have enabled capitalist networking algorithms to quietly penetrate our daily lives, becoming an integral component in the shaping of our identity. We no longer have sole agency over the presentation of self, as our everyday cycles of impression are laminated together to form a synchronized sphere of monetized data. Where total public transparency has become the default setting, and privacy glass is an alternative 'tickable' option.

Faux pas is an always-on intervention to contaminate the oil of the personal information economy with a foreign body of de-monetized labour. The live performance openly submits my personal sphere of 'life - my quantification, my autobiography and my social media persona - to be publicly curated, socially edited and playfully embodied by others to collectively transmit a faux performance of self.

**Keywords:** agency, identity, nudges, transparency, self-tracking, quantified self, personal Informatics, data politics

## Nudging Transparency

We are sleep walking into a transparent society of authenticated self-monitoring. Where the concept of self- tracking is pushed to be taken up voluntarily as a response to external encouragement, rather than as a wholly self-generated and private initiative. Self-tracking rationales and sites are proliferating as part of a 'function creep' of the technology and ethos of reflexive self-monitoring. The personal informatics derived from life logging are used by actors, agencies and organizations and go beyond the personal and privatized realm (Lupton 2014, 7). Self-tracking fosters a decontextualized blurring of common privacy boundaries by collapsing social contexts. This causes personal information that was formerly confined to and aimed at a particular social context or relationship to transgress its usual borders (Nissenbaum 2010, 40). In some contexts people are encouraged, 'nudged', obliged or coerced into using digital devices to produce personal data to be used by others. Nudging influences agents' processes of preference (and hence, identity) formation by the partial outsourcing of self-government. Under the allure of 'excessive convenience' we are systematically discouraged from shaping our will and agency over active choice. This prevents us from engaging in the existential (if effortful) task of self- constitution that is at the heart of the very process of identity formation (Schubert 2015, 22).

## Faux pas-formance

Faux pas breaks the dichotomy of transmitter-receiver and performer-audience by the dissolution of pre-defined dualities. My primary online identity is suppressed and possessed by an infinite array dissociated personalities, who dynamically re-define their roles to achieve a live state of my cohabitants. The faux performance of distinct personalities collectively adheres to current trends of identity authentication, and embrace the nudges of encouragement from external devices by providing a real-time feed of de-monetized labour.

http://leenutbean.uk/faux.html


Figure 1. Faux pas, 2014, Lee Nutbean, (Used with permission.)

## Biography

Lee Nutbean is a postinternet artist working at the transdisciplinary intersections of art and computation, across academia, research and the creative industries. His work explores the evolution of smart networked technologies through the participatory design of provocative prototypes, that elicit, process and respond to inspirational data. These electronic ecologies culturally probe the dynamic networks within and between corporeal and viral spaces, to reveal new phenomena that confront, question and push new digital practices.

http://leenutbean.uk/

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# PERFORMANCES

## Introduction

Alice Eldridge

ICLI 2016 showcased the incredible compass of practice-based research and critical performance that is taking place internationally, with over 30 performances across club, concert hall and church venues on campus and around town. Kicking off with a mongrel family of hybrid resonant feedback systems, later concerts featured augmented acoustic instruments, modified games engines, interactive dance, performative installations, mobile apps and gesturally controlled synths, rounded off with some immense AV live coding. The variety, calibre and inventiveness of performances at ICLI this year turned a stimulating conference into an inspirational festival for delegates and audiences alike. Bravo everyone.

# Pathfinder:
# A performance-game for the augmented drum-kit

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**Abstract.**

Pathfinder is a performance-game for solo drummer, exploring the synergies between multiple contemporary creative practices. The work navigates between music composition, improvisation, projection/light art and game art. At its heart lies a bespoke electro-acoustic instrument, the augmented drum-kit, used not only to provide the sonic content of the work in real-time, but also as a highly expressive game controller that interacts with an instrument-specific game. The musical instrument offers a much wider range of expressive possibilities, control and tactile feedback in comparison to a traditional general-purpose game controller, and as a result it affords a more diverse and nuanced game play performance. Live electronics, lights, projections and the drum-kit all make up the performance-game's universe, within which the performer has to explore, adapt, navigate and complete a journey.

**Keywords:** Games, New Instruments for Musical Expression, Interface Design, UI/UX

## Augmented Drum-Kit

The augmented drum-kit was developed over the course of five years, and consists of a traditional drum-kit mounted with sensors, contact microphones, speakers and bespoke software. The acoustic kit also becomes the control interface of the electronics with the use of machine listening techniques and gestural analysis resulting in a highly physical performance. There is minimal interaction with the laptop - all control of the electronic sound, game, light and projection control is carried out through the acoustic instrument; the computer serves only as the mediator for all assembled pieces of digital and analogue technology.

## Pathfinder

Within the game, the player explores an open environment by navigating through presets and managing resources. Playing too loud or too fast in the beginning, for example, would mean having fewer resources available for exploration later in the game. Also, the world can be explored non-linearly, and is different on each play-through. While the main mechanics are still in place, presets and resources are positioned differently each time the game loads; the player's strategy will have to adapt accordingly in order to explore as many areas of the world as possible. The interaction between the performer and the game ranges from a very clear and direct relationship between physical gesture and result on the screen, to more obscure relationships and mappings, all of which contribute towards driving the performance forward. From a musical perspective, the game can also be seen as the performance's graphic score, shaping the sonic output according to the present game state and the player's actions within each given situation.

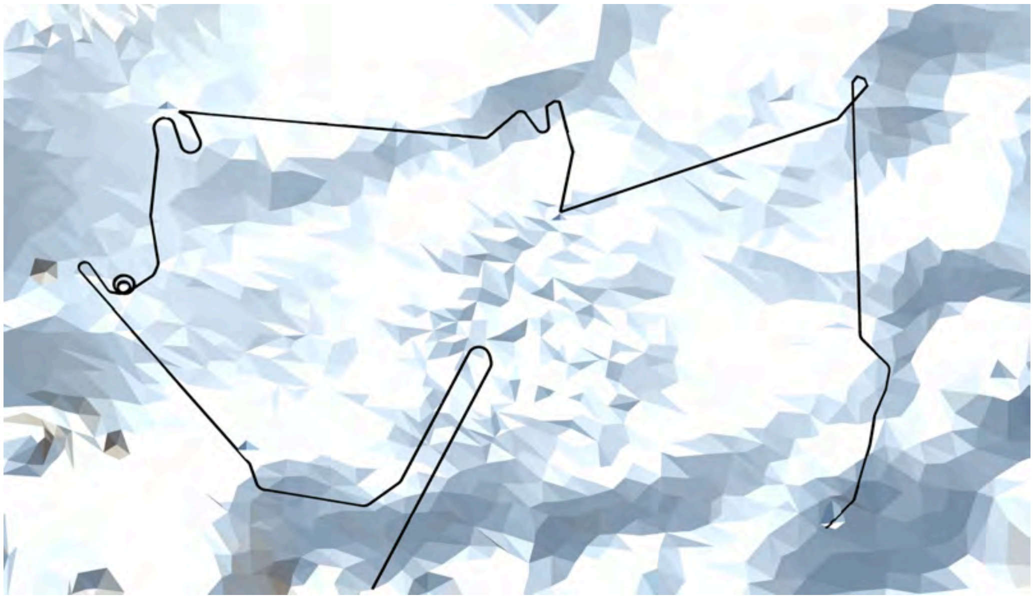

Figure 1. Pathfinder bird's eye view – Navigating through presets

## Biography

Christos is a composer, performer, sound artist and software developer. His work explores the relationships between sound, space, games and bespoke performance environments. He has presented works and talked at a wide range of conferences and festivals including the London Jazz Festival (London 2015), Game Developers Conference (San Francisco 2015), ACM Creativity and Cognition (Glasgow 2015), New Interfaces for Musical Expression (Oslo 2011/London 2014), International Computer Music Conference (Ljubljana 2012), International Symposium on Electronic Art (Albuquerque 2012) and Sonorities Festival of Contemporary Music (Belfast 2011/12).

Before joining Abertay University in Dundee as a lecturer focusing on dynamic audio for games and digital media, he worked as lead audio programmer and interface designer on software used in major films and games including Marvel's Avengers: Age of Ultron, Far Cry 4 and Evolve.

Having completed a BSc in Mathematics at the University of Crete in 2006, he moved to Scotland to pursue postgraduate studies at the University of Edinburgh. He gained an MSc in Acoustics and Music Technology, and a PhD in Creative Music Practice in 2013, examined by renowned composer and multi-instrumentalist Fred Frith.

# Circles

John Robert Ferguson

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**Abstract.** Made in the final days of 2015 this is a new work for self-made electronic instrument: Circles. This version is a wooden box that contains a single-board computer and two micro-controllers. Bespoke software is written in Pure Data and Arduino, running on Linux. Sampling is via in-built microphone. Semi-random and quasi-intelligent sequencing and the creative negotiation of imagined agency is the main agenda. The use of open-source tools is a conscious decision that is important to my aesthetic development and the project as a whole. Circles will be refined substantially throughout 2016 and all software will be available via GitHub soon.

**Keywords:** random, DIY, Arduino, Pure Data, Linux, open-source, post-digital, embedded computing, music technology.

## Description

Focusing on real-time interaction and the multiple connotations of 'performing technologies' the goal is a situation where it is unclear whether I am performing the technology or it is performing me. This, to some extent, might seem to undermine what might be perceived as the autonomy of a musician. However, I am not attempting to remove my own agency from the creative process; this is not in any sense a 'chance' based approach, but one which involves maximum attention and involvement. My approach explores the features and quirks of digital systems, it pushes beyond the digital to digital-analogue hybrid systems, and it seeks renewal through continuous engagement. Less about being in control of a situation than about ways to find lifelike resonances with which to interact, the relationship between imagination, expectation and material is at the foreground.

## Instrument

The more unique characteristics of Circles include the fact that it is self-contained and physical instrument (not a controller for an external computer), the tactile feel of the switches and the feedback offered by the LEDs is also important. Standard sampling and studio practices (re-pitching, time-stretching, filtering, reverberation) play an obvious role, alongside live sampling, sequencing, and drum-machine-style synthesis. However, the main performance strategy revolves around the various parameters that can either be manipulated directly, or via a number of layers of semi-random/stochastic processes. This leads to subtle variations, which is what gives the instrument much of its character.

The current version contains a single-board computer (Odroid C1) and two micro-controllers (Teensy LC and 3.1). Bespoke software is written in Pure Data and Arduino, running on Linux. Sampling is via in-built microphone and although not evident in this video, recording and playback of audio is as near to instantaneous as makes no difference.

## Background

Although I often build bespoke software/hardware or configure commercial devices in unusual ways, my practice to date has been strongly informed by use of standard commercial systems. For example, I have used Ableton software 'Live' since 2003 and keep returning to this platform for three reasons. 1) I find it important to retain a rigorous performance/composition practice outside of the more idiosyncratic instruments that I build/configure. 2) Keeping in touch with commercial offerings is essential in exploring the affordances of genuinely new technologies. 3) Making music is a different kind of art to making instruments. My interest in open source technologies has emerged somewhat obliquely over the last few years as a follow up to activities that I have called 'Feral Technologies'. These former activities are perhaps best described as 'Nicolas Collins style' handmade electronic music i.e. lots of hands-on making with analogue/electronic components, simple logic chips, and wires, but nothing that one would recognize as 'a computer'. Circles aims to explore aesthetics similar to the DIY focus of 'Feral Technologies', but merge these ideas with practices that I have developed through commercial systems. In short: I seek to explore the creative potential and flexibility of digital processing within the realm of open-source DIY aesthetics.

## Biography

John is a post-digital/electronic musician and senior lecturer/head of music technology at QCGU. Prior to this he was visiting assistant professor in the music department at Brown University (USA), and previously, lecturer in music/creative music technologies at Kingston University (UK). John's Ph.D. 'New Relations for the Live Musician?' was completed in 2009 under the supervision of Bennett Hogg and Sally Jane Norman at Newcastle University (UK). His thesis charts an idiosyncratic zone within the continuum of what it is to be a live musician at the dawn of the 21st century. John's work is published via Contemporary Music Review, Ashgate, Cambridge University Press, Creative Sources Recordings, and Clinical Archives. As well as academic conferences and festivals such as NIME, ICMC, NYCEMF, BEAM, and SEAMUS, he has presented live performance-based works at Borealis Festival for Contemporary Music in Bergen, Open Studio at STEIM in Amsterdam, and Club Transmediale in Berlin. http://johnrobertferguson.com

## Notes (and thanks!)

This project was developed through my experiences as a member of Sonic Interaction & eXperience (SIX), which is a research group led by Shawn Greenlee at the Rhode Island School of Design. Continued development is supported by a small research grant for the 'Performative Affordances of Microelectronics' which was awarded to Prof. Andrew Brown and I by the Queensland Conservatorium Research Centre in July 2015.

# Linguistic Margins/Visual Atolls 16: An Audiovisual Performance Suite

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**Abstract.** We will present an interactive audiovisual performance with John Butcher (saxophones), and real-time animations/sound by Bill Hsu. The suite comprises two sections, each of length 10 minutes, for a total of 20 minutes.

**Keywords:** interactive audiovisual performance, improvisation, generative systems, physics-based simulations

## Introduction

*Linguistic Margins/Visual Atolls 16 (after Gunter Brus)* is the latest instalment in my series of audiovisual improvisations. Earlier pieces from the series have been performed at SMC 2009, NIME 2011, Steim (May 2010), ZKM (June 2011), NIME 2012, NIME 2013, xCoAx 2014, and other venues.

## Description

*Linguistic Margins/Visual Atolls 16* is a suite of structured audiovisual improvisations for two to four performers, utilizing live electronic and acoustic sound, and interactive animations. Video is projected on stage, above/behind the performers. The version for ICLI 2016 comprises two distinct 10-minute sections.

The visual component of each section is a complex abstract animation environment, based on a generative system or physics-based simulation. In performance, two or more channels of audio enter the software system from microphones or the venue's sound system. The audio is analysed, and descriptors are sent to an animation environment. Each interactive animation system is influenced by the real-time audio descriptors from the musicians' performance, and by physical gestures from controllers. The animations are visible to the musicians and influence their performance, thus forming a feedback loop. Each section has both components that I control, and autonomous components with their own behavioral rules. Hence, each performance involves ongoing negotiation between the controllable components and the autonomous modules.

For ICLI 2016, we will incorporate two sections/pieces, each of duration 10 minutes, selected from our series: *Folly (Celestial)*, a 3D model inspired by celestial bodies and astrophysical phenomena, and *Fugue State*, a "polyphonic" visual fugue utilizing physics-based virtual materials. The performers will be Bill Hsu (interactive animations and sound), and London-based saxophonist John Butcher. None of these sections has been performed outside the San Francisco Bay area.

Bill Hsu and John Butcher, along with Californian percussionist Gino Robair, form the core of the audiovisual trio *Phospheme*. Earlier pieces in the *Linguistic Margins* series were developed for our residency and concert at ZKM in 2011. The full series comprises over a dozen distinct audiovisual pieces/systems, some with numerous variants. Musicians who have participated in performances of these pieces include Kyle Bruckmann, Chris Burns, James Fei, Jacob Felix Heule, Guro Moe, Havard Skaset, Birgit Ulher, and many others. A paper describing the design and implementation of the software system will be presented at this conference.

## Selected video excerpts

Live (with James Fei and Gino Robair) at Outsound Summit Festival, August 1, 2015 (*Folly (Celestial)* starts at 8:00, *Fugue State* at 17:00):

https://www.youtube.com/watch?v=NLFj26zfqsI

*Fluke* demo: https://vimeo.com/106125702

Trailer for *Phospheme* trio: https://vimeo.com/38317811

## Biographies

**Bill Hsu** is an Associate Professor of Computer Science at San Francisco State University. He has performed in the US, Asia, Europe, and Australia, including NIME 2007, 2011, 2012, 2013, xCoAx 2014, Blurred Edges Festival 2014 (Hamburg), San Francisco Electronic Music Festival 2013, Sonic Circuits Festival 2013 (Washing DC), ACM Creativity and Cognition 2013, Music Metacreation Weekend 2013, Festival art::archive:architectures (ZKM, Karlsruhe, 2011), SMC 2009 (Porto), Harvestworks Festival 2009 (New York), Fete Quaqua 2008 (London), MIX Festival 2007 and 2009 (New York), NIME 2007 (New York), and Stimme+ 2006 (ZKM, Karlsruhe).

**John Butcher** was born in Brighton and lives in London. His music ranges through improvisation, his own compositions, multitracked pieces and explorations with feedback and unusual acoustics.

Originally a theoretical physicist, he left academia for music after publishing a Ph.D. in 1982. He has since collaborated with hundreds of musicians, mostly involved with improvisation – including Derek Bailey, Rhodri Davies, Andy Moor (EX), Phil Minton,  Christian Marclay, John Stevens' SME, Gino Robair, Polwechsel, Mark Sanders, AMM, John Russell, John Tilbury, Okkyung Lee, Eddie Prevost and Gerry Hemingway.

Compositions include "Penny Wands" for Futurist Intonarumori, two HCMF commissions, two saxophone 4-tets and "Good Liquor Caused my Heart for to Sing" for the London Sinfonietta. "Tarab Cuts", a response to recordings of early Arabic classical music, was shortlisted for a 2014 British Composer's Award. In 2011 he received a Paul Hamlyn Foundation Artists Award.

Alongside long term collaborations he values playing in occasional encounters; from large groups such as the EX Orkestra & Butch Morris' "London Skyscraper", to duo concerts with Fred Frith, Akio Suzuki, Paal Nilssen-Love, Peter Evans, David Toop, Otomo Yoshihide, Tim Hodgkinson and Matthew Shipp.

Butcher is also well known as a solo saxophonist who attempts to engage with a sense of place. The well received "Resonant Spaces" CD is a collection of site-specific performances recorded during a tour of unusual locations in Scotland and the Orkney Islands.

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# xynaaxmue pulseone

Eleonora Oreggia[1] and Alex McLean[2]

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**Abstract**. pulseone is the next stage of the performance xynaaxmue, an audiovisual project by xname (Eleonora Oreggia, London UK) and yaxu (Alex McLean, Sheffield UK) featuring live coding with TidalCycles and self-built light controlled electronics implementing solar panels, light resistors and patch antennas. The two systems, one digital and the other analogue, influence one another via beat tracking of stroboscopic pulses and live coding of LED flood panels, in a cross modal interference of rhythmic patterns.

**Keywords:** techno, noise, tidalcycles, algorave, post-algorave, strobe, light, pattern, optoelectronics, ambient gabba.

## xynaaxmue

xynaaxmue is the amalgam of xname (Eleonora Oreggia, London UK) and yaxu (Alex McLean, Sheffield UK). In collaboration they make patterns across sound and light. xynaaxmue performed twice together in 2013, at Audacious Arts Space in Sheffield on 15th June[1], and at EarZoom festival on the 14th October. These performances have brought two practices together into an intensive whole; xname assembling pulsing noise from raw, hand-built circuits feeding from stroboscopic light, a practice inscribed in the context of experiments with synaesthesia, dream machines (Geiger, 2003), sensorial environments, optoelectronics and the hypnotic correlation of sound and music masterfully expressed, for example, in the work of Kurt Hentschlaeger (Feed, 2005-06), and yaxu constructing broken techno from live coded, functional interference patterns using TidalCycles (http://tidalcycles.org/; McLean, 2014), a domain specific language for pattern (Spiegel, 1981).

## pulseone

pulseone is a new development where the upturned computer monitor is replaced by a pair of colour LED flood panels, controlled over DMX via an Arduino microcontroller. The patterns that yaxu creates to make music are also transformed into DMX instructions. Live coding the behaviour of the lights, yaxu influences and determines the beat and in some cases the melodic structure of xname's instruments. Via beat tracking feeding back into yaxu's system, xname's arrangement of circuits and lights drive the tempo of both systems. The two artists' patterns work together to make cross modal interference, digital on the one hand and analogue on the other, playing within a system where they can respond to each other in a mixed form of live composition.
Pulseone follows the growing tradition of reworking material from rave culture, in this case strobes and an analogue drum machine connected with ad-hoc technology, and improvising together through the intensive audio/visual interference patterns that result.

[1] https://soundcloud.com/yaxu/xname-yaxu-audacious-art-space

## Biographies

xynaaxmue came into contact and became friends and collaborators through their participation in the international free software art scene around Piksel festival and goto10.

**xname** (http://xname.cc) is an interdisciplinary artist and independent researcher born in Milan and based in London. She received a Laurea (Summa cum Laude) in Visual Arts from the University of Bologna (DAMS, Department of Art, Music and Drama), with a thesis in Semiotics of Visual Art. In 2003 she was granted a Leonardo scholarship and she moved to Amsterdam where she worked as editor and researcher at Netherlands Institute for Media Art (NIMK). In 2008 she became Researcher in Design at Jan van Eyck Academie in Maastricht where she developed the software Virtual Entity. She then moved to London, completing a practice based MPhil in Cultural Studies at Goldsmiths College. She is currently pursuing a fully funded PhD in Media & Arts Technology at Queen Mary University of London where she develops electronic musical instruments within the Antennas and Electromagnetics Group and the Augmented Instruments Laboratory.
xname makes audiovisual pieces, software art, interactive installations and live performances. Her live compositions transform light and other electromagnetic frequencies in sound waves through self built synthetisers and complex semi chaotic machines. The result is an hypnotic spectacle dominated by industrial and noise-techno frequencies. Recent shows and commissions include Arts Council England, Union Chapel, the Barbican, V&A Museum. She is also the founder of Nebularosa, a record label promoting experimental electronic music that challenges the established modes of music production.

**Yaxu** (http://yaxu.org) is an interdisciplinary artist and independent researcher from the Forest of Dean, now living in Sheffield. He began making algorithmic music as part of Slub in the year 2000, and since 2004 has made all his music with handmade live coding technology, describing complex musical patterns with simple algorithmic structures. He co-founded the algorave movement, bringing this algorithmic approach to dancefloors, performing at dozens of festivals around the world. Alex has worked on his TidalCycles software since around 2010, primarily as a live coding environment. However in 2015 Alex began producing tracks with it, leading to the six track Peak Cut EP on Sheffield label Computer Club. Bleep.com said of it "… Yaxu's polyrhythmic and hyperreal strand of techno is showcased on cuts like Public Life and Cyclic showing that he is not just testing the confines of how music can be consumed but also how genres can sound."
Alex completed his PhD thesis titled "Artist-Programmers and Programming Languages for the Arts" in 2011, supervised by Geraint Wiggins at Goldsmiths. He has completed a research fellowship at the University of Leeds, which included co-leading the AHRC Live Coding Research Network with Thor Magnusson and leading the AHRC Weaving Codes project with Ellen Harlizius-Klück and Dave Griffiths. He is continuing to research pattern with Deutsches Museum and FoAM Kernow, and is developing a new strand of practice as sound artist in residence at the Open Data Institute in London, supported by Sound and Music.

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# The Modified Cello

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**Abstract.** With this paper I would like to propose a performance with the modified cello. The development of this instrument aims to achieve a tighter integration between acoustic and electronic technologies whilst expanding the sonic capabilities of the cello and performer. A combination of sensors, audio analysis and DSP software are used to provide a more expressive, accessible and intuitive control over the dynamics and subtleties of digital sounds and processes.

**Keywords:** Augmented, Cello, Audio Analysis, Unpredictability, Mapping, Interdependent, Interface Design, Tangible Interaction

## Modification of the Cello

The sensors were mounted on the body of the cello and positioned in order to compliment the pre-existing gestures used whilst playing the cello in a traditional manner. In particular, a series of sliders were placed parallel to the strings facilitating sequential and simultaneous interaction with the acoustic and electronic interface elements. Similarly, a large endless encoder was placed adjacent to the bridge, allowing manipulation with the bow. In this way, the addition of sensors to the cello encourages the development of new gestures and techniques whilst revealing new possibilities regarding sound and structure.

Figure 1: Playing the Modified Cello

## Expanding the Physical Capabilities of the Performer

The software uses delays and buffers to allow the performer to operate on multiple time scales and explore the rhythmic interplay between machine and human time domains. Such processes often result in iterative transformations and structures in which subtle timbral modifications of the cello sound are layered to create evolving textures of varying density.

The development of this instrument was focused around the composition of interdependencies between the cello, computer and performer. The implementation of gestural and audio analysis aims to capture the behavioral characteristics (tendencies and movements) of the performer and produce complementary or contrasting reactions within the processing of the cello sound. More specifically, the analysis data is used as a modulation source within the software which pushes and pulls against the parameter positions set by the sliders. This data is also recorded during the performance and used to create probabilistic responses which relate to the performer's input.

Figure 2: Details of the Modified Cello

## Unpredictability, Risk and Effort

The use of probabilistic processes combined with the unpredictability and subtle fluctuation inherent in acoustic interactions introduces the possibility of miscommunication and interference between gestural intent and the instrument's response. This blurring of causality allows the instrument to suggest possible direction for sonic exploration, inspiring the performer and encouraging a more engaging and serendipitous playing experience. During the 15 minute performance, the dualism between precision and ambiguity will be explored, highlighting elements of risk, effort and failure as the subtlety of human expression is amplified and juxtaposed with the more precise and quantised nature of digital technology.

Figure 3: Playing the Modified Cello

## Biography

Dan Gibson is an English musician and sound artist. In 2011 he completed a Ba (Hons) Degree in Creative Music Technology at the University Centre Doncaster and recently completed an MA in 'Instruments and Interfaces' at Sonology and STEIM in the Netherlands. Gibson's work incorporates experimentation and improvisation and aims to explore the sonic subtlety, textural nuance and dynamic intensity found in the natural soundscape through the embodied practice of playing and building investigative hardware and software instruments.

Gibson's recent work at STEIM focused around the augmentation of acoustic and physical objects in order to provide intuitive and tangible interfaces for real-time exploration, manipulation and organisation of sound. The aim is to provide the spontaneous and expressive control required in improvisational contexts through the use of gestural interfaces and dynamic mapping techniques.

# *evolver*: an audiovisual live coding performance

Alo Allik

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**Abstract.** This improvised audiovisual performance explores enhanced live coding as a strategy for real time multimodal synthesis and composition. The real time decision-making process of the programmer-performer is informed and aided by interactive machine learning, artificial intelligence and automated agent algorithms. These algorithms are embedded in a network-based distributed software architecture of a multimedia performance system called *evolver* which is comprised of computer graphics, sound synthesis and algorithmic composition clients. The system facilitates human-computer interaction through live coding during performances to create extemporized immersive multimodal experiences for audiences. The multimodal content during performances is created with reactive artificial life algorithms, evolutionary sound synthesis, machine listening and music analysis. Autonomous agent systems, audio feature extraction and linked semantic data formats help the performer cope with the complexities of multimedia performance environments.

**Keywords:** Live coding, audiovisual performance, computer music, computer graphics, evolutionary algorithms, Semantic Web

## Introduction

We live in a cultural environment in which computer based musical performances enhanced by multimedia have become ubiquitous. Particularly the use of laptops as instruments is a thriving practice in many genres and subcultures. The opportunity to command the most intricate level of control on the smallest of time scales in music composition and computer graphics introduces a number of complexities and dilemmas for the performer working with algorithms. Writing computer code to create audiovisuals offers abundant opportunities for discovering new ways of expression in live performance while simultaneously introducing challenges and presenting the user with difficult choices. There are a host of computational strategies that can be employed in live situations to assist the performer, including artificially intelligent performance agents who operate according to predefined algorithmic rules. This performance uses a software system for real time audiovisual improvisation and composition in which live coding as a computational strategy for audiovisual laptop performances is explored. The features of the framework intend to enhance the live coding practice by analysis of traditional music, evolutionary computing, reactive computer graphics and linked data technologies.

## System architecture

The basic architecture of the *evolver* environment consists of

- algorithmic composition libraries developed in the SuperCollider programming environment
- a precompiled graphics application developed in C++ using the Cinder library
- a CouchDB JSON-LD database
- a Semantic Web ontology that describes the synthesis environment

The name of the performance environment is derived from a method of evolutionary sound synthesis which provides the majority of sonic material. The evolutionary algorithm enables evolving large populations of complex synthesis graphs, either in real time or for later reuse. The structure of the evolutionary synthesis process is described in a lightweight OWL ontology, while the graphs are stored in a CouchDB database[1] and linked to the ontology using JSON-LD[2], a semantic extension of the standard JSON format. The computer graphics component implements a 3-dimensional world of cellular automata that operates in parallel as a self-organising map of audio analysis vectors in Cinder[3], an open source OpenGL library in C++.

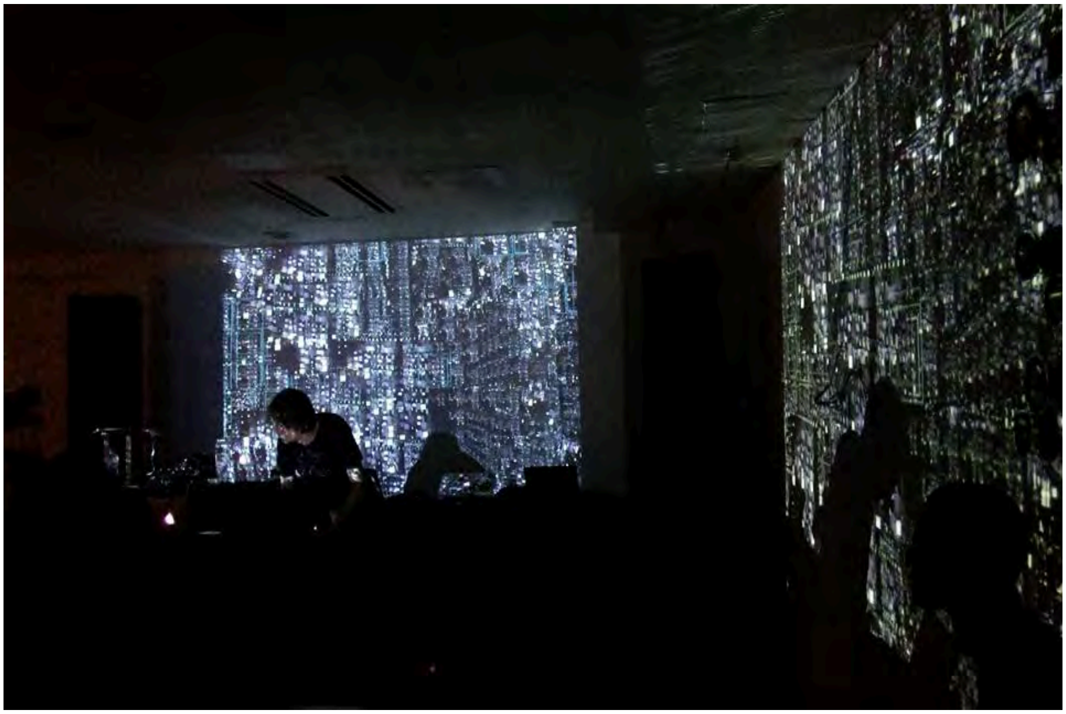

Figure 1. Performance with the evolver system

## Gene Expression Synthesis

Gene expression synthesis (GES) (Allik 2014) is a way to evolve sound synthesizers in computer code. These synthesizers are computer programs that produce sound when executed. Gene expression synthesis uses the methods of gene expression programming proposed by Candida Ferreira (Ferreira 2001). In gene expression programming the popuation of candidate solutions are encoded as linear strings and then decoded into tree structures representing computer programs. Each candidate solution defined as a chromosome consists of codons - elemental units of GES - that can be either functions or terminals. The translation from genotype to phenotype follows a simple, breadth-first recursive principle: as the codons of a gene are traversed, for each function encountered, the algorithm reserves a number of following unreserved codons as arguments to that function regardless whether they are functions or terminals. Once decoded as an executable program, each candidate solution in a population is subjected to a fitness evaluation that determines how well it performs at solving a target problem.

The computer programs evolved with GES are sound synthesis graphs in this case implemented in the SuperCollider programming environment[4]. Each solution generates a SuperCollider SynthDef object. The functions in a GES chromosome are Unit Generators, sound generating functions that serve as basic building blocks of synthesis graphs. Fitness is primarily evaluated in terms of a distance metric of features from target audio, while secondary methods are

[1] http://couchdb.apache.org
[2] http://json-ld.org
[3] https://libcinder.org
[4] http://supercollider.github.io

used to ensure the structural and functional integrity of each synthesis graph as well as balancing factors between resource efficiency and graph complexity. The main fitness function measures the distance of audio feature vectors between the candidate synthesizer and a target sound, which is selected by the user depending on the context of the experiment. Resource efficiency measure has been implemented in order to imitate the condition of limited resources of natural selection, so each candidate solution is assigned a CPU usage value measured during the execution of the synthesizer. To counteract the tendency towards simplicity, a conflicting fitness pressure is introduced to encourage structural complexity in the form of rewarding greater nesting depth. This way, the complexity can be maintained in populations, while still encouraging resource usage effectiveness. Once each individual has been assigned a fitness value, the population is subjected to various standard genetic operators, including **replication** (weighted random selection of individuals for next generation according to fitness), **mutation** (a random change of a single codon value based on a user defined parameter), **transposition** (copying of codon sequences to different locations on a chromosomes), and **recombination** (exchange of genetic material between chromosomes).

## Structured data storage

Due to large volumes of data potentially involving thousands of candidate solutions deemed suitable for performances, GES synthesizers with their associated metadata are stored in a CouchDB database as JSON data structures. This includes all the data necessary to reconstruct each synthesizer for use during a performance or as sources for subsequent evolutionary synthesis experiments. The *evolver* system integrates a customised SuperCollider live coding environment with a lightweight OWL ontology that enables representation of GES synthesizers on the Semantic Web. The synthesizer data that is communicated between CouchDB and SuperCollider is expressed in terms of the GES ontology using JSON-LD (Lanthaler and Gütl 2012). Listing 1 shows a fragment of a GES synthesizer data structure in JSON format as stored in CouchDB.

```
{
   "@context": { "ges": "http://geen.tehis.net/ontology/" },
   "_id": "1a75f4f87bdcac24b6ba5fc25c003ab2",
   "@type": "ges:Synth",
   "ges:environment": { "@type": "ges:Environment", "ges:headsize": 24, "ges:numgenes": 1, "ges:linker": {
      "@type": "ges:Function", "ges:name": "*", "ges:class": "AbstractFunction"
      }
   },
   "ges:defname": "gep_gen000_061_141212_225728",
   "ges:genome": [ "LFPar", "LFGauss", "SinOsc", "v", "PMOsc", "e", "j", "a", "c", "a", "a", "f", "g", "b"],
   "ges:features": {
      "ges:centroid": {
         "ges:mean": 526.07188020057,
         "ges:std_dev": 161.03829149232
      },
      "ges:flatness": {
         "ges:mean": 0.032055785092016,
         "ges:std_dev": 0.017184103858522
      }
   }
}
```

Listing 1.Fragment of a GES synthesizer JSON structure

## The *evolver* environment

The gene expression synthesis algorithm can be used for isolated experiments to generate populations of synthesizers for reuse during performances. However, the textitevolver environment enables the performer to evolve and play synthesizers live on stage. The semantically enriched live coding environment aids the performer in the decision making process when selecting synthesizers from the database or evolving them in real time. The synthesizers are classified according to audio feature vectors and different maps are created to visualize the distribution of feature vectors from different perspectives. For example, a plot of spectral flatness - how noise- like a signal is - against spectral centroid -

how ”bright” the sound is - gives an idea about the characteristic of each synthesizer. This can be further aided by classifying synthesizers with a self-organised 2-dimensional map of MFCC vectors. The performer can make informed selections of synthesizers either for use in the real time live coding composition process or as source material for real time evolution by going through the iterations of the GES algorithm.

One of the performance strategies involves selecting 2 chromosomes from the database to serve as source material for on-stage experiments. These 2 chromosomes are then subjected to genetic operators, including recombination, which involves creating 2 new individuals by exchanging genetic material between the initial 2 chromosomes. The population can be subsequently grown by doubling the number of individuals each generation, evaluating the fitness of each, classifying them using the features and the existing data and selecting which ones to use in the performance based on this information. The evolved synthesizers can be used in a number of different ways as compositional elements. The target sound towards which the algorithm is converging is selected according to context. For example, percussive sounds are more suitable if the GES synthesizers are used in a dance music context to fill rhythm patterns, whereas continuous drone-like sounds are more suitable for building ambient soundscapes.

## Additional Information

There are a number of existing examples of the system in use in various performance contexts:

- an experiment with evolving synthesisers in real time: https://soundcloud.com/tehis/evolver00
- a live algorave performance: https://soundcloud.com/user-665948413/osaka-live
- an example of evolver in audiovisual context: https://vimeo.com/75750212

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# Tuned Constraint

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**Keywords:** Music, Performance, Analogue Synthesis, Motion, Embodiment, Body, Wearable, Sensors, Affordance.

## Performance Description

In the past four decades, electronic music performance has seen several paradigm shifts in the way it is performed live. New electronic musical instruments and the role of the performer's body are still highly debated topics at academic conferences and in artistic environments. This is also due to the nature of the medium itself, as the presence of the performer is not strictly necessary for a performance to happen. However, some electronic performers rely heavily on their presence and make use of their bodies in very detailed and profound manners, for instance by performing with sensors capturing their biologic signals.

Figure 1. Still from the performance.

In this performance, I wanted to combine recent motion sensors technologies I have been using for my doctoral research with the classic modalities of interaction involved in traditional analogue synthesis, such as operating knobs and switches on a synthesiser front panel. My goal is to explore the constraints that both interface paradigms impose on the gestural behaviour of the body, and to use such constraints as constitutive expressive elements. From a research standpoint, I argue that there is an emerging vocabulary of gestures involved in electronic music performance that is becoming part of a shared knowledge, similarly to what we have observed with other instruments (Visi et al. 2015). In this work, the performer's body is the site were different control paradigms are actualised, and the actions involved in the process are integral parts of the musical experience of the audience. This practice as research work aims at exploring and reflecting on how the choice of interfaces (and consequentially its constraints and affordances) can have a radical impact on liveness, immediacy, presence, and flow of the performance.

# Additional information

## Biography

Federico Visi is a researcher, composer and performer. After obtaining his master's degree in communication, multimedia and design, he studied music for image in Milan and composition at the music academy Accademia Pianistica in Imola. He is currently based in Plymouth (UK) where he is conducting his doctoral research at the Interdisciplinary Centre for Computer Music Research (ICCMR). His research focuses on body movement in performances with traditional musical instruments. He has composed music for films and installations, performed live in solo sets, with bands and in contemporary theatre and dance performances, and presented his research at several international conferences. He has worked and is currently working on collaborative interdisciplinary projects with researchers in Europe (Ghent University, University of Bologna), North America (NYU, UCLA) and South America (Universidade Federal do Rio Grande do Sul).

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An excerpt of the performance can be viewed here: https://youtu.be/jdVw22D3NNM.

**Acknowledgements.** Some of the software technologies employed in this performance are the outcome of a collaboration between the Interdisciplinary Centre for Computer Music Research (ICCMR), Plymouth University, and MARL: Music and Audio Research Laboratory, NYU Steinhardt. The collaborative project was carried out in New York City, US, during Summer 2016 and was generously supported by Santander Universities.

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# Owego System Trade Routes: Round Trip

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**Abstract.** This performance will highlight the AppiOSC, a live interface that enables wireless, bi-directional control between a live coding graphics interface (the_force)[1] and a modular synthesizer. Our intention with the AppiOSC in the context of *Owego System Trade Routes: Round Trip* is to extend beyond the typical, unidirectional manifestation of interactivity in audio-visual performance, in which the audio signal drives, or influences the graphics, while the graphics signal has little to no direct impact on the audio. With bidirectional control, both the visual and audio artist can explicitly impact the other's outcome, enabling performative possibilities beyond a unidirectional system.

**Keywords:** live coding, OpenGL, fragment shader, modular synthesizer, Arduino, control voltage, Owego

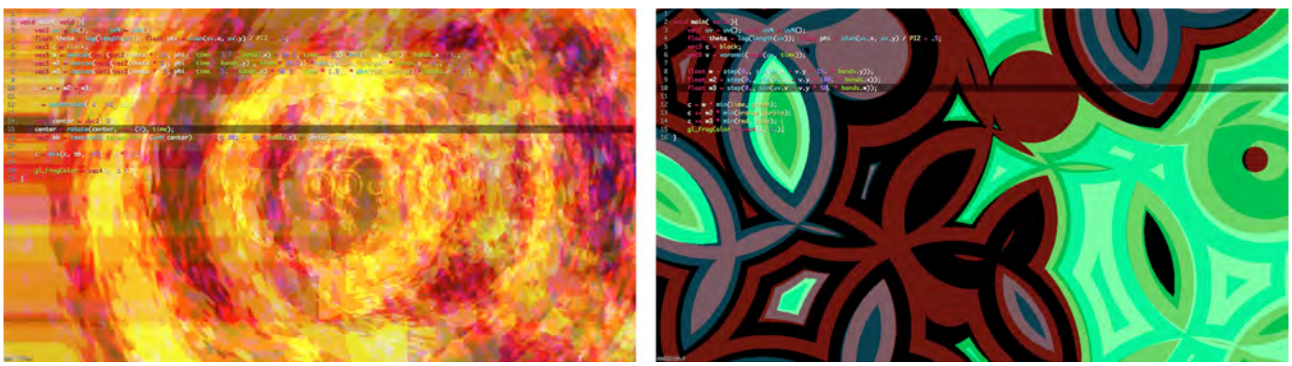

Figure 1. Two images from *Owego System Trade Routes*.

## Description

*Owego System Trade Routes: Round Trip* is an extension on the authors' collection of work titled *Owego System Trade Routes*. The latter demonstrates the first iteration of the AppiOSC, a hardware and software communication interface that enables the *transformation* of text within the live coded graphics into musically-useful control voltages that can be sent to the modular synthesizer. The former completes the *trip* by sampling control voltages from the modular synthesizer, and transmitting these values wirelessly to the live coding interface for usage by the visual performer. *Owego System Trade Routes: Round Trip* is a performance that incorporates this live communication interface, and will demonstrate how each performer grapples with the unexpected, real-time changes to the functionality of their *instrumentation*, live coded text or modular synthesizer respectively. By tethering each performer to the other via a constant stream of malleable and often uncontrollable variables, the performers must react and respond in real-time. As each performer reacts with particular modifications to their respective performance device, those changes are immediately reflected back on their counterpart, creating a constantly evolving feedback loop of mediated influence.

[1] See http://shawnlawson.github.io/The_Force/

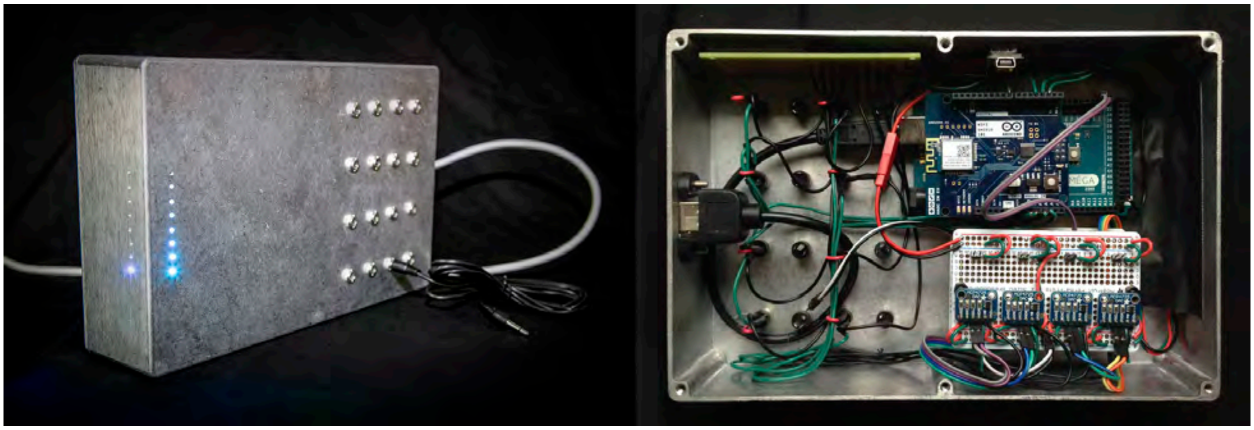

Figure 2. Image of AppiOSC device, outside and inside.

# Biographies

## Shawn Lawson

*Shawn Lawson* Shawn Lawson is a computational artist and researcher creating the computational sublime.[2] As Obi-Wan Codenobi, he live-codes, real-time computer graphics with his open source software, The Force.

He has performed or exhibited in England, Scotland, Spain, Denmark, Netherlands, Russia, Italy, Korea, Portugal, Brazil, Turkey, Malaysia, Iran, Canada, and the USA. He received grants from NYSCA and the Experimental Television Center, and he has been in residence at CultureHub and Signal Culture.

Lawson studied at CMU and ÉNSBA. He received his MFA in Art and Technology Studies from SAIC. He is an Associate Professor in the Department of Art at RPI.

## Ryan Ross Smith

*Ryan Ross Smith* is a composer and performer currently based in Fremont Center, NY.[3] Smith has performed throughout the US, Europe and UK, including performances at MoMA and PS1 [NYC] and Le Centre Pompidou [Paris, FR], has had his music performed throughout North America, Iceland, Australia and the UK, has presented his work and research at conferences including NIME, ISEA, ICLI, the Deep Listening Conference and Tenor2015, and has lectured at various colleges and universities.

Smith earned his MFA in Electronic Music from Mills College in 2012, and is currently a PhD candidate in Electronic Arts at the Rensselaer Polytechnic Institute in Troy, NY.

# Additional Information

**Acknowledgements.** Special thanks to Signal Culture for providing time and space through their Toolmaker Residency program to develop the software and hardware solutions to jump-start this work.[4]

[2] See http://www.shawnlawson.com
[3] See http://www.ryanrosssmith.com
[4] See http://signalculture.org

# Babil-on V2

Greg Beller

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**Abstract.** Babil-on V2 is a performance of augmented musical theatre, which describes the imaginary destiny of the Speech. Starting with pure vowels, some more complex elements like the consonants or further, the semantic meaning, appear as disruptive elements. Babil-on V2 surgically dissects speech to extract its emotional charge. The performer is equipped with a motion capture system enabling him to literally handle his voice in real time. In the context of a close-up, facing to the public, he cuts his voice, plays with it, spreads it in the surrounding space, catches it back, modulates it, multiplies it... The performance seems to stick to a technical demonstration, while an insidious truth appears. Babil-on V2 is a metaphor of Human destiny that can not cease to grow, to accumulate, to complicate His situation to the point of not being able to enjoy it without causing His own ruin.

**Keywords:** Speech, Voice processing, Gesture recognition, Sound Space, Interaction, Performance.

## Introduction

**From the imaginary destiny of the Speech …**

Babil-on V2 draws an original portrait of the Speech, as if it was an individual. Mixing various scientific approaches to speech, inherited from various domains: phonetics, phonology, bio-philological evolution, language acquisition, speech processing, G. Beller composed a structure depicting the imaginary life of this particular individual.

Of a birth marked by the enjoyment of the phonation and by the purity of the vowel, the babbling gets excited in hiccup, then in crisis to laugh. An accident occurs then: the irruption of a consonant. By contagion, the voice complicates little by little in the sketch of a pre-language. Then, the semantic sense bursts as a new disruptive phenomenon. It drives the speech in a continuous stream of linguistic actions, which will eventually impoverish the vocal material by exhaustion. It is the fall of Babylon. The wor(l)d is exhausted, only a pure singing will allow us a return in the original breath.

These three disruptions (the consonant, the sense, the noise) articulate four parts, the evolutions of which are more or less systematic. Simple situations start from these anchors, where new rules are given. The performer starts by discovering what he can make in this new world with his new "power". From a simple game, he slightly goes into some more complex situations, until he looses completely the control of the situation. The accumulation takes over and leads him to ruin.

Subtly, this process of comparing the Speech to an individual, bring us back to our self-condition of human beings. The constant growth underneath the structure of the piece is a direct translation of the evolution of the civilizations. Starting from simple and idealistic situations (Eden’s garden, for instance), we enrich a game we think we understand, to a point of no return, until the next disruption.

**… to the real fate of the Human**

## Genesis

Babil-on V2 started from research & developments made during the production of Luna Park, of Georges Aperghis, premiered in 2011. G. Beller, the computer music designer of the piece, invented SpokHands, a system to capture the gestures of R. Dubelski, who triggers pre-recorded voice sounds, by playing aerial percussions, during the show.

To play himself with the full range of the system he created, G. Beller then composed a first version of Babil-on, for R. Dubelski. This 15 minutes version has been premiered the 15th of October 2013, at Théâtre des Bernardines, Marseille, France, during CMMR'13, the 10th International Symposium on Computer Music Multidisciplinary Research on Sound, Music and Motion. In this pre-version, R. Dubelsky triggers again some pre-recorded voice sounds, but a step further has been done: The quality of the gesture modulates the quality of the vocal synthetic sounds.

G. Beller wants to go further. He wants to allow the performer for manipulating his own voice in real-time. Consequently, he started the Synekine project in 2014. This project brings together performance and scientific research to create new ways to express ourselves. By analogy in “synaesthesia”, the phenomenon in which two or more senses of perception are associated, the “synekinesia” would reflect our capacity to associate two or several motor senses.

One of the goals of this innovative project is to create new instruments that define new paths for vocal improvisation. Several Augmented Reality Sound Tools (no glasses, no video) allow the performer for manipulating in real time the sound of his voice. The names are evocative: Sound Space, Hand Sampling, Body Choir, Hyper Ball… For instance, with the Sound Space, the performer literary spreads his voice around him, creating an entire sound scene made of his voice, while interacting with it by the gesture.

Some of these new instruments have then been back propagated into the structure of Babil-on to produce an extended version called: Babil-on V2. G. Beller himself has premiered this 25 minutes version, the 17th of August 2015, at ISEA2015, AV Disruption, Vancouver BC, Canada. To sum up, Babil-on V2 is a testimony of a 5 years research process that G. Beller constantly conducted through different projects. It is also the first performance of a beginning series. Other chapters are to be written by the growing Synekine Dance Company.

## Additional Information

The Synekine Project brings together performance and scientific researches, with social aspects. The neologism “synekinesia”, is built from the Greek terms “syn”, (union) and “kinesis” (movement). By analogy in “synaesthesia”, the phenomenon in which two or more senses of perception are associated, the “synekinesia” would reflect our capacity to associate two or several motor senses. In the Synekine project, the performers develop a fusional language involving voice, hand gestures and physical movement. An interactive environment made of sensors and other Human-Computer Interfaces augments this language. Through collective exploration, we wish to see emerge a more faithful language to the expression of our emotions.

### Biography

Greg Beller works as an artist, a researcher, a teacher and a computer designer for contemporary arts. He defended a PhD thesis in Computer Science on generative models for expressivity and their applications for speech and music, especially through performance. While developing new ideas for signal analysis, processing, synthesis and control, he takes part in a range of artistic projects. He is currently the director of the department for Research/Creativity Interfaces of IRCAM, where he coordinates the works of the researchers, the developers, the computer music designers and the artists in the creation, the design and the performance of artistic moments. More information: www.gregbeller.com

Figure 1. General sketch (score reduction) of Babil-on V2


Figure 2. Illustration of the SYNEKINE Company by Nicolas Patrix

**Acknowledgements.** The author would like to kindly thank partners of the project: Idex Université, Bordeaux; l'IRCAM-CNRS, Paris; LaBRI, Bordeaux; NFC Interactive, Bordeaux; SCRIME, Bordeaux; SCENE44 N+N Corsino, Marseille; Ubris Studio, Marseille; Formes Elémentaires, Paris; people who made it possible: G. Aperghis, N+N Corsino, C. Béros, A. Cont, E. Flety, J. Henrot, P. Bondu, F. Bévilacqua, N. Schnell, R. Borghesi, J. Françoise, Yann Philippe, Samuel Toulouse, Jules Françoise, Patric Schmitz, Joseph Larralde, Léa Ikkache. Special thanks to Richard Dubleski for his voice and his complicity and to other performers, so far, involved in the Synekine project : Valencia James, Stéfany Ganachaud, Jean-Charles Gaume, Dalila Khatir, Jean-Pierre Drouet, Lenny Barouk, Greg Beller, Martin Seigneur, Alex Nowitz, Scott Shepherd, Haim Isaacs.

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# Synap.sys

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**Abstract.** Memories from the past or the future, collective or personal, instincts or knowledge acquired over time. These topics are covered in this audiovisual performance of approximately 45 minutes, performed live through an interface created by the artist. This instrument symbolizes links that occur in the human brain: synapses, which are connections between neurons in order to allow the encoding of information acquired by the senses, recording of these throughout time, in addition to serving as a source for our memories. The performance deals with sensations and feelings that somehow pass through memory, through abstractions, images and sounds that are part of the forming process of these memories, which during life shape our personality and affectivity.

**Keywords:** audiovisual interface, generative, HOL, audiovisual performance, custom-made instrument, visual music, abstract art, lasers, arduino, acoustic.

## Introduction

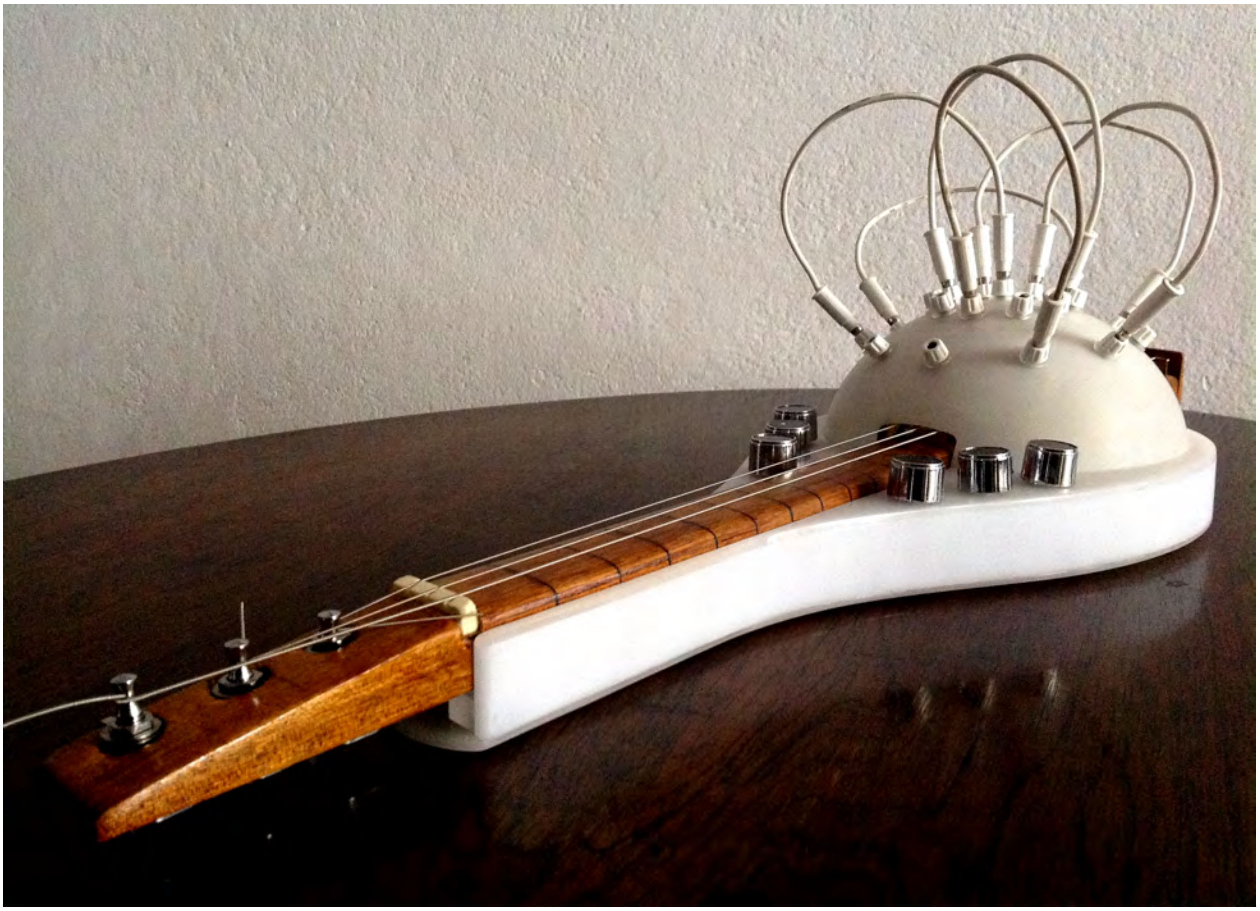

Figure 1. Instrument

Memories from the past or the future, collective or personal, instincts or knowledge acquired over time. These topics are covered in this audiovisual performance of approximately 45 minutes, performed live through an interface created by the artist. This instrument symbolizes links that occur in the human brain: synapses, which are connections between neurons in order to allow the encoding of information acquired by the senses, recording of these throughout time, in addition to serving as a source for our memories. The performance deals with sensations and feelings that somehow pass through memory, through abstractions, images and sounds that are part of the forming process of these memories, which during life shape our personality and affectivity.

The show has 3 main parts: the connection between external and internal worlds through the data input; how this information is stored; and recall, when the data is retrieved in the format of memories. Each part has its own abstract narrative, using fundamental elements of sound and image in order to create metaphors that tell the history.

The instrument has 3 guitar strings and a pickup inside its bow. The acoustic part is independent from the digital and sends its signal to an EHX guitar pedal. The digital part is made of an arduino mega that gets the input from 20 connectors and sends them to the computer, where this information controls the audio and visual elements of the performance. Using jumpers I connect two inputs and the max/msp patch gets this data and uses it according to the part of the piece I'm playing. It can change the part of the performance I'm playing, control visual and audio elements, according to my previous made code.

I also use a custom-made laser instrument that is played using a midi track from ableton Live. Midi information passes through a max/msp patch that controls the position of the servos where laser pointers are mounted on and the triggering of the lasers. This way I can get a very accurate synchronization between the lasers and the other elements of the show.

Figure 2. Live at Sonica (Glasgow, 2015)

Figure 3. Live at Multiplicidade (Rio de Janeiro, 2014)

## Links to Further Documentation

More information, photos and videos: http://hol.1mpar.com/?page_id=1271

## Biography

Henrique Roscoe is a digital artist, musician and curator. Works in the audiovisual area since 2004. Is graduated in Social Communication (UFMG) and Electronic Engineering (PUC/MG) and has expertise in Art and Culture (FUMEC).Has a conceptual and generative project called 'HOL'. With this project had performed at the main live images festivals in Brazil like Sónar, FILE, ON_OFF, Live Cinema, Multiplicidade, KinoLounge, FAD and also abroad, in England (NIME, Encounters), Germany (Rencontres Internationales), Scotland (Sonica), Poland (WRO), USA (Gameplay), Greece (AVAF), Italy (LPM e roBOt), Mexico (Transitio) and Colombia (Festival de la Imágen). Participated of videoart festivals in many countries as Germany, France, Spain, Holand, USA with documentation of the performances.Is the curator of FAD – digital art festival - that happens in Belo Horizonte since 2007. Makes part of the audiovisual duo 'ligalingha'. Develops interactive installations, programming in Processing, vvvv and Max/Msp. Builds instruments and interactive interfaces using sensors and common day objects. Produces stage design for bands like Earth wind and Fire, Skank, Roberto Carlos and events in Brazil, Germany and USA. As a VJ participated of the festivals Skol Beats, Creamfields, Nokia Trends, Motomix, Eletronika among others.
www.1mpar.com

# An Algorave with FoxDot

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## Description

FoxDot is a new Live Coding system developed as an extension to the Python programming language that interfaces with SuperCollider to create electronic music. While FoxDot's development is still in its infancy, the purpose of this proposal to perform at the International Conference of Live Interfaces (ICLI) is to showcase its ability to create music easily, quickly, and in a human-readable format. This performance will not only demonstrate the advantages of integrating an existing programming language into a Live Coded music performance by importing existing libraries, whose application will be rerouted into musical patterns, but also exemplify the ease of "blank slate" performances with this new system.

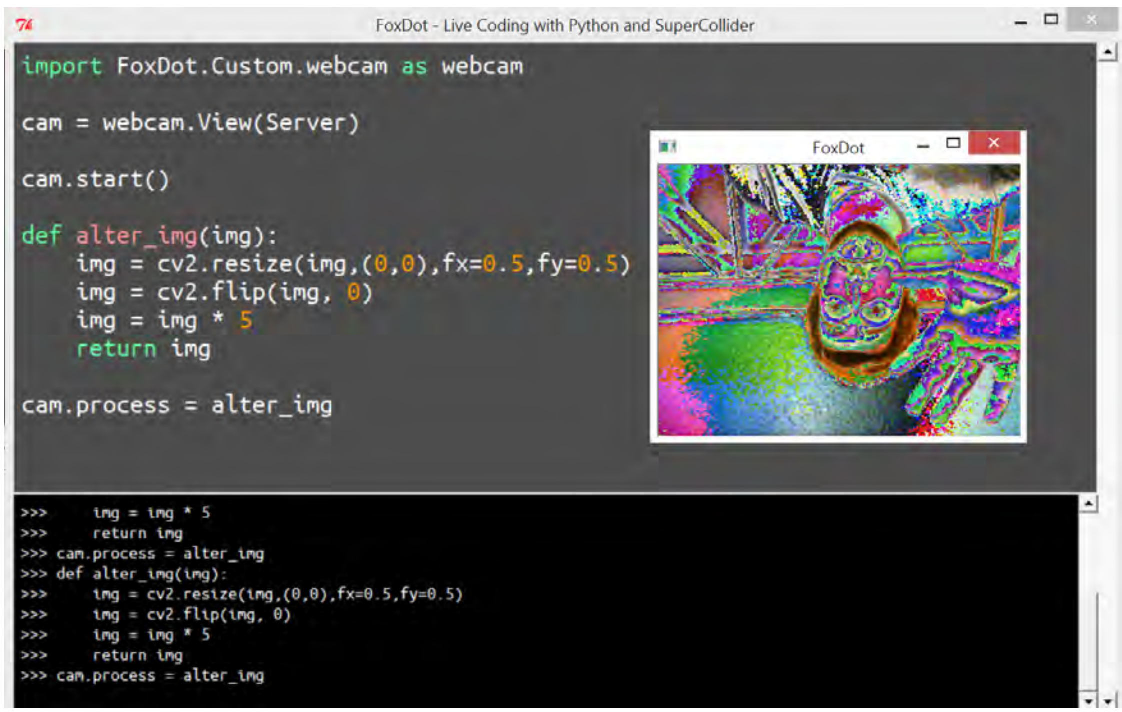


Figure 1. Live image processing with FoxDot

Live coding can be used to create music from a wide range of genres but is most commonly associated with live performances of dance or drum and bass music at nightclubs, known as "Algoraves". Performances usually consist of one or more laptop performers using a programming language to create music and projecting their screen so audience members can gain an insight into the performer's creative thinking by watching the code be written in real-time. "Algorave" events are designed to get people dancing and the nature of Live Coding allows the performer to react and engage with the audience and create a fun and exciting atmosphere. For this reason my proposal is to perform using FoxDot in a semi-improvised "Algorave" style in a nightclub venue for a duration of 25 to 30 minutes. The music will be generated by combining synthesised sounds and the manipulation of samples through the use of objects that iterate over musical patterns in an algorithmic fashion.

FoxDot is a new interface for musical expression and, as a Live Coding language, is inherently a form of notation for Human-Computer Interaction (HCI). By projecting the screen the performance also becomes one of an audiovisual nature. One of the advantages of using Python as the foundation language for FoxDot is the ease at which external code can be imported into a performance from Python's existing library or a user's own module. This is demonstrated in one of my pieces called "Webs"[1] that uses a Python module for downloading web-pages and converts the HTML into music. While the type of music generated in this instance is not appropriate for a nightclub setting, I am currently writing a plug-in module using OpenCV to compliment the "Algorave" style I intend to perform (see figure 1). The plug-in connects to, and displays the image captured from, a web-cam and generates Open Sound Control (OSC) messages to send to SuperCollider based on my gestures. I will then perform live-coded image processing to alter the display and consequently change the sonic output, combining multiple types of HCI into one performance.

## Biography

Ryan Kirkbride graduated from the University of Leeds in 2014 with a first class degree in Computer Science before completing his MA in Computer Music in the summer of 2015. He started working on FoxDot as part of his masters module in Composition and has since continued development. One of Ryan's research interests lies in algorithmic composition and his Masters dissertation, "The Infinite Remix Machine"[2], was part of the research workshop at the Electronic Visualisation and the Arts (EVA) 2015 conference in London. He is currently in the first year of his PhD studying the use of non-verbal communication in ensemble performances using motion capture technology and spends his free time working on FoxDot and researching Live Coding.

1 https://www.youtube.com/watch?v=EnaKvs-GlYo
2 http://ewic.bcs.org/content/ConWebDoc/54873

# Hacking the Body 2.0 Performance: *Flutter/Stutter*

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**Abstract.** Flutter/Stutter is an improvisational dance piece, part of the Hacking the Body 2.0 project, that uses networked soft circuit sensors to trigger sound and haptic actuators in the form of a small motor that tickles the performers. Dancers embody the flutter of the motor and respond with their own movement that reflects this feeling. This research explores using the concept of hacking data to repurpose and re-imagine biofeedback from the body. It investigates understandings of states of the body and hacking them to make new artworks such as performance and costumes. Through performance we aim to communicate to the public new ways to engage with their bodies and technology with intimacy and sensation embedded in wearables.

**Keywords:** Wearable tech and e-textiles, Performance, Sustainable garments, Ethical data collection.

## Description of Work

Flutter/Stutter is an improvisational dance piece that uses networked soft circuit sensors to trigger sound and haptic actuators in the form of a small motor that tickles the performers. Dancers embody the flutter of the motor and respond with their own movement that reflects this feeling. The sensors and actuators, along with the garments they are embedded within, are bespoke designs by Becky Stewart and Tara Baoth Mooney that interact, influence and interrupt the dance and hack the body.

This research explores using the concept of hacking data to repurpose and re-imagine biofeedback from the body. It investigates understandings of states of the body and hacking them to make new artworks such as performance and costumes. Through performance we aim to communicate to the public new ways to engage with their bodies and technology with intimacy and sensation embedded in wearables.

Duration: approximately 20 minutes

Figure 1. Images from performance of the piece in February 2016 in London, UK

## Links to Further Documentation

Project's site with links to social media accounts: http://www.hackingthebody.co.uk

Blog documenting the project: https://hackingthebody.wordpress.com

Film of the April 2015 residency of the project: https://vimeo.com/133353621

Film of the November testing, leading to the February Performances https://vimeo.com/162185498

Documentary of the project and performances https://vimeo.com/168129310

## Biographies

### Kate Sicchio

Kate Sicchio works at the interface of technology and choreography. Her work includes performances, installations, web and video projects. She has presented work internationally across the US, Canada, Germany, Australia, Belgium and the UK at venues such as the V&A (London), EU Parliament (Brussels), Banff New Media Institute (Banff) and Arnolfini Art Centre (Bristol UK). She currently is Adjunct Faculty at Parsons The New School for Design and New York University. See www.sicchio.com

### Camille Baker

Camille Baker is a media artist/curator/lecturer in digital media with recent work in participatory mobile and sensor performance using wearable technologies, now exploring creative coding and electronic development for smart-fashion projects. Baker has a fascination with all things embodied, felt, sensed, the visceral, physical, relational, and participatory, using video, mobile and biofeedback devices. She is passionate about working with new technologies, expressive methods, in art and performance, seeking new methods to connect people over distance, in better and more embodied, emotional ways. She explores new mechanisms to elicit engaging experiences using evolving approaches to participatory performance. See her portfolio site www.swampgirl67.net and camillebaker.me

### Rebecca Stewart

Rebecca Stewart is a Lecturer in the Centre for Digital Music within the School of Electronic Engineering and Computer Science at Queen Mary University of London. She is an engineer, developer, and educator working with real-time, interactive systems for wearable computing. She builds physical computing interfaces and specialises in e-textiles. Stewart completed her PhD in acoustics, spatial audio and interfaces for music search with the Centre for Digital Music in 2010, an MSc in music technology at the University of York in 2006 and a BMus in music engineering technology and computer science at the University of Miami in 2005. http://antialiaslabs.com

### Tara Baoth Mooney

Tara Baoth Mooney is a PHD candidate at the University of Wolverhampton where she is exploring textiles and fashion as triggers for memory and narrative for people living with dementia.

Tara has trained and worked as a designer in the textile industry in New York, The UK, India, China and Ireland where she is an associate research fellow at SMARTlab based in UCD Ireland. She also works as a consultant for UNIDO on the Better Work in Textiles Project which enables knowledge transfer and sharing of specialist activities between London College of Fashion's 'Centre for Sustainable Fashion' and the Bangladesh University of Fashion and Textiles. Her work explores garments as a form of outer cladding and what that can mean for our lived daily meanderings. External cladding or garments, can act as an interface between individuals and their immediate environment. Tara poses questions around the value of garments in a world, which increasingly devalues objects. How can our collaboration with our clothing, subjective experience and environment be developed to create more meaningful experiences with our environment. https://tarabaoth.wordpress.com

## Additional Credits

Performers: Tara Baker and Phoebe Brown

Sound design: Rick Loynes

**Acknowledgements.** This work was supported by Arts Council England Grant for the Arts.

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# s.laag (2016) - for game-audio with 3D body-scanned performer, composer and instrument

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**Abstract**. This paper unfolds key compositional aspects of 's.laag', an interactive musical work composed by Ricardo Climent for Dutch Bass Clarinettist Marij Van Gorkom, as part of the dutch-uk.network project. It includes 3D models by both Climent and Manusamo & Bzika based on 3D Body scanners provided by Simeon Gill at the School of Materials Design & Fashion, University of Manchester. The piece employs sonic path-finding techniques using game-engine tools to explore the concept of "modular metaphor". It navigates across the intersections between the Real, the Virtual and the modular augmentation of a musical instrument. The Dutch word 'laag' means *low* but also *layer*, *stratum* and *thickness,* which resonate more with the compositional thinking behind this piece. Slaag (*pass* in Dutch language) evokes the sonic fluxus between the acoustic instrument and the electronic medium.

**Keywords:** Bass Clarinet, game-audio, 3D body-scan, Expo 58, gamification*,* Extended Reality, Modular metaphor, Virtual Reality.

## Creative Background

**The dutch-uk.network 58/58 project** is a new network started in 2015 between the Institute of Sonology at the Royal Conservatory of The Hague and the Music Composition department at The University of Manchester, UK. It aimed to build bridges between UK and mainland Europe, via addressing creative questions in the form of concert events, new musical compositions, workshops and debate. The network proposed the "Philips pavilion" as a concept and model, which may inform the project, just 58 years after this World's Fair pavilion was designed for Expo '58 in Brussels.

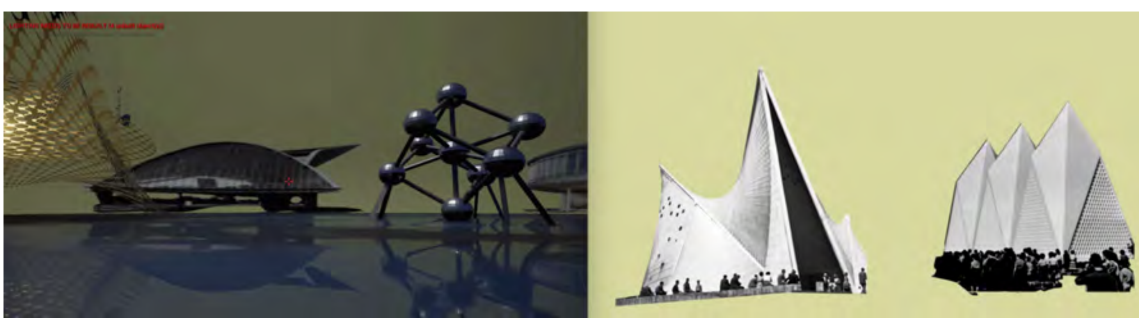

Figure 1. s.laag's Expo 58 buildings in Unreal Engine 4, informed by models from  the Philips pavilion and the Atomium

**Previous work on game-audio composition:** s.laag builds upon several game-engine collaborative works by the composer on this paper. It features musical instruments as virtual characters in a game-engine driven stage performance. Recent examples include the Timbila (a marimba of Mozabique) for the piece "Xi" with Miquel Bernat, a VCS3 analogue synthesizer for "Putney" with Mark Pilkington performing the VCS3 and now featuring a Bass clarinet for "s.laag". The 3D modelling for these works was sketched by Climent and finally rendered by Manusamo&Bzika (Alena Mesarošová and Manuel Ferrer). Such game-audio compositions often employ the concept of "modular metaphor" (Climent, Pilkington, Mesarošová, 2016), to transcend the physicality of the real instrument during game-play. Such metaphor occurs when the whole becomes more than the sum of its parts through the aural assemblage but as in s.laag, it can also become something else. Such immersive experiences are conceived as game-audio journeys highlighting distinctive aspects of the instrument being explored. For example, they investigate unique timbral or gestural properties, which gradually unfold while the instrument becomes re-assembled as the piece progresses.

## Compositional Methodology

**Recording session:** aural scores

The composition approach to gathering Bass clarinet raw material for s.laag was built upon the concept of 'Aural Score' (Rick Nance, 2006), which was adapted for recording purposes. The ultimate aim of this system is to extract 'DNA' from instrumental performers' unique aural memory, which they are not even conscious about. In the past, the composer in this paper investigated this technique with violinist Darragh Morgan and percussionist Miquel Bernat, providing him with a wealthy pool of their DNA's aural material. For s.laag, a 2-hour 'crunch file' with silent gaps was assembled, where the performer had to insert restricted musical responses to materials on the fly; e.g. by mimicking or playing against within a range or technique. The crunch file is never to be used in the final composition. Instead, the player's response becomes the basis for compositional inventions. In s.laag, six types of materials were crunched, ranging from manipulated excerpts of Jimi Hendrix's best solos, to Peter Frampton's talking box guitar, a 1957 recording from Edgar Varèse in a workshop of Jazz musicians, harmonica phrasing from Sonny Boy Williamson, a performance by Japanese Koto Player Fuyuki Enokido, all intercalated with some extended techniques from the composer's own alto saxophone, transformed with a BigMuff distortion pedal.

**Scanning typologies:** mosaic-size musical cells

After listening to the recording session, only 20 % of materials were selected and edited. They served as raw sources for further transformations. At this point, several compositional tools were applied with the aim to generate a large collection of mosaic-size musical cells with specific sonic taxonomies. For instance, 101 mosaic-size soundfiles were created using aural scanning and manual editing, 69 with a custom-made waveform pointer to 'chop' materials, 190 files were obtained from a clatter system (Bachelor, 2003), 93 using a doppler tool, a sound freezer, 60 sound excerpts using a Csound sndwarper, 10 mid-size phrases from a MaxMSP granulator, 17 produce by a 'gestural faker' (a constructor of gestures from micro-materials) and 20 via a Nebulae (Qu-Bit Elextronix, 2015) voltage-controlled granulator synth. Total of hours: 76.5 h.

**structural artefacts:** 3d scenes

For arranging materials at structural level I already had the scenes from the game-audio and engine version in mind. The abstract visualisation of a scene-oriented journey in a 3D environment provided me with four aural pools to make compositional decisions. [0.00 - 2:27 Interactive Counterpoint // 2:27- 4:25 Spectral Multi-phonics // 4:25 - 6:01 Valve Variations //6:01 - 8:43 Inner-pulses]

**Scoring the music and building the electronic counterpoint:** studio composition thinking

The compositional methodology was arguably closer to working with studio practices than to composing a piece for acoustic instrument alongside electronics. As a result, sound materials were dealt in abstract and layered in two parts; an upper stratum consisting mostly of non-transformed materials, (although heavily edited) and a highly-articulated counterpoint of electronic responses to them, moving outside the physical limits and idiom of the acoustic instrument.

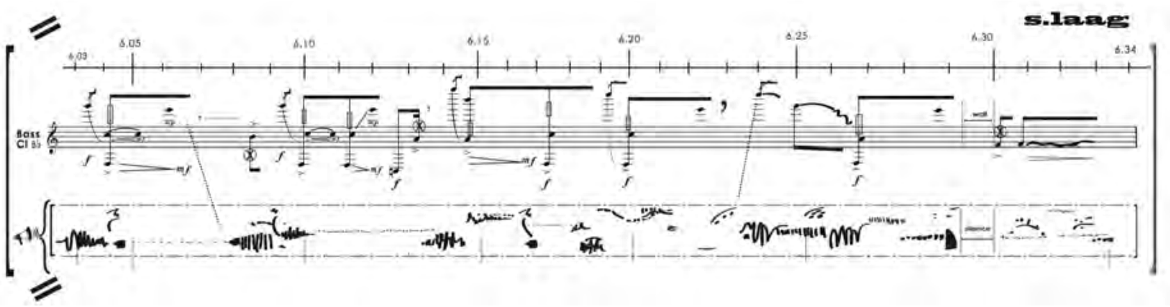


Figure 2. s.laag's reference score:
Splitting the counterpoint between instrument (top) and dynamic media (bottom)

## Composing With Game-Engines

**The modular metaphor:** gamification of the performance environment

Imagine we were to dismantle every part of a musical instrument with the purpose of reassembling them in alternative ways while keeping some of their functions and behaviours intact. Envisage also we were able to extract the sonic nature and extend it and make every part sonically capable of achieving musical outcomes. This is what constituted s.laag's 'modular metaphor'. The bass clarinet modules became a windchime-like mobile (as in Earle Brown's music), clarinet keys marches as in Pink Floyd's *The Wall*'s hammer scene, or became multiple characters informed by Silly Symphony's experimental cartoons in the 1920s and 30s. How could the new 'game-instrument' sound like? Would the sum of its parts become something aurally outrageous?, would its sound resonate with the instrument's DNA? Can this form of re-embodiment provide new modes of expression in a performative game-engine's domain?
To explore so, s.laag heavily relies on the use of physics-graphics-game-audio engines often found in ludic contexts and video consoles, it recontextualises such technologies in a performative environment. The virtual game-audio scenes become a pseudo-score where pre-composed sonic materials are introduced and need to find musical directions during game-play (which are preconceived by the composer as alternative routes and engine matinees). The computer musician plays the role of the composer and performer (seen in 3D) and unfolds the electronic materials by navigating the scenes and interacting with the different parts of the instrument as they appear (via colliders, Deph of Field rays and virtual sonic scanners).


Figure 3. Performative stage on left ("Putney Ponoskty", 2016), and s.laag's bass clarinet hammer march-like scene (on right)

**Immersive performers:** 3d body-scanned characters

Performer, Instrument and composer were 3D body-scanned at the School of Materials Design & Fashion, University of Manchester and then imported into the game-engine (recombined via Makehuman, Blender and UE4).

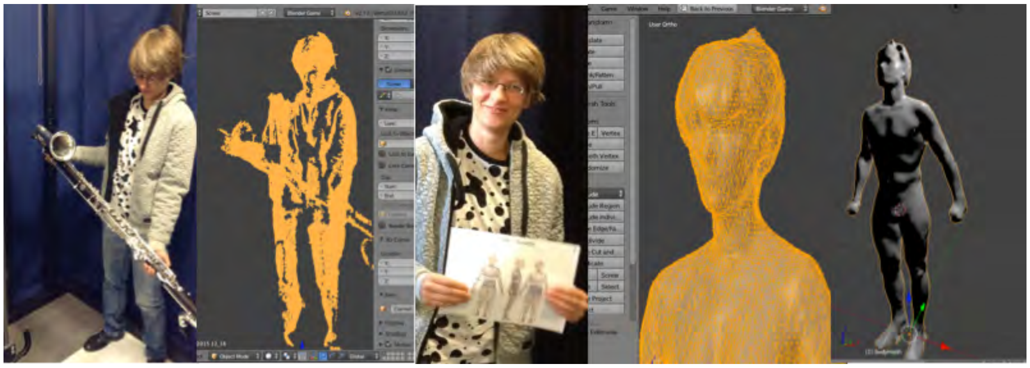

Figure 4. High Poly 3D scanning session at the School of Materials involving performer (left) and composer (right)

**Bass clarinet 3d parts:** mobile wind-chime construction and rigged performer

Instrument parts and humans were 3D modelled in Blender and exported to Unreal Engine 4 as the final performance tool.

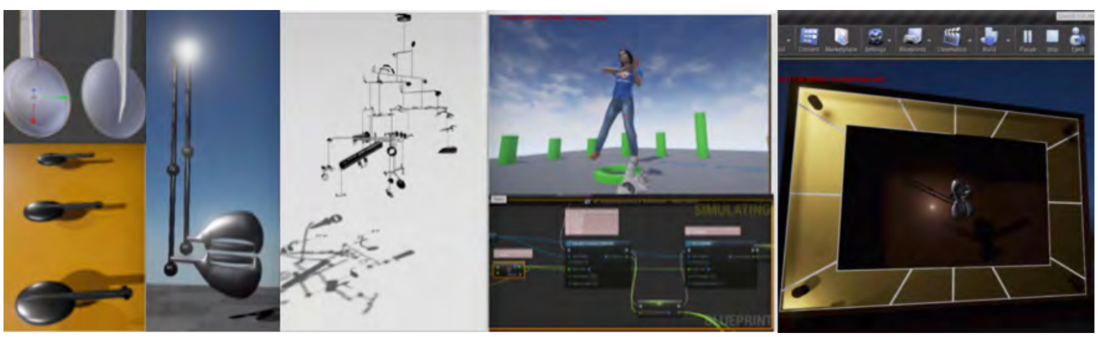

Figure 5. Clarinet parts mounted as musical mobiles and a performer's rig and clock driven by Bhv files and FFT analysis

**Frequency analysis:** the environment is the main character

The piece heavily relies on real time FFT analysis of frequencies and dynamics to drive and excite the environment and characters on stage (using the visualisation plugin in Unreal Engine 4). For instance, the 3D-mobiles, which are constructed by collecting instrument parts, are FFT driven, while the character's rig is driven by motion capture BHV files.

## Conclusion

s.laag is a musical composition aiming to push the boundaries of existing work using game-audio and 3D environment at the core of the compositional thinking. The project is a collaborative work between performer, composer, 3D scanners and modellers. The piece targets non-specialised audiences by facilitating the computer musical language and game-audio aesthetics via the use of gamification processes. This is to say that game-engine tools and the concept of game-play become part of an immersive journey, where audiences perceive complex musical ideas and structures via different channels of perception. In such effort, the composer aims to preserve the musical identity of the original work, which in this case was conceived before its game-audio implementation. Finally, s.laag aims to explore creative outcomes in a game-audio format, using the "modular metaphor" as the means for assembling aural complexities in the spirit of the dutch-uk.network project.

## Additional information

Link to Materials: http://game-audio.org/

Dutch-UK.network http://dutch-uk.network

Motion capture BVH files: www.cgspeed.com  (for performance mock before collecting own data)

**Acknowledgements. Dutch-UK.network** is supported by: Research Network Fund. School of Arts, Histories and Cultures, The University of Manchester, UK.  Special thanks to **Kees Tazelaar** (Institute of Sonology director), for providing an insight about the recording archive of the Philips Pavillion Expo 58. http://dutch-uk.network
3D Body scanners were provided by **Dr Simeon Gill** at the School of Materials Design & Fashion, University of Manchester. Bass Clarinetist **Marij Van Gorkom** for her recording session and workshops which took place in Studio 1, NOVARS Research Centre. http://www.novars.manchester.ac.uk

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# Owl Project - Rock Music

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**Abstract.** During the last year Owl Project have been developing a ranges of interfaces and techniques for transforming the ancient process of making a hand axe into a live musical performance. In Rock Music Owl Project delve 5000 years back in time to one of the oldest known creative processes, making sharp tools from rock such as flint. We are interested in turning “non-musical’ processes that are bound up in the history of production into music. The constraints of working with these processes create new musical possibilities and provide a way of re-examining old technologies. In this project we bring together experimental archaeologists and equally experimental electronic musicians in an attempt to couple the primal act of chipping rock from rock with the considered precision of synthesised music.

**Keywords:** Biophysical sensors, New interfaces for musical expression, Non-musical performance interfaces, The Acoustic and the digitals.

## Introduction

Owl project are interested in how rhythms are the creators of forms and also one of the foundations of music, previously they have explored making electronic music from early industrialized processes, including a traditional “Pole Lathe” Soundlathe, and a “Jacquard Loom”. The Rock Music project was developed during a residency at the Manchester Museum during which they reflected on older technologies and processes to create objects.

## Technology

The basic tools of flint knapping including, rock and reindeer billets, leather leg protector have been modified to contain a range of movement and pressure sensors. These “extensions” of the knapping process are plugged into a number of Eurorack synth modules that manipulate the signals and produce a range of sounds. Ancient tools for working with stone are turned into new performance interfaces.

## The Performance

Owl Project will perform alongside a fully insured professional flint knapper. It will last for approximately 30 minutes. The audience will witness the creation of a hand axe and a unique audio visual performance.

# Biographies

## Owl Project

Owl Project is a collaborative group of artists consisting of Simon Blackmore, Antony Hall and Steve Symons. They work with wood and electronics to fuse sculpture and sound art, creating music making machines, interfaces and objects. In 2009, working in collaboration with Ed Carter, they won a major commission to create '~Flow' a floating tidal water wheel powered electro acoustic musical instrument responding to the river. It was one of twelve public art commissions for 'Artists Taking the Lead' celebrating the 2012 Olympic Games, installed on the River Tyne, Newcastle, attracted over 50,000 visitors. They have performed and exhibited internationally, in 2013 they had a solo show at Bildmuseet Umea, Sweden. Sound Lathe continues to be shown as part of Sound Matters a touring show curated by the Crafts Council. 2014 saw newly commissioned works for 'Barnaby Arts Festival' and a residency project at 'Manchester Natural History Museum'.

## Karl Lee

Karl Lee s a master flintknapper and archaeologist with over 20 years experience of teaching the manufacture and use of stone ("lithic"), bone and wooden prehistoric tools. After obtaining a degree in archaeology at the University of Wales College Newport, he was accepted as a research student working on an archaeological PhD also with the University of Wales. He has also provided extensive teaching collections for several British universities including Bristol, Liverpool, Durham and branches of the University of Wales, and have carried out demonstrations and experimental research for the British Museum, London.

# Additional Information

More information can be found at http://www.owlproject.com/rockmusic.

Owl Project and Karl Lee rehearsing Rock Music, 2016

# DRIPPIGMENT

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**Abstract**. Drippigment reflects on how new emerging interaction techniques influence preconceived notions of painting. A Leap Motion device is used as interface, capturing the gestures made by the performer. A custom application developed in Max reads and parses the motion data and sends control messages to the Arduino, making the machine's motors move. In this current version the Drippigment's performance uses hand's gesture as the input for the act of painting, however, the hands are detached from the paintbrush: the paper is not touched by any brush, rather the pigment is dripping. The artistic processes emerge from two stages: the interaction between physical and digital interfaces and the balance between art as experience and art as an object.

**Keywords**: Installation, Interface, Aquarelle, Art, Performance, Interactive System.

## Drippigment

*Drippigment* is a performance that allows users to control an unfamiliar medium for creating aquarelle artwork. The machine is composed by a wooden cubic structure, with 1 meter long edges, and an electronic mechanism made of one stepper motor and four servo motors, all driven by an Arduino micro controller. The performance starts when the performer places both hands over the sensor. The performer as access to two different controls parameters: the ability to drop pigment and to rotate the position of the servo motors.

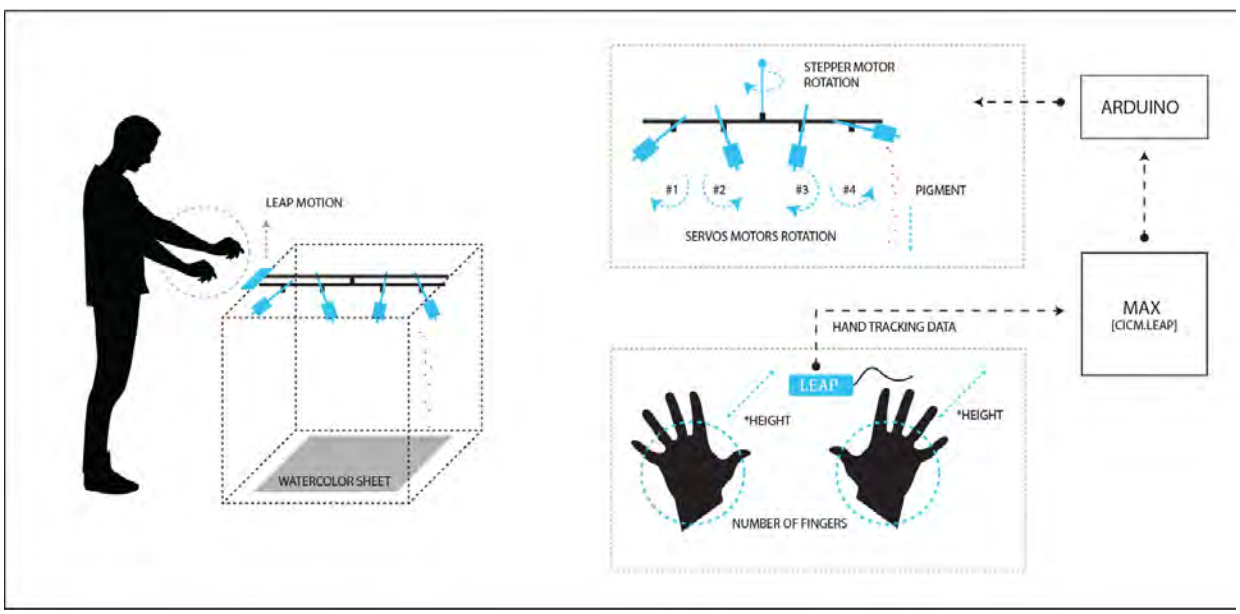


Figure 1. Interactive Scheme: User makes gestures over the Leap Motion device,
data is read by a Max application and sent to the Arduino, which controls the motors.

The number of fingers showed on each hand controls the rotation of the stepper servo on the top. For example, when making a fist, the performer controls the rotation (right fist = clockwise; left fist = counter-clockwise). Also worth mentioning, is the modular nature of the interaction: we can configure the system in different ways, making any hand control all motors, or making each hand control only one or a pair of them. Finally, in order to explore different interactions and data sources, future versions of *Drippigment* have been tested. As of today we are exploring with: i) an autonomous data-driven version, with no human interaction, resulting in a actions driven by random generated algorithms; ii) live data feeds from online sources are used as input and translate into actions, providing a aquarelle data-visualization; and also, iii) a reactive set-up, with music as input.

## Thematic Statement

Digital technology has come a long way in the last 30 years. We have rapidly become used to having real-time, mobile and social interactions with each others, technology and the world around us. The ubiquity of these digitally connected tools added more voices to the debate, more creators to the field, and has blown open ways audiences can be reach. As a digitally connected society, indeed, we are more globalized and industrialized but also, more than ever before, we have the tools to create and distribute unexpected forms of expression that diverge from any other previous conceived standard. When the experience is in itself an outlier, preconceived notions are inevitably put into question. In our work, art is seen both as an expression of human nature and as a tool for re-contextualizing concepts: Can a mass-consumption device be stripped of its meaning/purpose and be used as a new interface for creative inquire? What was painting before we experience this new interface? What is painting now? Who is the artist: developer, performer and/or the interface itself? What did we think we were doing when engaging with art? Who am I in this setting? The answer to these questions will not be deterministic, for each individual reflection will derive from a combination of the i) experience, ii) education and iii) social and cultural background of each of the participants. In sum, we are always influenced by our own representation of our activities to ourselves. Every new experience influences the way we perceive old experiences, and vice-versa.

## Related Work

This performance is based on Jackson Pollock's painting technique "Dripping", which is broadly characterised by the non-contact between the brush and the canvas. Pollock uses his canvas on the floor, on the horizontal plane, allowing the ink to fall - dripping. The gesture and the movement of the body in relation to the canvas are the most important features of this abstract expressionist technique. Pollock uses the gesture and the randomness to create his work. PRO[1] (Painting Robots Orquestra), from the contemporary Portuguese artist Leonel Moura, makes use of digital media - robots that produce paintings - on the horizontal plane. In Leonel's work, the sound is used as an input to produce random frequency-dependent paintings.

> Currently, modern art is rooted on the exploration beyond common sense reasoning towards the fields of subjectivity, experimentalism, randomness, and more recently chaotic determinism and emergence.[2]
> (Leonel Moura)

We establish a relation between these two approaches to develop our performance. In Drippigment, the gestural input is captured by a digital interface, which is then transformed by an algorithm that will output the dripping technique as a random canvas. With practice we are able to further improve the esthetic in order to control the final output.

[1] http://www.leonelmoura.com/pro.html

[2] http://www.leonelmoura.com/

## Media Assets

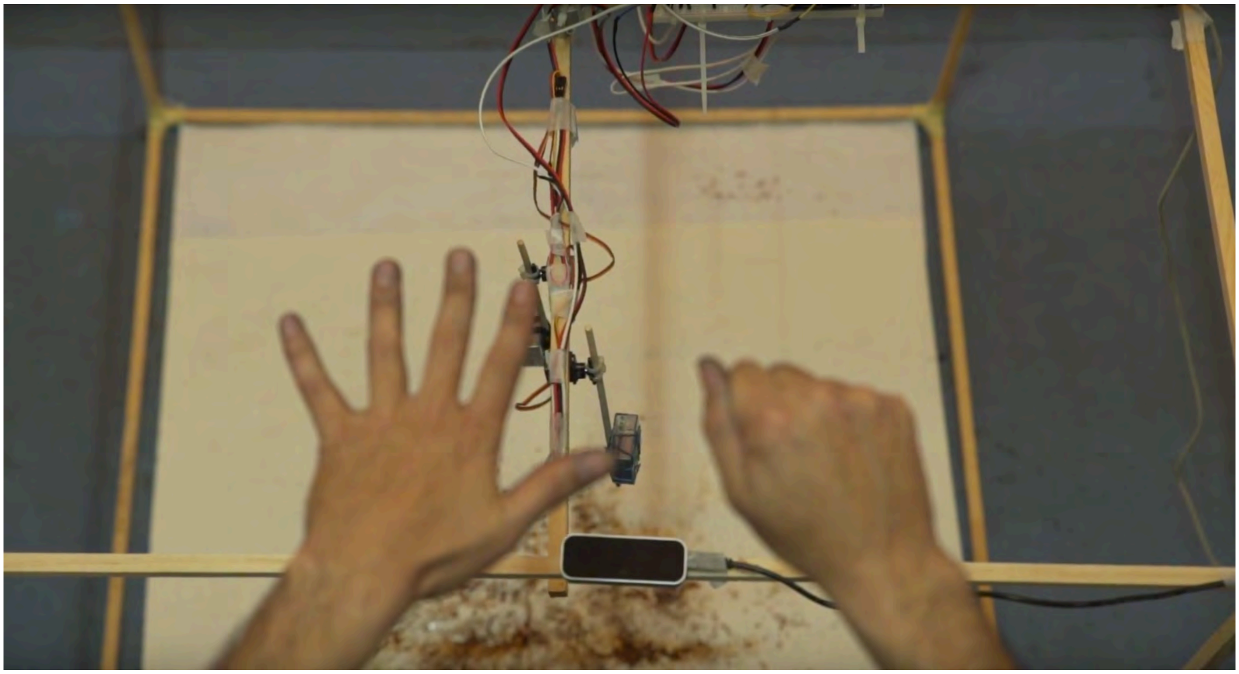

Figure 2. Still image from Drippigment's teaser video

Images and video documentation from Drippigment can be found at the following URL:
https://drive.google.com/folderview?id=0B5IfB2zAq4gZSGNBMGV0NGgwSjA&usp=sharing

## Authors

*Ivo Teixeira* (Espinho, 1979), visual and new media artist from Porto, Portugal. Graduated in painting and a Master Degree in Art and Design for Public Space at Fine Arts School of University of Porto. Nowadays is a PhD researcher under UT Austin/Portugal program in Digital Media at University of Porto/FCT and his work explore interactive systems in audiovisual installations and live performance between the private and public space, the physical and digital creating Augmented Spaces in his artistic work.

*Rodrigo Carvalho* (Porto, 1983), designer & new media artist from Porto/Portugal. Graduated in Design (U. Aveiro-PT, 2005) and with a Master Degree in Digital Arts (U.Pompeu Fabra, Barcelona, 2009). Rodrigo's work on live visuals, coding and interactive art involves a range of different outputs, from screen digital work, interactive installations, audiovisual live acts, or interactive visuals for stage performance. He is currently enrolled in a PhD program for Digital Media at the University of Porto/FCT under the UT Austin/Portugal Program. His research is focused on the relations and the synergies between sound, movement and image in audiovisual real time systems and environments.

*Tiago Gama Rocha* (Porto, 1981), Creative thinker from Porto/Portugal. Graduated in Film Studies (ESAP, Porto 2006) and with a Master Degree in Documentary Filmmaking and Society (ESCAC, Barcelona 2007). Tiago's curiosity as droved him to work on numerous settings: artistic, cultural, technological, entrepreneurial and industrial. He is currently enrolled in a PhD program for Digital Media at the University of Porto/FCT under the UT Austin/Portugal Program. His research focuses on distribution strategies for the digitally connected audience.

*Francisca Rocha Gonçalves*, (Porto, 1978), having a background in biological sciences with a degree in Veterinary Medicine in ICBAS - University of Porto and right now attending a Multimedia Master (Interactive music and sound design) in FEUP - University of Porto, she combines her interests in music and nature. Using interactive installations she pretends to raise aural awareness in the society, promoting environmental education and assessing the impact of noise in animal communication.

# Half-closed Loop - an improvisation environment for covered string and performer

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**Abstract.** The performance “half-closed loop” is a take on an instrument for a storytelling improvisation. By means of feedback induction on various levels, particularly by a custom instrument consisting of a string in a brass pipe and a wooden board with attached structure-borne drivers, the design’s idea is to not only allow the performer to produce a broad range of musical expressions but to also integrate elements of instability into the performance. Being designed as an open system with a significant amount of complexity in routing and control, the instrument lets performer and instrument “fuse” into one meta-system of human-instrument entanglement.

**Keywords**: control, interaction, performance, feedback, analogue, digital, improvisation, wavesets, resynthesis, musical instrument


Figure 1: “Half-closed loop”: Setup (a), Performing (b) and driver arrangement (c).

## Introduction

Improvisation is the - possibly complex - process in which performers contribute to a piece by selecting while playing from an extensive repertoire of figures and phrases. Their choice is based on personal interpretations and bias as well as the direction the performer intends the piece to advance.

At the same time, the form of an instrument for improvisation influences the sonic character of a performance thoroughly. Its features and characteristics determine how much effort it takes to carry out an intended expression. They have a crucial impact on what the player decides to play.

One form of sonic improvisation can be named “sonic story-telling”. The listener is invited to close her eyes and listen to a sound world to take shape. More quite parts alter with loud and intense phrases, parallel streams take turns in leading or following the soundscape’s gestalt, while surprising elements appear and have to be integrated into the sonic world by both, the performer and the listener.

The performance “half-closed loop” is a take on an instrument for such a storytelling improvisation. Its intention is to not only allow the performer to produce a range of phrases and musical expressions but, to a prominent part, to integrate elements of instability into the performance. These instabilities help keeping the performer alert, her struggle with playing the instrument turns into an inherent part of the storytelling process itself. Being designed as an open system with a significant amount of complexity in routing and control lets performer and instrument “fuse” into a meta-system of human-instrument entanglement (Hinrichsen et al. 2014).

## Components

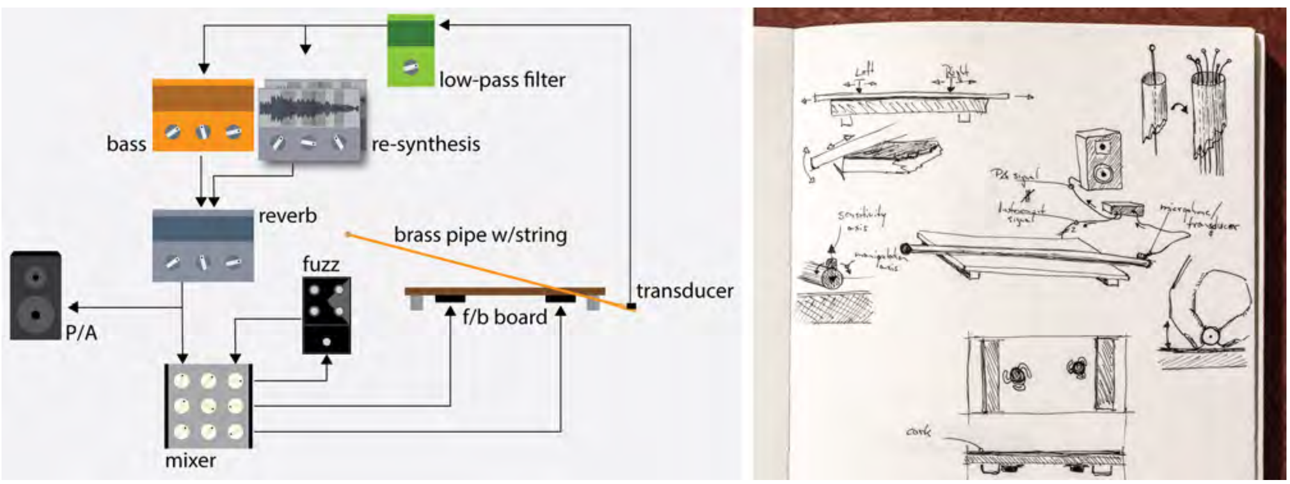


Figure 2: Routing and components of “Half-closed loop”.
Note that the components in the upper left are digital implementations that are controlled with a mixer-like interface.

“Half-closed loop”[1] consists of several parts, each serving a specific purpose for the improvisation setup. The two visually most prominent elements are a brass pipe and a hardwood board. Together they assemble a feedback instrument (see Figure 1): The brass pipe has an audio transducer attached to one of its ends and contains a tightened string that is inaccessible from the outside during performance. The pipe therefore serves as the passive element of the feedback system since it captures vibrations. With two structure-borne drivers attached to its floor-facing side, the hardwood board can be recognised as the active element. Sitting on four rubber feet, its vibrations are picked up by the brass pipe, when placed on its surface.

The signal from the audio transducer is sent to the computer where it is processed by a low-pass filter and a digital reverb.[2] Additionally, it is fed into the analysis part of a WaveSet re-synthesis engine (de Campo 2011)(Wishart 1994). The software setup eventually renders a stereo signal combining the filtered pipe sound, two reproduction parts of the WaveSet re-

[1] A documentation video of one of the first sessions with the system can be viewed at https://vimeo.com/156190237.
[2] JPVerb by Julian Parker, http://tai-studio.org/index.php/deind-ugens/.

synthesis engine, and a bass synth (a feedback FM oscillator wrapped in a ladder filter). The rendered sound is then passed to an analogue matrix mixer (Collins 1997)[3] by which it can be enriched by an analogue effect box containing a ladder filter and a JFET drive circuit.[4] All software parts are implemented in SuperCollider.[5]

With this set of sound generators and shapers, “half-closed loop” provides a broad range of sonic expressions to the performer. Its sonic gestalt is based on environmental as well as artificial parts (audio transducer vs. synthesiser) while at the same time being rooted in multiple domains; analogue and acoustic feedback is opposed by digitally-sounding re-synthesis of previously played elements, which allows for semi-automated regular patterns based on the sonic character of the other elements. At the same time, percussive sounds can be created via physically knocking the pipe or the board, whereas the audio feedback allows to create sustained sounds. All those sounds can be linearly as well as non-linearly altered and time-smeared.

## Interaction

Creating and playing a dynamic soundscape with several acoustic levels is challenging for one player. After all, the number of items to control is limited by the number of hands and fingers of the performer. One approach to lower the amount of controls while still keeping a significant amount of complexity is the use of cross-linking mapping matrices as it is described by de Campo (de Campo 2014). The approach used in “half-closed loop” is to outsource decision processes to the system itself: By being prone to external influences such as vibrations in the room, the subliminal muscle tremor of the performer’s hands, or just minimal posture changes - e.g., when turning a knob on the matrix mixer  the system changes, resulting in a (small or more severe) variation of its sonic output.

All parameters of the digital and electronic sound shaping can be accessed directly via dedicated knobs, buttons, or faders. This immediacy in sound generation combined with a relatively simple playing interface allows for fast reactions to the described unforeseen events. It is supported by vibrational feedback through the hardwood board; changes in the system can be felt much earlier than heard.

**Acknowledgements.** The used RTWaveSet UGen set was implemented by Fabian Seidl. The realisation of the 3DMIN project (Bovermann et al. 2014), and thus this paper and its related research, was funded by the Einstein Foundation Berlin.

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[3] Analogue matrix mixer as described at http://tai-studio.org/index.php/matrix-mixer/
[4] Moog MF Drive.
[5] SuperCollider can be found at http://supercollider.github.io

# Union

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**Abstract.** Union is an algorithmic system for mediating collaboration in telematic improvisation. OFFAL (Orchestra For Females And Laptops), a geographically dispersed collective of female sound artists and musicians, will perform using this system. Remote artists will send audio streams from their locations to the performance venue in a live collaborative improvisation. The musicians interact via the Union system which is an algorithmic mechanism which aims to mediate interaction between performers and find 'musical consensus' in the incoming audio streams.

**Keywords:** Improvisation, Telematic, Algorithmic, Collaboration, Machine Listening.

## Description of Work

*Union* is an algorithmic mixing mechanism which aims to mediate interaction between geographically dislocated performers and find 'musical consensus' in their audio streams. The system analyses audio streams sent by the performers to an online server in realtime using SuperCollider's Music Information Retrieval library. Streams which are sonically the most 'average' are mixed louder than divergent streams. The algorithmically mixed streams are played in the performance space and sent back out to server so performers can hear the final mix as it is played in the performance venue.

The mixing process is regulated by an algorithm which generates a sonic density graph for the performance, which defines how many audio streams are audible in each section, to ensure a musical ebb and flow to the performance. This is balanced by a further algorithm which tries to give all performers approximately the same amount of 'air time'.

*Union*, and the later formation of OFFAL, responds to the logistical challenges of developing a large ensemble of female laptop musicians and aims to mediate collaboration between geographically distributed performers in a non-hierarchical way. Strategically the most practical way to develop a large ensemble of female performers was to develop a system for telematic collaboration. This allowed the inclusion of many more women without the need for large funding grants to rehearse and perform. In order to be inclusive to as wide a range of participant the system uses free and open-source software, allows performers to collaborate with minimal intervention to their normal performance setup, and work on non-institutional and low-speed and -bandwidth internet connections. The audio streaming software used is IceCast which is low bandwidth but has a long network delay time (up to ca.10 seconds), meaning performers are playing with a degree of asynchronicity.

This temporal dislocation adds an interesting structural challenges to collaborating with performers who are already dislocated from the site of the performance and from each other. Temporal asynchronicity and lack of visual feedback mean performers can less easily perceive the actions of the other performers in relation to their own actions. *Union* aims to ease these challenges by taking care of some elements of musical organisation and structure. The chat client also provide a site of social cohesion, to describe the remote locations, performance site and audience interaction, and to give textual feedback and discuss creative aims.

During the performance the online chat between performers will be projected along with processed video content from the performers which will show which performer's are currently audible in the mix. The performance will be multi-channel with spatial panning of the audio streams relating to the geographical location of performers and the audio similarities of the streams. A visualisation of the panning gives a further indication of the output of the algorithmic process.


Figure 1. OFFAL performing with *Union,* 12th March 2016.

## Biographies

The infrastructure for *Union* is designed and programmed by Shelly Knotts. The performers are OFFAL (Orchestra For Females And Laptops).

Shelly Knotts develops performances and systems for technologically-facilitated improvisation which explore aspects of live-coding, algorithms and computer networks. She performs internationally, collaborating with computers and other humans. She is studying for a PhD in Live Computer Music at Durham University with Nick Collins and Peter Manning, where her research interests lie in the political practices implicit in collaborative network music performance practice and designing systems which play with particular data structures for algorithmic and improvised music creation. The improvisation systems she designs explore social (and/or antisocial) structures in collaborative performance situations. She has received commissions and residencies from Digital Media Labs, Sonic Pi: Live & Coding, PRSF and Sound and Music. Current collaborative projects include network laptop bands BiLE (Birmingham Laptop Ensemble) and OFFAL (Orchestra For Females And Laptops), and live coding duos UIAESK! (with Holger Ballweg), ALGOBABEZ (with Joanne Armitage) and *[Sisesta Pealkiri]* (with Alo Allik).

OFFAL (Orchestra For Females And Laptops) is an international collective of female[1] laptop performers who devise performances involving multi-location collaborative improvisation. The group formed in 2015 in response to research around gender in digital technology and laptop ensemble practice. As a non-hierarchical collective it aims to connect an international group of women engaged in electronic music by developing technological systems and organisational structures that facilitate collaboration. The group provides a platform for the creation and performance of new laptop music by women. Current members include Joanne Armitage (UK), Lina Bautista (ESP), Alexandra Cardenas (MX/DE), Libertad Figueroa (MX), Annie Goh (UK/DE), Shelly Knotts (UK), Diana Medina (ESP), Jenny Pickett (FR), Andrea Young (USA/CA).

[1] OFFAL use an inclusive definition of “women” and “female” and welcomes any member who identifies with a gender other than male.

# Do the Buzzer Shake

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**Abstract.** This performance explores a setting where the music is entirely created by the audience using their mobile phones, and there are no predefined hierarchies beyond the proposed interface. The piece is specified as a number of mobile accelerometer gestures that are recognized in a web application. Each gesture triggers a recognizable sound. The main goal is to study the social diffusion of the discovery process.

**Keywords**: audience participation, gesture sonification

## Introduction

A long tradition exists for music based on gestures using sensors. However, for most of this time digital sensors were only available to specialists. The popularization of smartphones and the easy deployment of web technologies have created an opportunity for the emergence of gesture languages for music. This piece explores social learning of gestures in a musical context using web audio. The audience is asked to connect their smartphone to a web location. The web page will start producing sounds in each user's phone. They are then asked to search for gestures that will produce identifiable sonic patterns. An example is given. The central part of the piece is then a dictionary that maps gestures to sonic patterns, and a machine learning system for detecting gestures using accelerometer signals. Everything is executed in the browser. The performance investigates how the gestures are learnt and propagated in a social setting.

## Technology

The software is implemented using web standards. A neural network has been trained to recognize a set of gestures using mobile accelerometer sensors. A training interface is used by the authors to record accelerometer data and train a classifier. In preliminary evaluation, the system has been evaluated using 2-second frames and 5 basic gesture classes, achieving 87% accuracy. The model is then loaded in a mobile browser using javascript to recognize the gestures in real time. In real-world usage, we have found it is really easy to get the system recognize the basic gestures. In initial trials they have generally been discovered by participants without showing them. Gestures trigger simple sounds synthesized using the Web Audio API. Loud square waves are used to maximize the volume when using mobile phone speakers. In initial tests, the technical requirements for smartphones can be reduced to having a recent Webkit browser (Chrome or Safari), which includes most recent phones.

## Rules and design

The piece depends on audience engagement and the acoustics of mobile phone speakers. A base sound is used for general synchronization, and basic instructions are given through projection. The main objective is to encourage the discovery of new sonic patterns. An example gesture is initially shown. The following rules have been given to participants in initial trials:

- Please don’t talk or laugh
- Turn volume up
- Do not allow the phone to lock the screen
- Tap on "START" and wait for the page to display the message "Touch to start"
- Wait for a signal from us to start
- Practice the first example for a bit and try to discover new gestures
- When you find a new gesture, a new sound will be produced, and your phone will vibrate
- In such case, show it to your neighbours!
- Stop after the final countdown

## Initial trials

The piece is intended to be premiered at ICLI2016. Some initial trials have been made at different scales: one, six and about a hundred participants. The system showed potential for engaging the audience, although some important factors are the size of the room and a quiet and focused audience.

# Interactive Tango Milonga: Fragments

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**Abstract.** Interactive Tango Milonga1: Fragments is an interactive dance performance using the Interactive Tango Milonga system, which enables dancers to drive musical outcomes via their movements within the Argentine tango music and dance tradition. Tango dancers are given agency over music in order to increase connection, the Argentine tango concept describing a transcendent experience of relation and synchronization between partners and music. Motion sensors are attached to the ankles and back of each dancer, and the information coming from these sensors are then translated into tango music. Like an improvising musician in an ensemble, each dancer receives musical feedback from both her movements and her partner's. Thus, each dancer can respond to the music, receiving further musical feedback, becoming further involved in both the sound and her partner's movements.

**Keywords:** NIME, Argentine tango, HCI, Embodiment

## Interactive Tango Milonga: Fragments

*Interactive Tango Milonga: Fragments* is an interactive dance performance danced by Courtney Brown and Brent Brimhall in the style of Argentine tango. Courtney Brown is also the creator of the interactive tango system and the tango music composer. The performance will be a structured improvisation as Argentine tango is traditionally improvised, lasting 4.5-5 minutes.

Figure 1. Dancers using the Interactive Tango Milonga system

[1] Milonga refers to a formal Argentine tango social dance event.

*Interactive Tango Milonga: Fragments* demonstrates a new instrument for musical expression for the Argentine tango dance and music tradition. Argentine tango dance was born in diverse immigrant working class communities of Río de la Plata, combining several traditions including the habanera, the Andalusian tango, and the candombe, an Uruguayan slave dance. Argentine tango music emerged after the dance tradition, and unlike most other Western social partner dances, like salsa, no standard basic step set to a particular rhythmic figure exists within the dance. Instead, movement in each moment is the result of nonverbal communication. Tango dance couples respond to the same music with diverse rhythms, movement qualities, and figures. Tango dance musicality, i.e., how dancers engage and respond to the music, requires creative decisions and negotiations between each leader and follower. Dancers improvise their own musical interpretations and also respond to their partner's via touch and movement. *Interactive Tango Milonga* is a new musical interface giving voice to this movement, allowing skilled dancers a novel avenue of connection, through sound.

Movement qualities and actions are translated into musical outcomes in a number of ways. For example, in the video documentation in the link below, follower steps and kicks control the onset of pieces of melody. Additionally, perceptual characteristics of movement are translated to similar musical perceptual characters, building a unified tango music-movement perceptual space. Many movement and music features with different weightings determine which perceptual category each falls into and how each is mapped. For instance, the smoothness or choppiness of the couples' movements are reflected in the music, how staccato or legato it is. Another example is how movement density is reflected in music density. So, how busy or sparse movement is determines this quality in the music – how many notes are played, what the thickness of the orchestration is. Dancers may also add musical ornaments and gain continuous control over their timbre and volume by performing a few specific tango gestures, such as the circling foot adorno.

Argentine tango is largely a social dance, taking place in dance halls, restaurants, and bars rather than the stage. The space between performers and spectators is fluid one, where those who are experts and novices both dance together and share the dance floor. By dancing, participants are engaging with a larger community and living tradition. Argentine tango performance grows out of this social tradition, where tango students, experts and professionals, demonstrate their skills and highly personal style to an audience of fellow dancers during a milonga, usually around midnight. Performance has also been a crucial to the export of Argentine tango and how new dancers come to know and join the global tango community. The interactive tango system, *Interactive Tango Milonga*, is also primarily a system for social dance, and the performance, likewise, arises out of the tradition of demonstration and interpretation.

## Additional Information

Video Documentation: http://vimeo.com/courtneydbrown/interactive-tango-milonga-performance-demonstration
Video Explainer: http://vimeo.com/courtneydbrown/interactive-tango-milonga

### Biography

Courtney Brown (creator, engineer, composer, dancer) is a sound artist, researcher and Argentine tango dancer. She is a doctoral candidate in Digital Media and Performance at Arizona State University, and a graduate of Dartmouth's Electroacoustic Master's Program. A former Fulbright Fellow, she developed interactive Argentine tango dance during her residency in Buenos Aires, Argentina. This on-going project gives dancers agency over music, their movements driving real-time musical composition within an Argentine tango social dance context. Through the physical act of creating sound, her works are a catalyst for investigating and altering embodied experience. Her continuing project, 'Rawr! A Study in Sonic Skulls', allowing both gallery visitors and musical performers to give voice to an extinct lambeosaurine hadrosaur, won an Honorary Mention from 2015 Prix Ars Electronica in Digital Musics & Sound Art. For more, go to http://www.courtney-brown.net.

Brent Brimhall (dancer) has been an Argentine tango dancer for five years has a background in martial arts, yoga, somatics, and post-modern contemporary dance.

# Horizonal

Ben Neill

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**Abstract.** *Horizonal* is a series of audio-visual pieces by composer Ben Neill for his self-designed electro-acoustic instrument, the *mutantrumpet*, with live interactive audio and video. The pieces utilize digital reproductions of paintings by artist Andy Moses as their visual material. Musically the work blends Neill's richly timbral melodies and textures with glitchy, minimal beats and deep sub bass lines. A series of subtly shifting sonic animations of Moses' paintings are generated simultaneously with the music through Neill's performances on the mutantrumpet. *Horizonal* is flexible in duration and can be presented either in a performance or installation format.

**Keywords:** new interfaces for musical expression, audiovisual, multimedia, acoustic and digital, human computer interaction, improvisation

*Horizonal* is an audio-visual performance by composer Ben Neill with imagery by painter Andy Moses. In *Horizonal* live computer interactivity is implemented in the realms of both digital audio and video simultaneously using Neill's self-designed hybrid instrument, the *mutantrumpet*.

> Hybridity has become a term commonly used in cultural studies to describe conditions in contact zones where different cultures connect, merge, intersect and eventually transform…In the case of digital environments, we must also address communicative interaction in the convergence of real and virtual spaces. Digital hybridity works across and integrates a diverse range of modes of representation, such as image, text, sound, space and bodily modes of expression. (Spielmann and Bolter 2006)

The concept of hybridity is a central focus of Neill's work as a composer/performer. The mutantrumpet itself is a hybrid amalgam of expanded acoustic instrument and electronic technologies. The synthesis of audio and visual material has been a strong theme throughout Neill's career, as well as the blending of ideas and compositional techniques from high art and popular culture. *Horizonal* continues these multimodal approaches, blending improvisation with composition and blurring the lines between art music, popular music and visual art.

The mutantrumpet was initially designed as an acoustic instrument combining three trumpets and a trombone in the early 1980's. Neill added electronics in the mid 1980's when collaborating with synthesizer inventor Robert Moog. In 1992, while in residency at the STEIM (Studio for Electro-Instrumental Music) research and development lab for new instruments in Amsterdam, Neill made the mutantrumpet fully computer interactive. In 2008 Neill created a new version of his instrument during another residency at STEIM, and has continued its development there in 2014 and 2016. The current mutantrumpet has two normal B flat trumpet bells, two sets of valves, and one piccolo trumpet bell that is attached to a trombone slide, making glissandi possible. The extra set of valves controls the switching between the three bells, and different mutes are used to give each bell a distinctive timbral quality. Half valving makes timbral shifts reminiscent of electronic filtering possible, and a quartertone valve enables microtonal performance. The acoustic trumpet sound is converted to MIDI data via a pickup in the mouthpiece connected to a pitch to MIDI converter that generates note, velocity, volume and aftertouch information. The current mutantrumpet incorporates a STEIM Junxion board, mounted under a plate of clear Lexan plastic. There are eight momentary switches on the Lexan panel, as well as four continuous MIDI controllers in the form of potentiometers and a fader. On top of the instrument, right next to the second set of valves, are two joysticks with X/Y axis controls. Another potentiometer is mounted on the first valve slide, located on the other side of the instrument body. The mutantrumpet connects to the computer via USB; the Junxion software maps the controllers on the board to a variety of routings. Many different configurations can be created in Junxion, including tables which shape the response curves of the controllers. There is a clip-on microphone attached to the bottom bell, making the acoustic sounds of the instrument available for processing. All MIDI notes are generated by the mouthpiece pickup, which helps to minimize feedback or glitching of the Pitch to MIDI device. Software applications frequently used include Junxion, LiSaXC (the STEIM live sampling program), Ableton Live, Jack Router, and numerous audio plugins. Resolume is used for the live video interaction.

Figure 1. The current version of the mutantrumpet, built in 2014.

Subotnick describes the two types of input control in live electronic performance as “static control in which the computer is told to activate certain functions by simple start/stop commands” as well as “dynamic control in which some form of sensing device is used which reads aspects of performance qualities.” (Subotnick 1999) Both approaches are used in *Horizonal* and are applied to several different processes.

1. Live sampling with LiSa XC

As Neill performs, the acoustic sounds of the mutantrumpet are sampled in real time using LiSa XC. The sampling process is triggered by switches on the instrument. One switch initiates replacing the sample buffer, another overdubs the sound to the existing recorded audio. The samples are then played back either through Neill’s played MIDI notes or by Ableton Live, whose MIDI sequences can control the playback of LiSa. Neill modifies the samples in real time as they are played back using the instrument’s continuous MIDI controllers. Parameters that are modulated include filtering, length and start points of the samples, granular synthesis, duration, pitch, and dynamics. The output of LiSa is connected to an audio track in Ableton Live through Jack Router, making the live sampled sounds available for further processing using plugins in Live. The live sampled sounds are directly connected with the acoustic performance and make up the primary melodic and harmonic structure in the music. The emphasis is on transformation of the acoustic sounds into complex sonorities and textures.

2. Ableton Live performance control

*Horizonal* is an open ended performance which is broken up into multiple sections or scenes of flexible duration. The mutantrumpet's switches are used to navigate through and activate the scenes. Ableton Live is fully controlled by the mutantrumpet's continuous and momentary controllers. Software synthesizers are played directly from Neill's notes and dynamics, and the percussion and bass sounds are also triggered in Live. Live's capability to introduce chance or random elements to the playback of sequences is utilized extensively. In addition, Ableton sends program changes to the video program Resolume that trigger the visual presets for each piece.

3. Resolume video control

The visual component of *Horizonal* consists of sonic animations of paintings by Andy Moses. Each section uses digital reproductions of two paintings that are mixed and animated in real time using Resolume's MIDI and audio control capabilities. The mutantrumpet's controllers are mapped to both audio and visual parameters, creating a true synthesis of the two media in performance. For instance, filter frequency is often mapped to the same controller as image brightness or color, creating a perceptible connection between the audio and visual dimensions. The joysticks, which are frequently used for pitch control of live sampling, are mapped to tables that outline the harmonic series; this overtone mapping is also applied to the visual parameters, creating audio/visual harmonics. The audio of the mutantrumpet, its directly played synthesizers in Live, and its live sampled sounds are all used to animate the visual material. The visual feedback can help the audience to perceive the interactivity of the performance. (Arfib 2005)

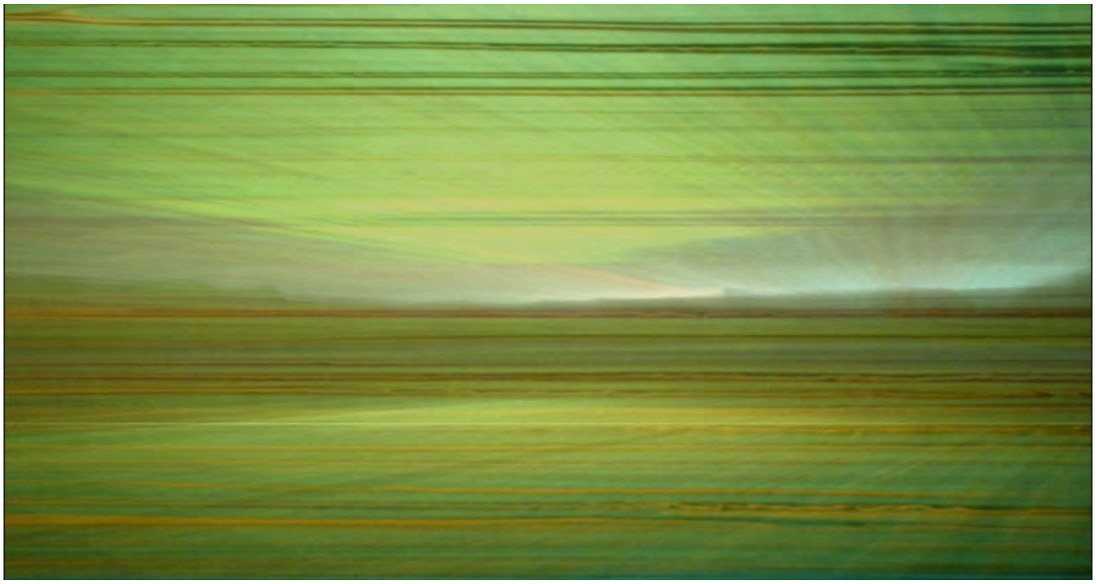

Figure 2. Still from *Horizonal* video, original images by Andy Moses

Moses' paintings are a futuristic hybrid of abstraction and landscape suggesting the theme of a horizon through the use of smooth horizontal lines. Often painted on concave and convex surfaces that resemble Cinerama movie screens, the luminous pieces evoke a sense of dynamic movement and the play of light. Neill chose the imagery because of its simplicity and minimal composition, which directly relates to his musical aesthetic. Following on the theme of dynamics and light in Moses' paintings, Neill's performance highlights the simultaneity of sonic and visual control. The video can be mapped on to multiple screens or projectors depending on the venue and mode of presentation. In addition to concert performances, *Horizonal* has also been presented in an installation format.

Neill has always conceived the mutantrumpet as a vehicle for his compositional ideas and approaches as opposed to being primarily a design project; the instrument is inseparable from its musical applications. As discussed in a recent *Leonardo* article by Johnston and Ferguson, “We need to consider fully the reciprocal relationship between the new instrument and creative practice, not just how well it supports existing practices, which are implicitly assumed to be static.” (Johnston and Ferguson 2016) Since “real-time operation is in fact better suited to performance and improvisation than to genuine composition” (Risset 1999), over time Neill has incorporated more improvisation into his performances. By populating pre-composed rhythmic and harmonic structures with spontaneous musical material played acoustically, a dialogue is created between the acoustic and electronic elements of each piece. The multi-timbral quality of the mutantrumpet’s acoustic sound adds to the complexity of the sonic exchange. The emergent melodic and harmonic patterns that unfold from the improvisational process often become primary material in the compositions. Jordà and Keith have both discussed the importance of improvisational approaches in performance with new instruments.

> The performer is not in control of everything; some external, unpredictable forces, no matter what their real origin or strength are, affect the system, and the output is the result of this permanent struggle. Whether surprise and dialogue is encouraged through randomness, by ungraspable complexity or by the machine's embedded knowledge, independently of the degree of unpredictability they possess, at their best, these new instruments often shift the centre of the performer's attention from the lower-level details to the higher-level processes that produce these details. The musician performs control strategies instead of performing data and the instrument leans towards more intricate responses to performer stimuli. (Jordà 2007)
>
> Improvisation has particular value for the single-performer-and-computer model, as external musical influence in the form of either collaborators or instrumental input is absent. This can run the risk of developing a ‘closed circuit’ in which the performer bears complete responsibility for navigating a fixed musical space. By developing a more reciprocal interchange between human agents and performance software, the concept of performance in contemporary electronic music is expanded from a reliance on pre-built arrangements, loops, and structures, to one that incorporates elements of real-time music creation—focussing on creative interaction, improvisation, and immediacy. (Keith 2010)

The combination of composition and improvisation is reflected in the video component of *Horizonal* as well. While the same images are always associated with specific sections of the music, the variations of the resulting video are different each time the work is performed depending on a complex series of interactions between the physical performance and software. “The only way to find things out about what happens when complex objects such as media systems interact is to carry out such interactions – it has to be done live, with no control sample.” (Fuller 2005) In designing the video, limiting the scope of the controlled parameters is very important in order to keep the shifts of color, movement and dimensionality within a subtle range that is implied by the paintings. The articulation of the images is as important to the overall performance as the musical decisions, and the multiplicity creates unexpected results. “Multiplicity is induced by two processes: the instantiation of particular compositional elements and the establishment of transversal relations between them. The media ecology is synthesized by the broke-up combination of parts.” (Fuller 2005)

Like many of Neill’s projects, *Horizonal* demonstrates strong influences from popular music. This is another example of the notion of hybridity that is central to Neill’s artistic output. A former student of minimalist La Monte Young and a long time denizen of New York City’s downtown music scene, Neill has always embraced popular music along with avant-garde ideas and practices. “Following on minimalism's ground breaking innovations, postmodernism gave 1980s art-music composers license to utilize popular culture elements and techniques as never before.” (Neill 2002). As described by Keith, “recent years have shown little discernible increase in the relationship between computer music research and more popular music forms, a number of intrepid live coders notwithstanding.” (Keith 2010) *Horizonal* is the latest example of Neill’s artistic project, which is aimed at bridging the gaps between new musical instrument design and popular culture. “Ben Neill is using a schizophrenic trumpet to create art music for the people.” (Berry 1997)

## Additional Information

Examples of the music and video:

Video: https://youtu.be/IWl2TsBzR9c

Album: https://open.spotify.com/album/0RQZdGgXHNo4rD0Zoc792j

Mutantrumpet demonstration video: https://www.youtube.com/watch?v=umBVBu6nFbI

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# WORKSHOPS

## Introduction

Paul McConnell

The ICLI 2106 conference hosted a number of workshops that approached the concepts of Live interfaces from diverse perspectives. These included software, computation, producing resonator instruments as well as group tasks that explored iterative feedback and distributed agency in performance. The workshops hosted at ICLI provided a great space to explore new concepts as well as learn and apply new skills for academics and practitioners alike.

# Sound and Space: Performing Music for Organ and Electronics

Dr Lauren Redhead[1] and Dr Alistair Zaldua[2]

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**Abstract.** This workshop will introduce the organ as an interface, and then explore its use in music for organ and live electronics. The workshop will be instructional for composers, introducing them to the instrument and its repertoire, and for those interested in extending the organ through technology. A second part of the workshop will be a 'lab' in which two pieces are explored and developed live, with a focus on the organ as a technology and its duet role in music for organ and live electronics by Alistair Zaldua and Thor Magnusson. In the final part of the workshop, Lauren Redhead and Alistair Zaldua will perform a selection of pieces from their repertoire that demonstrate the relationship of organ and live electronics in recent pieces.

**Keywords:** Organ and Electronics, Live Performance, Spatialised Sound, Post-electroacoustic, Acousmatic

## Background

Since 2010 Lauren Redhead has commissioned around 20 works for solo organ and for organ and electronics, with a further focus on contemporary experimental music and on graphic and extended notation for the organ. Working in a duo with Alistair Zaldua, she has toured these works throughout the UK and produced extensive CD and online documentation of the music. The duet has concentrated on exploring the live interface between the organ and electronics, sound and space. Their performances span the possibilities of the combination from organ with stereo fixed media sound, to organ with live diffusion, organ with live electronics and performances incorporating live notation. This has taken in collaborations with composers taking innovative approaches to technology including Jesse Ronneau (US/DE), Thor Magnusson (UK), Charles Céleste Hutchins (US/UK) and Rob Canning (IE/UK).

Whilst the sounds of the organ and of electronics have been rarely heard together in the late twentieth and twenty first centuries, they were also 'separated at birth'; as a combination they work extremely well, revealing interesting and unexpected things about the organ as an instrument and about the spaces in which the pieces are played. Redhead's and Zaldua's performance practice over the last five years has focused on pieces which explore this combination of organ and electronics/sound and space alongside contemporary solo organ works which also explore sound in space. Each performance is a new opportunity to explore the resonant possibilities of the spaces in which the organ is found. The organ and electronics work so well together because of the way that organs are built: they are installed in the space. The same is true of electronics, meaning it is possible to get a highly blended sound from the two, and have them sound with one voice. In many ways, the organ is the perfect instrument to team with electronics because it already works on a system of extending the sound through stops. Its sound doesn't come from a single source and its mechanistic method of sound production offers parallels with the creation of digital sound.

## Workshop Outline

**Introduction to the Organ and the Repertoire [90 minutes]** This workshop will begin as an introduction to the organ - as a live interface in and of itself - for composers and other interested parties. The links between the construction of organ sound and electronic sound will be brought out in this introduction. [30 minutes]

The workshop will then explore some examples of composing and performing practices for the combination of organ and electronics, focusing on technical and notational solutions. In this part of the workshop issues of ensemble, rehearsal and duet performance and technology (including MIRA and networked performance) will also be discussed. This will be illustrated with specific examples from Redhead and Zaldua's repertoire, that they have performed multiple times and in multiple spaces. Particular focus will be given to the technical and aesthetic demands of the works, and to the collaborative elements of work with their composers. [45 minutes]

Despite the possibilities of this combination of sound and instruments, many performance issues are raised by this pairing. These issues are logistical, due to the unusual nature of some performance spaces, and also aesthetic, posing issues for the performer-as-collaborator. These aesthetic issues will also be presented and discussed. [15 minutes]

**Exploration of New Work [90 minutes]** This section of the workshop will explore two new works for the instrument.

The first focus will be on a new piece, created by Alistair Zaldua for the workshop, which explores the MIDI capabilities of the organ. The focus here will be on using MIDI to control the organ (electronics as an interface for the organ) and using the organ as a MIDI interface for the electronics (organ as an interface for the electronics), thus expanding the possibilities of the organ console itself. The composer will introduce the piece and its technology and lead a workshop exploring and refining its possibilities.

The second focus will be on the piece, *Fermata*, which uses the Threnoscope interface developed by Thor Magnusson. The composer will introduce the piece and the software, including a networked aspect of the performance for the organist. The possibilities of this combination will then be explored live.

## Concert

The workshop will close with a performance of works from Redhead and Zaldua's repertoire. The pieces chosen take an innovative stance to technology as well as the organ:

*The Cathedral and the Sea* (2010) - Mesias Maiguashca - 6'
*Immrama* (2014) - Charles Céleste Hutchins - 5'
*Nemo's Organ* (1972-1990) - Mesias Maiguashca - 20'
*ijereja* (2015) - Lauren Redhead - 5'
*Diapason* (2012)- Jesse Ronneau - 12'

## Programme Notes

**The Cathedral and the Sea** (2010)
Prelude to a Prelude for Organ and Sea Noises

In the piano prelude La Cathédrale Engloutie Debussy describes a curious landscape: a Cathedral, moreover, a whole region appears covered by the sea. Time seems still, it is stretched to infinity. The legend of the engulfed City of Ys gives a clue for the origin of this landscape. In my composition The Cathedral and the Sea time is active, things happen: the sea, symbol of astronomic time devours (in five minutes, the duration of the composition of Debussy) a cathedral, symbol of human time. Time devours time. (Mesias Maiguashca)

**Immrama** (2014)

The notation for Immrama is created in real time via a process which collages various elements that can often be found in graphical scores – geometric shapes, de-contextualised and transformed bits of notation, and phrases of written text. The text is taken from the program that generates the notation, so that the program examines and uses its own source code. The result is intended to be a query into the elements that make notation musical. (Charles Celeste Hutchins)

**Nemo's Organ** (1972-1990)

Every time I re-read the book 20,000 Leagues Under the Sea by J. Verne I was always fascinated by the question of how Captain Nemo's organ, on board the Nautilus, must have sounded. In the summer of 1971, whilst listening to my piece ÜBUNGEN for tape (1971, with sounds generated from an electronic organ and synthesizer) I believed myself to have come near to this sound. The mixture of ÜBUNGEN with sounds of a real organ created a mixture which is both unique and bizarre, and suggestive of the sound of the Nautilus. The main parameters of ÜBUNGEN are timbre and continuity. The timbre moves between sine-like tones and white noise, through a very carefully thought-out scheme where continuity is the main criteria. The same rules control the organ part. It clearly moves according to its own scheme. The paths of the organ part and the tape part meet, they cross over and accompany themselves and therefore create a labyrinth: a labyrinth that represents the curious structure of psychic meandering conceived by J. Verne.

Nemo's Organ was written for S. Szathmary and was premiered at the Metz Festival in 1990. (Mesias Maiguashca, trans. Alistair Zaldua)

**ijereja** (2015)

ijereja is a transliteration of the transliteration of the Mycenean Greek word for 'priestess' in the Cretan-Minoan script known as Linear B. This project draws on materials including real and fictional maps, sound poetry, Linear B and its (mis)translations, recorded improvisations and strategies for performing and responding. These materials enable their live interpretation and reinterpretations as a multi-layered, open and 'digital' opera. ijereja is interested in the interrogation of the potentially liminal space between performance, voice, speech, language, text, writing and notation. (Lauren Redhead)

**Diapason** (2012)

Diapason

1. A full, rich outpouring of harmonious sound.
2. The entire range of an instrument or voice.
3. Either of the two principal stops on a pipe organ that form the tonal basis for the entire scale of the instrument.
4. The interval and the consonance of an octave.
5. A standard indication of pitch.
6. A tuning fork. (Jesse Ronneau)

# Additional Information

## Composer Biographies

**Charles Céleste Hutchins** was born in San Jose, California in 1976. Growing up in Silicon Valley, he started programming at a young age and has continued to do so, even after leaving dot coms to peruse music composition – obtaining an MA form Wesleyan University in 2005 and a PhD from the University of Birmingham in 2012. His recent work has focussed on gendered labour and AI.

Born in Quito, Ecuador, the 24th of December, 1938, **Mesias Maiguashca** studied at the Conservatorio de Quito, the Eastman School of Music (Rochester, N.Y.), the Instituto di Tella (Buenos Aires) and at the Musikhochschule in Cologne. Productions in the Studio for Electronic Music WDR (Cologne), the Centre Européen pour la Recherche Musicale (Metz), IRCAM (Paris), Acroe (Grenoble) and ZKM (Karlsruhe). He has taught in Metz, Stuttgart, Karlsruhe, Basel, Sofía, Quito, Cuenca, Buenos Aires, Bogotá, Madrid, Barcelona, Györ y Szombathely (Hungary), Seoul (Corea). His work has been performed at the most important European festivals. He was professor for electronic music at the Musikhochschule Freiburg from 1990 until his retirement in 2004. Together with Roland Breitenfeld, he founded the K.O. Studio Freiburg in 1998, a private initiative for the practice of experimental music. He lives in Freiburg since 1996.

**Jesse Ronneau** originally from Chicago, is a composer and improviser. His works have been performed by Ensemble Sur Plus, the h2 Quartet, ensemble cross.art, Carin Levine, Ian Pace, Pascal Gallois and many others throughout the EU, the USA; in Thailand, South Africa and Australia. He was a lecturer of Composition in Ireland for 7 years and now lives in Berlin.

## Performer Biographies

**Dr Alistair Zaldua** is a composer and conductor of contemporary and experimental music and currently teaches at Canterbury Christ Church University (aesthetics, composition, and conducting). His work has been performed both internationally and in the UK: Huddersfield Festival (2014), Sampler Series Barcelona (2014), Borealis (Bergen, Norway, 2014), Leeds New Music Festival (2013), UsineSonore (Malleray-Bevilard, Switzerland, 2012), Quantensprünge ZKM (Karlsruhe, 2007 & 2008), Música Nova (Sao Paolo, 2006). Alistair currently works with Lauren Redhead in performances for organ and live electronics, and improvises in a duet with film maker Adam Hodgkins (violin and live electronics).

**Dr Lauren Redhead** is a composer of experimental music, a performer of music for organ and electronics, and musicologist who focuses on the aesthetics as socio-semiotics of music. Lauren's music has been performed by international artists such as Ian Pace, the Nieuw Ensemble, Trio Atem, Philip Thomas, BL!NDMAN ensemble and rarescale, and she has received commissions from Yorkshire Forward, the Huddersfield Contemporary Music Festival, Making Music and the PRSF for Music, Octopus Collective with the Arts Council of England and most recently from TRANSIT festival. Lauren's music has been performed at Huddersfield Contemporary Music Festival, Gaudeamus Muziekweek, the London Ear Festival, London Contemporary Music Festival, Firenze Suona Contemporanea, Composer's Marathon V (Vienna), Full of Noises Festival, the New York City Electroacoustic Music Festival, and many locations throughout the UK and Europe. A CD of Lauren's chamber works entitled *tactile figures* was released on the engraved glass label in 2012. She has since released two albums with the pan y rosas discos experimental music label (Chicago) and her work 'concerto' featured on the debut album of the Vocal Constructivists, 'Walking Still' (Innova). As an organ performer Lauren is actively involved in promoting and commissioning new works for organ and electronics and graphic and open notation works for the organ. She co-curates the 'Automatronic' concert series for organ and electronics with Huw Morgan and Michael Bonaventure. In 2015 she released a duet organ and electronics album with Alistair Zaldua on the sfz music label.

## Links to Work

CD: *Diapason: Music for Organ and Electronics*: https://automatronic.bandcamp.com/releases
Collective, 'Automatronic': http://automatronic.co.uk

Further audio links:

https://laurenredhead.bandcamp.com/album/organ-electronics-tour-some-highlights
https://laurenredhead.bandcamp.com/album/sound-image-resonance
https://soundcloud.com/laurenredhead/rob-canning-dislocated-spaces
https://soundcloud.com/laurenredhead/mic-spencer-clstrfck

# Distributed Agency in Performance

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**Abstract.** Building on the recent *Interagency in Technologically-Mediated Performance* symposium at Bournemouth University, this workshop will aim to practically explore intersubjective relationships between networks of human and non-human actors in the context of artistic performance.

**Keywords:** performance ecosystem, agency, irreducibility, resistance, adaptability, embodiment, co-tuning, emergence, mediation, feedthrough

## Description

Our workshop is targeted at performers, designers and researchers who have an interest in practically exploring complex emergent behaviors and dynamic relationships in 'performance ecosystems' (Waters 2007). We aim to arrive at a better collective understanding of the following questions:

- How is agency distributed across people and things in performance environments?
- Can we move the thematic of performance away from demonstrating control to developing empathy and skilful adaptability?
- How can we move past the design motivation of interface transparency towards a recognition and celebration of resistance, instability and co-tuning?
- What happens when we transduce between different domains, e.g. sound -> electricity? Can we develop a more shaded account than simply talking of losses, noise or imperfections?
- How can we better understand sounding assemblages that are irreducible? If something doesn't lend itself to being understood in terms of its component parts, then can we develop workable tactics for designing and playing with such things?

We will begin the workshop by contextualising these questions through discussion of existing artistic works and ideas, before moving swiftly on to collaborative practical exercises. Our aim here is to deepen our knowledge of music making through 'doing' and 'showing' rather than merely 'telling'. Following this introductory stage, while working in small groups with the facilitators, you will design and physically sketch a human-scale (partially functioning) prototype of a performance ecosystem. This network will include a range of interrelating agents, possibly including: people, elastic bands, cardboard boxes, computer code, sensors, actuators, step ladders, masks, books, tacit rules, and explicit methods for resisting equilibrium and/or provoking crises. Following this stage, each group will deliver improvised performances while acting out the necessary elements of the physical sketches. These improvisations will provide the basis for critical discussion and subsequent performative iterations. Our team of artist-researchers will facilitate the workshop and provide expertise in designing musical interactions, physical sketching, rapid prototyping, improvising, and critical reflection.

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## Artistic Works

Nicolas Collins *Pea Soup* (1974; 2001-2014)

Tom Davis & Paul Stapleton *Ambiguous Devices* (2012-)

Agostino Di Scipio *Audible Ecosystemic Interface* (2003-)

Bennett Hogg *Ghost Orchestra* (2008)

Stanley Lunetta *A Piece for Bandoneon and Strings* (1966)

Tom Mudd *Control* (2015)

John Richards et al *Dirty Electronics* (2003-)

# A Practical and Theoretical Introduction to Chaotic Musical Systems

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**Abstract.** This paper is an extended dialogue on the workshop themes of nonlinearity, feedback, and chaos in musical instrument and interaction design. Following a brief introduction to the area, perspectives are brought from the three authors on their practice and research in this field. Cross examination of these perspectives leads to the suggestion of some open research questions. The original workshop description is included as an Appendix.

**Keywords:** nonlinear dynamics, chaotic musical systems, interaction design, agency, autonomy, emergence, feedback, audible ecosystems.

## Introduction

This paper emerged from a collaborative workshop proposal on the subject of chaotic musical systems. Behind the workshop was the desire to collide the various perspectives the authors bring from their engagement with chaotic and nonlinear systems in their research and musical practice. The intended aim of this three-headed approach is to illuminate the points of resonance and difference between the positions of the authors - with the hope that this knowledge sharing could be fruitful in theorising the overlap between musicality and unpredictability, and stand as a platform for further research in this area. At the heart of the workshop and this paper is a double articulation between theoretical and practical concerns, where multiple perspectives are brought into dialogue - with an emphasis on the challenges posed by these techniques to the various features of musicality as it relates to digital instrument design. Nonlinear and chaotic systems provide a distinct set of resistances and affordances in performance, cleaving a space for reassessing our categories in thinking human-machine interaction.

## Background

A wide body of literature and practices have developed around the use of chaotic systems for musical ends over the past 50 years. Ranging from their deployment as structural processes for composition (Pressing 1988), to their use in digital and analogue synthesis methods (Choi 1994, Dunn 2007, Slater 1998, Tudor 1995). They may be used explicitly as named systems, such as Choi's use of Chua circuits, Dunn and Ikeshiro's use of the Lorenz attractor, Pressing's use of the Logistic map and predator-prey models, Di Scipio's sine map, Ian Fritz' implementation of a Jerk (Elwakil 2004) equation, or Andrew Fitch's implementation of coupled Wien Bridge oscillators (Yang and Li 2002) for analogue synthesis. They may also be explored more intuitively in feedback systems, whether with analogue electronics, microphones and loudspeakers, guitars and amplifiers, or in digital feedback systems. While a full literature review of the subject is beyond the scope of this paper (see Sanfilippo and Valle (2013) for a useful overview), it's important to note that chaotic systems have enabled a rich and diverse set of musical practices at multiple time scales - both at the level of sound generation, and at higher order structural levels - often with feedback and interdependency between the two. Without being overly deterministic, a theme that runs throughout this canon of practices is that systems which are iterative, structurally coupled internally and/or to their environment, and display some degree of self-organisation – all bear some resemblance to and have resonance with the loose and distinctly humanist category of 'musicality'.

# Perspectives

## Tom Mudd

My interest in nonlinear dynamical systems stems from wanting to improvise with digital tools. In particular wanting to create tools that I can explore over extended periods of time, finding and discovering sounds and behaviours that I couldn't have envisaged in creating those tools. Many free improvisers have described a sense of surprise with their instrument even after months, years or decades (Kopf 1986, Warburton 2001, Prévost 2008). How can instruments that may be relatively simple in construction be so endlessly unpredictable and explorable? My recent research has been investigating the role of nonlinear dynamical processes in musical interactions: iterative systems where the output is a nonlinear function of both the current inputs to the system (e.g. the musician's actions at a given point in time), and the previous output from the system. Although the abstract mathematical nature of these systems may seem distant from the concerns of saxophonists or violinists, acoustic instruments can be seen in very similar terms. Reed and bowed instruments in particular can be seen as nonlinear dynamical processes (Smith 2010), and physical models of such acoustic instrument necessarily involve nonlinear functions and feedback.

The result - whether implemented digitally or acoustically - may often produce situations where the interaction is confusing and difficult. While this may sound like a problem, particularly in the context of interaction design, in musical situations this can be a virtue: the instrument will throw things back at the performer that they may not have been able to predict, and allows room for an interaction in which the musician has a relationship with the instrument rather than commanding it (Unami, 2005). The mechanisms that create the "difficult" interactions may also be responsible for the richness of possibilities on those instruments. John Butcher provides an excellent example: through exploring the points where the reed ``seizes up and brakes down [...] on the edge of controllable sound'' (Warburton 2001) he finds a wealth of amazing resources which may be explored seemingly endlessly. A somewhat trite comparison might be to the infinite detail that may be found at the edges of a fractal structure, only in this case this is not an analogy at all, as fractals are, in general, also iterated nonlinear functions and the levels of detail found at these edge points are potentially connected in a very real way.

These ideas were explored in a recent study into how musician engage differently with digital systems that do and do not contain nonlinear dynamical components (Mudd et al, 2015). Participants of varying musical backgrounds engaged with a range of representative systems, and their behaviours, responses and attitudes were recorded and analysed. The study suggested potential links between the inclusion of such processes and the affordance of exploration and serendipitous discovery. The results are difficult to generalise from the specific systems considered to nonlinear dynamics more broadly however.

My musical practice has involved digital implementations of nonlinear dynamical processes to synthesise sound. Recent, fruitful work couples relatively `simple' nonlinear dynamical systems, such as the Duffing Oscillator, to banks of resonant filters. The output from the filters is fed back to the nonlinear equation at audio rate (currently implemented as an external in MaxMSP). This bears a resemblance to many physical models, where the reed or the bow behaviour represents the nonlinear function, and the resonant filters represent the linear response of the string or vibrating air column. The resonant filters serve to tame the chaotic nature of the nonlinear dynamical system to an extent, so that controlling the resonance controls the stability of the system. The systems are similar in kind to those described for the empirical study (Mudd et al 2014; 2015) and are described in more detail there.

## Tristan Clutterbuck

My perspective on nonlinear and chaotic musical systems derives primarily from an interest in the provocation these tools provide in challenging our theorisations of what it means to be 'social' in musical practice. This provocation lies in the ways in which these kinds of systems tend to display complex behaviours over multiple orders and timescales - the question this poses is how can it be said that objects *do* things in the course of social action? In order to address this problematic I turn to the sociology of actor-network and material semiotics (Latour 2007, Law 2008, Suchman 2006). My background lies much closer to the social sciences than mathematics or physics - so whilst I'm interested in the various means of describing these systems mathematically and the aesthetics of their behaviour, my stake is not so much in carving out a partisan position on interaction / system design. I'm more interested in describing the ways in which these systems, and the various nebulous concepts which orbit them (agency, autonomy, etc.), collide with the rich social fabric of *musicking* - a concept which somehow brings together practices, rituals, genres, sounds, time, histories, amongst countless other ideas. My recent research has been involved in grappling with the difficulties of writing a longitudinal sociological analysis of musical practices which construct incredibly complex assemblages of 'autonomous' technologies, institutions, bodies, and identities. A strong focus is on trying to overcome simple anthropomorphisms in describing the agency of chaotic musical systems by widening the frame, or *unit of analysis* of these tools. In order that we might illuminate the *other* entities which transform, mediate, overcome, and dominate the 'agencies' of our musical systems. When our systems act, what else is acting?

The other side of my research which feeds these theoretical concerns, is musical practice based in free improvisation with chaotic and nonlinear systems. Engaging with explicitly 'agentive' musical systems, systems which display varying degrees of autonomy at micro and meso structural levels. This began with a close exploration of Rob Hordijk's (Hordijk 2009) rungler circuit in both analogue and digital instantiations, but has been followed by engagement with the analogue circuits of Grant Richter, Ian Fritz, and Andrew Fitch. All of these designs share the emergent property through performance that they *feel* like you're engaging with something which has it's own sense of direction and agency. The instrument is in a complex play between equilibrium and instability, with myself interfering in order to push it in either direction. These tools *operate* on us in strange ways, through their seeming capacity to make 'musical' decisions – even if, when we open up the black box these behaviours are the emergent property of some incredibly simple processes. A concept of cognitive scientist Andy Clark's (Clark 1998) which I find useful to employ to describe this relationship is that of continuous reciprocal causation. A double articulation is at the core of this interaction, it's impossible to separate the movements of the performer and the movements of the instrument - these entities cannot be viewed under a strict 'action - response' paradigm.

Given these observations, one might propose to apply some thesis on objectural agency to musical practice in order to tie up these loose ends. But on closer examination things are not that simple, and what on face value looks like a singular agency displayed by this kind of system, turns out to be not as straightforward as it might seem. For one thing, they seem to play two roles at the same time, at once a straightforward musical instrument (nonlinear, chaotic, and multistable characteristics are displayed in a number of traditional musical instruments, and canonised experimental systems from the avant-garde onward), and at the same time acting as an instance of cultural memory, operating more in the capacity of a score than an instrument, (I'm referring to their meso structural capabilities, and larger scale structural decisions made by systems like George Lewis' voyager (Lewis 2000)) where the designer reaches through time and space to 'takeover' and constrain a performer's agency during performance. Here agency is dislocal, and decontemporalised, and the dichotomy between designer and performer is often unclear - but again, could the same also be true of traditional musical instruments? Could the cello for example, also be viewed situatedly, and ecologically, as a meso-structural device based on the parameters of the length and speed of a human arm, and the size of the body of the instrument. A difference only of agential scale, not type. These multiple duplicities put a strain on traditional theorisations of instrument/performer relations. There's a plurality at the heart of these objects, a kind of phasing between states, which makes it difficult to make any definitive truth claim about their being or capability to act, at once faced with something seemingly so singular, and unique in it's ability to act, yet also strikingly familiar in their resemblance to traditional forms. It's my contention that complex systems are no special case of objective agency, but rather act as a kind of compressor for musical agency *writ large*, a drawing into a single locale vast networks of relationships, threads of agency, transformations in the course of action. Entities which are normally so distributed in time and space as to have their effect written out of, or merely into the background of the course of social action. These systems are vast ecologies scaled to the everyday interaction space of the human mind that is locally and concurrently.

To focus on these as objects of a singular type with the capacity to act in musical interaction is to close down an analysis of how they are embedded in a complex web of social mediations at multiple scales (Born 2010).

### Dario Sanfilippo

My research focuses on the exploration and study of topics that include complexity science (Mitchell 2006, Morin 2006, Kitto 2006), cybernetics and systems theory (Ashby 1956, Heylighen 2001), chaos theory, graph theory, interactivity and synergetics (Corning 2002), as well as their applications for the design of living and intelligent sonic systems for human-machine interaction performance, autonomous sound installations, and nonconventional sound synthesis and processing techniques (Sanfilippo 2013). Within this framework, concepts, technology and creative practices are interdependent and codetermine themselves with the goal to merge science and art by establishing a bidirectional communication between these two areas.

The implementation of systems which are capable of evolving autonomously and non-trivially (von Foerster 2003) is a fundamental aspect of my work, as a condition where both the human and the machine can generate actions and reactions is necessary in order to have mutual influence — interaction. These systems exhibit an individuality, organicity and expressivity characterising some sort of artificial life form that emerges from networks of recursive and nonlinear interdependencies, for which improvisation is the functional mechanism - aural feedback - that allows the cross-coupling of two entities which simultaneously perturb and adapt to each other. Even in the low-level, sound streams affect each other and shape themselves and interactivity becomes a structural characteristic distributed at all scales and domains. Time and frequency are indeed strictly interrelated and as a result the sonic quality (timbre) affects the quality of the dynamical behaviours (form) and vice versa (Di Scipio 2003).

Every component - analogue or digital - which is within a feedback loop (Sanfilippo et al. 2013) in the network becomes a unit with a systemic and fundamental role in the totality: something that contributes to the resulting global behaviour of the system. As a consequence, the quality of the single devices or algorithms used is meaningless in relation to the whole. Different components, regardless of their quality, will generate different emergent behaviours which are not to be considered as better or worse than others. The environment, too, can become structurally connected to the system by means of external feedback configurations - for example using aerial microphones and loudspeakers - so that the particular anti/resonances and all the possible perturbations of an environment will be essential for that specific sonic result. This way, there is no constraint as of what kind of equipment/technology is used and what the characteristics of an environment are, as every situation is potentially an interesting one.

## Openings

Rather than provide conclusions from this brief overview, it seems more useful to cross examine the perspectives and histories provided to suggest some open questions, or areas of further research in this field. Chaotic and nonlinear systems in relation to musical practices weave together a complex set of threads from cognitive science, biology, physics, mathematics, the arts, social sciences, and philosophy. With obvious prospects for interdisciplinary work, and knowledge sharing between the arts and sciences. Open questions fall around the utility of 'simple' modelling techniques to describe a reduced version of incredibly complex 'real' systems of humans and non-humans. How can we mobilise our mathematical understanding of complex systems in the description and understanding of something as 'loose' and heterogeneous as musical practice? What role do these systems already play in our interactions with musical tools, and how are these systems understood by musicians that use them? What can qualitative methods tell us about the scale of nonlinearity required for a system to feel musically useful?

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# Interfacing the Txalaparta Workshop

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**Keywords:** txalaparta, generative, interface, interactive.

## Description

The workshop will consist on an introduction to the Basque tradition of the txalaparta and the research that lead into the creation of the Interactive txalaparta software.

The txalaparta is a percussion tradition from the Basque Country. The instrument consists of a variable number of wooden planks placed horizontally and beat vertically with wooden batons (figure 1). It is played by at least two players who alternate their beats performing through an improvisatory call-and-response pattern.

The Interactive Txalaparta is software developed by the author during his PhD at the University of the Basque Country. It listens to a human playing a txalaparta using the microphone input. It analyses and extracts several parameters from the play and generates the second player's part of the rhythm in real time allowing a single human to improvise together with a computer using a real txalaparta. The software reacts to the human play in a txalaparta and by doing so the txalaparta instrument effectively becomes the interface to control the Interactive Txalaparta software (figure 2).

Participants will learn about the history and the main characteristics of the txalaparta and they will gain a basic understanding of playing it, practising in pairs using a real txalaparta. They will also learn about its history and the changes it has undergone since the recovery in the 60s and the current state of the matter.

They will also be able to test the Interactive Txalaparta software playing the real txalaparta together with the computer. Different aspects of the research and the development will be covered and explained in depth adapting to the participants' interests and questions. The author expects to gain interesting feedback from musicians with no previous knowledge of the txalaparta, which will contribute to his ongoing research on txalaparta.

## Additional Information

Two txalaparta players
https://www.youtube.com/watch?v=X4LQ85RMX_U&index=6&list=PLauBVgFtMcLDCSNNLCngm0BtBas2SsFB7

Interactive txalaparta software demo
https://www.youtube.com/watch?v=EjRBDxHjbv0&feature=youtu.be

## Bio

Enrike Hurtado lives in Bilbao where he studied his BA in Fine Arts. He later studied an MA in Design for Interactive Media in London. Recently he has completed a PhD on the basque percussive tradition of the txalaparta at the University of the Basque Country.

Figure 1. The Ugarte brothers playing txalaparta. Picture by Xabier Eskisabel

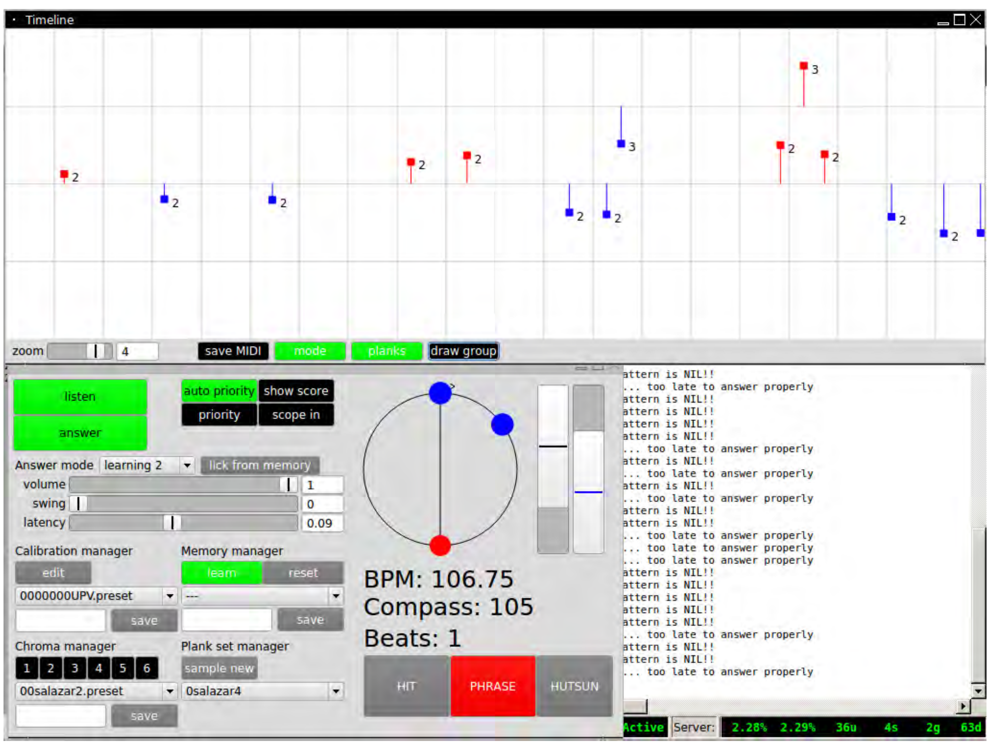


Figure 2. The Interactive txalaparta software

# Making High-Performance Embedded Instruments with Bela and Pure Data

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**Abstract.** Bela is an embedded platform for ultra-low latency audio and sensor processing. We present here the hardware and software features of Bela with particular focus on its integration with Pure Data. Sensor inputs on Bela are sampled at audio rate, which opens to the possibility of doing signal processing using Pure Data's audio-rate objects.

**Keywords:** embedded audio, sonic interaction design, sensors, low latency, musical instrument design.

## Introduction

The increasing power and availability of microcontrollers and single-board computers has given rise to many new platforms for creating musical instruments and platforms for interactive audio. Choosing a suitable platform can be a challenge, involving tradeoffs between computing power, hardware connectivity, ease of programming and price.

Many current approaches to designing sounding objects combine two or more devices together, for instance an Arduino which handles analog and digital sensor input communicating via USB-serial with a a computer running the audio processing. Using a self-contained embedded platform in the creation of DMIs and interactive audio systems has several advantages over such a setup.

- **Reliability** Using a single device is less prone to communication errors and it is easier to provide a backup solution for a simpler system.
- **Performance** With a composite setup as the one described above, the serial connection is slow and the throughput is limited. As such, the latency, sampling rate and jitter of the acquired data are all affected negatively, which may in turn affect the expressiveness of the performance. MIDI devices typically perform better than serial ones, while wireless links may be affected by packet loss or channel congestion (McPherson, Jack, and Moro 2016).
- **Reproducibility** It is easier for other people to recreate a device if it does not rely on multiple pieces of software and hardware devices and specific revisions of each of them.
- **Sustainability** Similarly, the developers themselves will find it easier to maintain and develop a system that does not have multiple dependencies, also to the advantage of making software version control easier.

## Recent Embedded Platforms for Digital Musical Instrument Creation

Arduino and similar boards are an accessible way of providing low-level connectivity to analog and digital sensors, but the low-powered AVR microcontroller does not allow audio on-board audio processing. The x-OSC board provides analog and digital I/Os over a wireless link (Madgwick and Mitchell 2013).

Two audio-oriented, self-contained platforms based on a 168MHz Cortex M4 microcontroller hit the market in the past few years: the Owl[1] programmable digital effect (Webster, LeNost, and Klang 2014), which surfaced in 2013, and Axoloti[2], which

[1] http://hoxtonowl.com/
[2] http://www.axoloti.com/

came out early 2015. The former can be programmed through a C++ API or can run Pure Data patches using the Heavy Audio Tools from Enzien Audio,[3] while the latter provides a custom graphical patcher which includes DSP modules and can be expanded with C++.

Raspberry Pi is arguably the most popular single-board-computer in the world and its latest revision 3 features a quad-core 1.2GHz 64bit CPU. The CCRMA Satellite distribution[4] (Berdahl and Ju 2011) was developed to provide an efficient audio-oriented environment for the Raspberry Pi.

Coala is an audio processing platform based on the BeagleBone Black[5] which was presented in (Piéchaud 2014). The software and hardware architecture of Coala were developed for the specific task of modal control[6], which requires a very tight feedback loop. The platform is therefore optimized for fast sample-by-sample processing in order to minimize round-trip latency.

## Bela: an embedded platform for audio and sensor processing

Bela[7] (formerly known as BeagleRT) is a combined hardware and software environment that consists of a BeagleBone Black with an expansion "cape" (McPherson and Zappi 2015a). It was originally developed for the D-Box Hackable Digital Instrument (Zappi and McPherson 2014) which required multiple low-latency hybrid analog-digital feedback loops (McPherson and Zappi 2015b). Bela combines the connectivity of a microcontroller with the processing capability of a single-board computer. The cape provides stereo audio I/O including 1W speaker amplifiers, 8 channels each of 16-bit analog I/O, and 16 digital GPIO pins. Bela is open-source hardware and software. Source code and design materials are publicly available.[8]

The Bela software uses a Debian Linux distribution with the Xenomai[9] real-time kernel extensions. The Programmable Realtime Unit (PRU), a 200MHz microcontroller on the same chip as the BeagleBone Black CPU, transfers audio and sensor data directly to the hardware, bypassing the kernel drivers. The user's Bela code therefore runs at the highest priority of any task on the board, including the Linux kernel itself. This allows audio block sizes as low as 2 samples, resulting in round-trip audio latency of 1ms (or even down to 100us if using the analog inputs and outputs rather than the audio converters) (McPherson, Jack, and Moro 2016).

On Bela, every analog and digital channel is automatically sampled at audio rates, synchronously with the audio clock. The high sampling rate of the analog and digital channels are unique to Bela and their jitter-free alignment with the audio makes it ideal for interactive, intuitive, responsive audio applications.

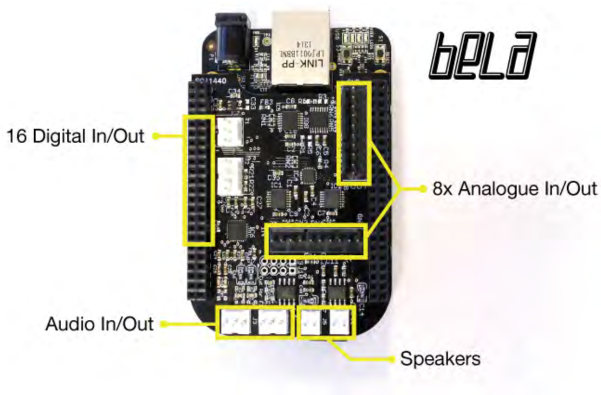
Compared to Axoloti and Owl, Bela has more processing power, while still providing hard real-time performances, with the added convenience of a full Linux OS and while being minimally affected by system load. It is more general-purpose than Coala which addresses the specific field of real-time control, though Coala is capable of even lower latencies than Bela. On a Raspberry Pi running CCRMA Satellite, despite the high processing power available on board, audio depends on the standard Linux audio drivers, so that low-latency processing is difficult because of the presence of other processes on the board, which may cause underruns at small audio blocksizes even when the CPU load is low on average. The BeagleBone Black CPU is less powerful overall but the Xenomai extensions used in the Bela software allow reliable and consistent performance with sub-millisecond latency. Additionally, the number of I/Os available in Bela is greater than those on commonly available Raspberry Pi hats.

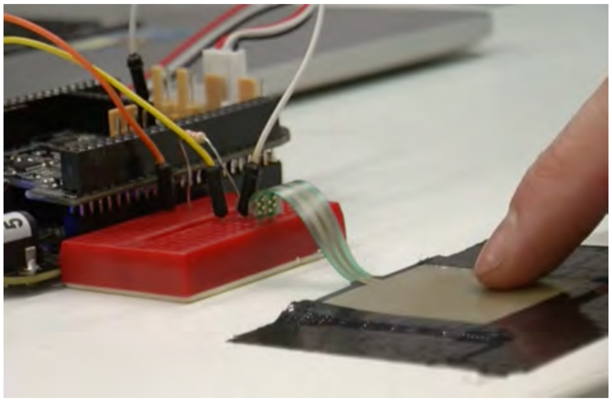
[3] http://enzienaudio.com/
[4] https://ccrma.stanford.edu/~eberdahl/Satellite/
[5] http://beagleboard.org/black
[6] http://instrum.ircam.fr/smartinstruments/
[7] http://bela.io
[8] http://bela.io/code/
[9] http://xenomai.org/

Bela, providing a large number of I/Os for audio and sensors, power output for loudspeakers, and providing enough processing power to satisfy most needs, entirely fulfills the requirements of a self-contained device, which can be embedded in a stand-alone Digital Musical Instrument or sounding object.

## Pure Data on Bela

Pure Data[10] (Pd) is a popular open source graphical programming language widely used by musicians and sound designers alike, which allows for quick prototyping of sound and sensor mappings. Pd patches are usually run within Pd itself, or using the shared library libpd[11]. The messaging architecture and the audio engine of Pd was not designed to be fast and computationally efficient which can lead performance penalties on platforms with limited computational power.



kk Figure 1: The Bela cape

Figure 2: Using a force sensitive resistor with Bela

**Heavy Audio Tools** The Heavy Audio Tools from Enzien Audio use Pd as a front-end to generate optimised C code. By analyzing the graph of connections between objects in the Pd code, Heavy is capable of producing high-performance vectorized C code which can outperform libpd, making it particularly well suited for embedded devices and, more generally, hardware with limited computational power. Heavy is a proprietary, cloud-based service and the generated code is licensed under the MIT non-commercial license.

The C code produced by Heavy is well-suited to be integrated in a Xenomai environment, as memory is allocated on the stack, thus avoiding system calls during execution. An automated script takes care of uploading the Pd patch to Heavy's server, collect the generated C code and compile it on the Bela board. The entire process generally takes less than one minute and most of the time is spent compiling the C code on the BeagleBone Black.

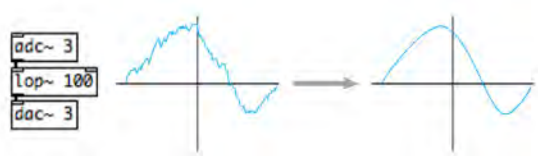
**libpd** Minimal modifications were required to port libpd for Bela, these included allowing blocksizes as small as 8 samples per block and removing socket and disk I/O from the audio thread. Additionally, the calls to the pthread functions were wrapped into Xenomai functions. The resulting shared library can be linked to a Bela program and `libpd_process_float()` is then invoked from within Bela's audio callback.

Deploying a Pd patch using libpd is virtually instantaneous as it does not require compiling. As soon as the patch is saved on the BeagleBone's filesystem, the Bela program can be restarted and it will load the updated patch. An added advantage of using libpd is that it is easier to port Pd externals when their source code is available. The same precautions listed above should be taken for new externals in order to make sure that new objects do not introduce Xenomai mode switches in the audio thread[12].

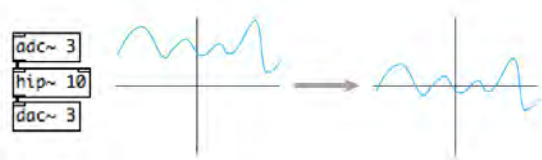
[10] http://puredata.info
[11] http://libpd.cc/
[12] https://xenomai.org/2014/08/porting-a-linux-application-to-xenomai-dual-kernel/

**Performance comparison** Running an example patch containing a generative audio composition, Heavy code compiled with the clang[13] compiler uses 26% of the CPU. The same Heavy code, compiled with gcc[14], occupies 43% of the CPU cycles. Running the patch using libpd uses 53% of the CPU.

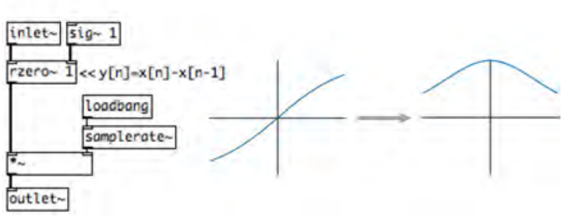
Traditionally, the highest-performance platforms have also placed the most technical demands on the programmer. For many years, custom DSP boards offered the best balance of hard real-time performance and high processing power, but they were generally programmed in low-level languages using custom development environments. High-level music programming languages often come with significant processing overhead. Running Pure Data on Bela, especially through the Heavy Audio Tools, provides a convenient graphical environment with minimal sacrifice in performance compared to programming in C++.



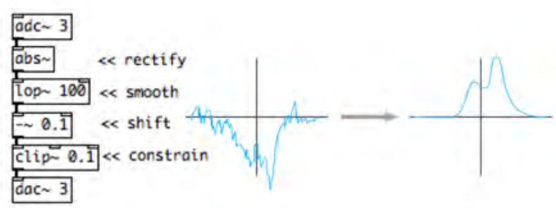

(a) Smoothing




(b) Re-centering




(c) Differentiating




(d) Thresholding

Figure 3: Using Pure Data objects to process sensor data

## Sensor processing in PureData

Many interactive systems take approaches where sensors are sampled at low and non-constant rates and the most recent frame of sensor data is used to modulate a particular sonic parameter. But in actual fact, the meaning of sensor data is often deeper, in its behaviour over time or its frequency content. A high sampling rate yields a very high bandwidth of interaction which captures subtle details that might be lost at lower sample rates. Though all the same techniques could be implemented at control rate, audio-rate sensor data can help reorient the designer's thinking to become more aware of these possibilities. When using Bela with Pd, this allows to conveniently process sensor signals using audio-rate objects. Some examples include:

- **Smoothing** Some sensors are inherently noisy, for instance a potentiometer may generate high-frequency noise when it is actuated, or an infra-red optical sensor may be subject to transient perturbations from other emitting sources. The noise in the sensor readings may leak into the audio signal, depending on the signal flow. An easy approach to remove high-frequency noise is to apply a low-pass filter with an appropriate cut-off frequency, as in Figure 3a.

[13] http://clang.llvm.org/
[14] https://gcc.gnu.org/

- **Re-centering** Readings from accelerometers and other sensors have inherent DC-offsets which may be undesirable for certain applications. A quick way of removing them which does not require calibration is using an high-pass filter with an appropriate cut-off frequency, as in Figure 3b.
- **Differentiating** Some sound-generator parameters are better controlled using the velocity of a sensor reading, rather than with the raw reading. A high-pass filter with a cut-off frequency of 0, properly rescaled can used for this purpose, as in Figure 3c.
- **Thresholding** A more complicated example in Figure 3d shows how to combine full-wave rectification, smoothing, DC shift and constrain to threshold a signal.

## Conclusion

There are several tradeoffs involved in different digital musical instrument design tools: processing power, latency, connectivity, sensor bandwidth, ease of programming and accessibility. With any of the programming environments, Bela brings together the connectivity and CPU power of an embedded Linux computer with the low latency and precise synchronisation of a microcontroller and brings a high-bandwidth dimension to sensor processing. Using either the Heavy or the libpd environments, Bela is also suitable for rapid prototyping using the widely-used Pure Data graphical programming language, with full access to both audio and sensors.

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# BRIGHTON MODULAR MEET

## Introduction

Andrew Duff

To round off proceedings, ICLI hosted the 2016 Brighton Modular Meet on the Sunday. The Brighton Modular Meet at Sussex began as an ad hoc gathering in a TV studio on campus in 2012 as a way of bringing members of a web forum together to meet and talk offline, to show their modular synthesisers, and to discuss ideas behind them and their use. As the modular synth scene has grown, the meet has also developed substantially, and over the last four years we have changed venue and attracted more manufacturers and developers - from small one-man-band companies such as ALM Busy Circuits and Synovatron, to larger international companies such as Roland and Studio Electronics.

This year the normal modular meet took place in the ACCA cafe, there were stalls selling DIY kits and modules from THONK and Cymru Beats, with additional spaces opened up in the building for video synthesis, curated by Alex Peverett and Chris King from Video Circuits, and a manufacturer room which hosted FutureSoundSystems, ALM Busy Circuits, Synovatron, Studio Electronics, AJHSynths, Roland and Abstract Data. In addition to this we also scheduled performances and demos from Cherif Hashizume (http://www.hrimmusic.com), Matthew from ALM Busy Circuits (http://busycircuits.com/), Dann Hignel (http://www.distantanimals.com/), Dan & David from Roland (http://www.roland.co.uk/aira/), Eden Grey (https://soundcloud.com/eden-grey), Tom Richards / Mini Oramics technical demo (https://vimeo.com/tomrichardsworks), Ian Helliwell (http://www.ianhelliwell.co.uk/), VCOADSR (http://www.vcoadsr.com/) and Cold Waves (https://twitter.com/ColdWavesPrjkt).

Next year we hope to expand on things further running a two-day event of workshops, talks, demos and installations ending in a concert on the Saturday, followed by a modular meet with talks, demos and performances on the Sunday.


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IN MIX
IN WAVE
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1V/Oct
BP
6dB
24dB
RISE
LENGTH
WRITE
PULSE
SCALE
NOISE
OUT
CLOCK OUT
ABSTRACT DATA

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