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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.

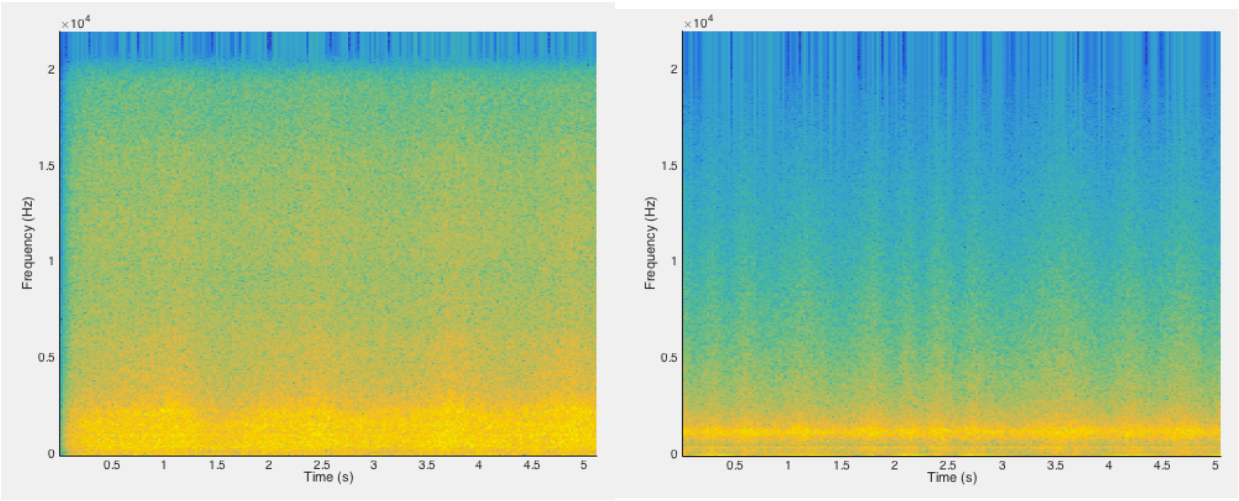

Figure 1. A spectrogram in Matlab of the acoustic wind machine (left) and its digital counterpart (right) during the same 5 seconds of performance.

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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