SQUIDBACK: A DECENTRALIZED GENERATIVE EXPERIENCE, BASED ON AUDIO FEEDBACK FROM A WEB APPLICATION DISTRIBUTED TO THE AUDIENCE

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ABSTRACT

Squidback is a participatory and contemplative experience, a collective generative soundscape without a central preferred point of view, whose sound sources are the audience's smartphones or computers working as audio feedback generators. The work aims at creating a ritual space to explore fields of play between being performer and audience, situating control, affect and listening in between human/machine and machine/environment ecosystemic interactions.

Squidback is implemented as a browser-based app, hosted on the Internet as a perennial web installation [1]. The code is open-source and available online [2]. Evaluation has been done by examining activities in which the system has been used, and comments from artists who included it in their works.

1. GENERAL CONCEPT

Squidback is a technological system and a concept for a participatory performative installation. Its generative process is based on audio feedback (also known as Larsen Effect [3]). Thus, it is naturally responsive to everything surrounding participants' devices, from their acoustic environments to objects and people nearby. It features a custom adaptive filter that adjusts itself autonomously, thereby avoiding users' direct interaction with parameters. Instead, it promotes a contemplative attitude, inviting them to find other ways to affect the process, for example by moving in the room, by creating shapes with their hands around the device, or by approaching other participants and their devices.

No centralized control strategy is implemented: the participants/devices become an ensemble of independent instances of the same process, each giving different results and thus composing a collective, generative, spatialized soundscape. Furthermore, sound spatialization and feedback are in mutual interplay through the decentralization of the system: participants' movements affect sound generation, which in turn affects the spatialized soundscape even if the participants are still; by moving, participants change what they hear (which region of the collective soundscape) and the sound they produce, realizing a further layer of mutual influence between collective and individual dimensions.

Squidback has been originally used as a native smartphone application, for performances where participants shared the same room, and later was made available as a web application, featuring remote online participation. It is thus currently possible to combine these settings by having groups of people, each sharing the same space, performing together online.

2. BACKGROUND

This work was first developed as part of the first author's practice-based research project *Becoming Program, Becoming Performance* at the Rytmisk Musikkonservatorium, Copenhagen (Aug 2017-Jun 2019), which focused on designing and performing with different systems: computer programs, machines, ensembles of musicians and directions for improvisation; in composition, improvisation and production settings. It binds together the main topics informing the first author's general research frame: generative music, decentralized systems, sound in space, and relations between acting and listening during performances.

Squidback was at a later stage ported to a Web Audio application for two reasons: to exit from smartphone-native apps' commercial distribution circuits, and to unify the codebase, ceasing to have two different versions for Android and iOS.

Finally, a real-time audio sharing feature was implemented (using WebRTC [4]), to allow participants to perform together without being in the same room. This opened new possibilities in terms of Squidback's significance as an experienced, reflecting more of the ongoing cultural transformations connected to digital life and communications.

3. RELATED WORKS

The presented work relates closely to three categories of past works: feedback-based resonant assemblages [5] [6], smartphone-based participatory techniques [7] [8] and ecosystemic works [9].

3.1 Feedback generation

As a system and performative installation concept, Squidback fits into the description of *Hybrid Resonant Assem-*

blages coined by Bowers and Haas [5], which features: involvement of different materials and media (sound, lights and objects/textures in the room); *immanent* sound generation (feedback); *transient* performative gestures (i.e. the room-system's construction, deconstruction and exploration) inviting to a gathering and to rethink wider notions of touch and instrumentality.

Squidback's sound process is based on feedback suppression systems (a survey is provided by Waterschoot and Moonen [10]), but instead of completely eliminating feedback frequencies upon detection, exploiting them as musical material. With the piece *Pea Soup* [6] Nicolas Collins was doing this already in 1974, using at first dedicated hardware, and then moving to software emulations. The piece is closely related to Squidback, because it was also produced in both concert and installation format. The difference with Squidback is the array of audience-owned devices, creating a spatialized sound system, bringing the process closer to participants and breaking down the boundary between performers, audience and installation as a completely autonomous and self-standing entity.

3.2 Smartphone-based participation

Among works for smartphone, we can distinguish between implementations which envision devices as instruments for performers to play (like much of the works from *Stanford Mobile Phone Orchestra* [8]) and others that are meant to be run by the audience, almost always including some form of centralized orchestration, or networked operations (like Tate Carson's *A More Perfect Union* or Andrey Bundin's *Concert For Smartphones*). A survey of smartphone-based audience participation strategies is provided by Oh and Wang [7], focusing on the relationship between audience and a "master performer", with audience-audience communication as an emergent property.

Compared to these works, Squidback's approach stands for a decentralized aesthetics, whose unifying force and compositional effort is the development of a singular system that will be run by independent instances, these affecting each other only by sending and receiving sounds through the rooms and/or the Internet. Distributed music as a performance practice has been reviewed by Taylor [11].

3.3 Ecosystemic organization

In his inspiring article "Sound is the Interface", Agostino Di Scipio [9] defined an ecosystemic approach to interaction which differs from the most widely implemented paradigm, turning compositional attention from *interactive composing* to *composing interactions*, and from a question of exerting the proper control over a separate sound generator to the interrelationship between system and environment. The topic has been further elaborated by Pirró [12], first by considering such mutual influences as a central cognitive mechanism, in relation to enaction, and on the other hand through the mathematical language of dynamical systems.

Fitting in Di Scipio's definition, Squidback is an ecosystemic work as much as it is "a dynamical system exhibiting an adaptive behaviour to the surrounding external conditions, and capable to interfere with the external conditions themselves", where man/machine interactions are situated in a system of machine/environment ones. In avoiding centralized control and control interfaces, Squidback reduces the predominance of humans as control agents, allowing the participants more explorative and contemplative roles. However, human activity is still a central component in this work's performative concept, as it is left to the participants to decide both their degree and mode of activity while listening to and exploring the performative space.

4. DESIGN

The main goal of the current design is to generate a variety of frequencies from feedback, avoiding a single frequency becoming dominant for too long, while maintaining ecosystemic interactions within the space where the system is situated. This achieves a balance between its autonomy and users' physical agency. The feedback process is controlled through a bank of peaking filters, wherein individual band gains are automatically adjusted according to the balance of the incoming sound's spectral magnitudes over time. Not being a purely technical problem, it is approached empirically, designing and tuning the process and its reactivity, to follow aesthetic intuition in dialogue with technical insights and theories.

On a high level, Squidback as a single process is depicted in the graph in Fig.1. Sound read from an input device is analyzed for frequency magnitudes, which are stored into a history buffer recording magnitude values from the last M analyzed frames. This historical data is used together with statistics about the most recently analyzed spectrum, to compute individual band gains of a bank of filters processing the input. The last stage of the process is an automatic overall gain adjustment, after which the processed sound is fed to the output mixer, where it's sent to remote peers, and is mixed with their incoming sounds. The choice of not feeding sound from remote peers to the analysis and filtering process is meant to keep the algorithm focused on local input (especially the auto-gain), otherwise sounds from remote peers would decrease its reactivity to the local user's agency.

Naturally, putting a filter bank in between a feedback chain is adding feedback to feedback, thus affecting the generative process. In other words, the system becomes an important part of the room, and it was not a focus of this work to tell apart the instrument (Squidback, and the device itself) from the "measured phenomenon" (the room and its resonances).

5. TECHNICAL IMPLEMENTATION

The application logic was developed in Javascript, using only the Web Audio API [13]. At the time of writing, Web Audio's most modern features, namely Web Assembly and AudioWorklets, were supported only by the latest versions of some major browsers. Therefore, a choice was made not to rely on them.

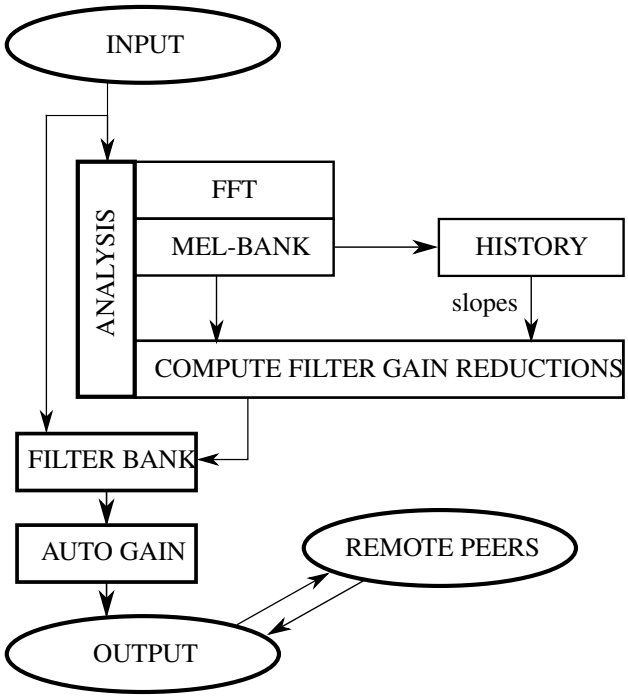

Figure 1. Squidback process diagram

DSP parameters and control strategies were chosen and tuned empirically through several tests on different devices, in accordance with the first author's aesthetics. As Squidback doesn't offer any parametric control interface, all values are hardcoded, and the following subsections refer to the setup chosen at the time of writing, which may well be subject to changes.

5.1 Analysis

5.1.1 FFT

Spectral analysis is performed by calculating the input's FFT, using Web Audio's AnalyserNode. Window size was set at 2048 frames, to provide enough perceptual resolution at low frequencies. Web Audio does not overlap frames, but linearly interpolates magnitudes over time by a factor of 0.8 (default) [14].

5.1.2 Mel-Frequency Filter Bank

In order to more closely match the system's reactivity to a perceptual dimension of pitch, FFT magnitudes are then passed through a bank of triangular filters, to compose their values into a number *nFilters* of mel-frequency bands, within a frequency range between *minFreq* (twice the lowest fft bin's center frequency) and *maxFreq* (10kHz). Although *nFilters* could be variable, a fixed number of 30 filters was chosen to provide some variety and still not be too computationally heavy, especially on a mobile device's CPU. The effect of mel-frequency mapping on the process' reactivity is a mitigation of the over-representation of high pitches, due to the linearity of FFT bin center frequencies distribution. Mel-frequency mapping was chosen over Constant-Q Transform (CQT) because it was found to be easier to implement in Javascript without relying on WebAssembly, like Javascript CQT implementations [1] commonly do to apply Brown and Puckette's spectral kernels method [15].

5.1.3 Reduction calculation

On the most recent mel-frequency spectral frame, minimum, maximum and average magnitudes are calculated. Then, for each bin *k*, a magnitude difference is calculated:

$$\Delta_k[n] = average[n] - magnitude_k[n]$$

Where *n* is the index of the most recent analyzed frame. Then, the system takes into account spectra from past frames, to calculate different corrections whether each band has been increasing, decreasing or stayed within a small range of magnitude values. Historical data is recorded as a weighted average of successive magnitude variations for each band. Magnitude differences across the last M frames (slopes) are considered to be zero (and the band to be constant) if their absolute value is less than a chosen threshold. Then each band gets a score depending on the sign of its slope: on each frame, if the band wasn't constant, its score increases or decreases by one corresponding to whether its magnitude was rising or falling. For constant bands, the cumulative score increases by the opposite of its own sign, bringing it one step closer to 0. Deltas are then adjusted according to the score, in order to stabilize the intensities of each band.

$$\Delta_k[n] = \begin{Bmatrix} 0.5\Delta_k[n], & \text{for } score_k[n] > 0 \\ -0.5\Delta_k[n], & \text{for } score_k[n] < 0 \end{Bmatrix}$$

Before the last calculation phase, coefficients are prevented from being positive, so as to disallow positive gains, and linearly smoothed by a factor λ:

$$\Delta_k[n] = min(\Delta_k[n], 0)$$
$$reductions_k[n] = \lambda(\Delta_k[n-1]) + (1-\lambda)(\Delta_k[n])$$

It was found that the system tends to resonate at a small number of dominant frequencies, if nothing changes in its environment. So, to help the system to change shape over the time of a performance, prioritizing the emergence of a variety of new tones, it is beneficial to gradually penalize frequencies that have already been reduced, even further. Therefore, a fraction *m* of the computed reduction is stored in memory as a persistent correction, independently of live spectral data, so that each band that has been reduced accumulates a trace of this activity.

$$reductions_k[n] = reductions_k[n] + mem_k[n]$$
$$mem_k[n] = m(reductions_k[n-1]) + mem_k[n-1]$$

Finally, the minimum reduction across all frequencies is calculated, to remove any constant gain factor applied to all frequencies, thus letting the filter work more on frequency balance than on absolute values. This is achieved by calculating the total frequency response of the filter bank, and subtracting its maximum value from each gain.

[1] https://github.com/mfcc64/showcqt-js

5.2 Filter

A bank of peaking biquad filters is created by using Web Audio's BiquadFilterNode, corresponding to the frequency scale used by the mel-frequency part of the analysis process. The first, lowest frequency filter, is set to be a low-shelf type, and the last, highest frequency filter is set to high-shelf. For aesthetic reasons, only reductions are allowed, as it was empirically found that gains applied to individual bands would result in smoothing out too much of the desired Larsen effect's roughness.

5.3 Auto Gain

At the end of the chain, gain applied to the signal is controlled by monitoring the signal's amplitude, so that the magnitude of the loudest bin in the analyzed spectrum, smoothed across subsequent frames, approximates a set threshold. At the time of writing, the smoothing factor was set to 0 (no smoothing), with a threshold at -20 dB and a maximum possible applicable gain of 20 dB.

5.4 Remote Participation

Remote connections are achieved through WebRTC [4], where each client is a peer in a mesh network, and a server is used only to facilitate discovery among clients. Connections among clients are then peer-to-peer.

Figure 2. Visualization

5.5 Visualization

Squidback has a visual output: it displays spectral magnitudes as analyzed by the mel filterbank, overlayed with corresponding filter gain reductions. The current implementation draws a white rectangle originating from the bottom of the screen representing energy in each spectral band, and a black one from the top representing reductions for each filter. Filter graphs are obtained as frequency responses for each band, and their total sum, through Web Audio's BiquadFilterNode.getFrequencyResponse(). The background is colored depending on pitch class [2] and the octave of the loudest bin in the mel-spectrum. While other options (such as more or less smoothed curves) were also implemented, the choice of using rectangles is both for efficiency and aesthetics reasons. To this regard, the visualization provided is not conceived to attract users' attention too much, but to provide some intuitive insights into how the system works, as a complementary experience during performances.

[2] https://en.wikipedia.org/wiki/Pitch_class

6. PERFORMANCE

Squidback can be played as a participative performance, which participants join at the same time, or as an installation, which participants can enter, join, and leave as they wish. Both forms can be played by participants sharing the same physical space, or online on the Internet, or in any combination of the two.

6.1 Physical

A typical performance starts with participants gathering at the entrance of the chosen performative space, which can consist of a single or multiple rooms, preferably indoors to exploit the reflective properties of closed walls. To begin, the first author typically explains how the system works and how to get it and run it. It is important to briefly inform participants of what feedback is, in order for them to form an intuition of how it works, and what they might do to affect it by moving the device and acting on their physical environment. If there aren't strict requirements about the performance's duration, the participant are told that they can stop the process and/or leave the performance whenever they want; otherwise participants will be informed that when it's time to stop, they will receive a signal from either a person or a change of lights in the room. A typical performance duration is between 20 and 60 minutes. After the spoken introduction, participants are invited to explore the performative space and to choose a location where to start the application. Spaces can optionally be prepared with speakers to which participants can connect their devices if they want, to enjoy a wider and/or louder output spectrum, or with objects/musical instruments to interact with. Albeit not strictly required, such setups can offer additional performative approaches to participants, and associate Squidback more tightly with the specific place where it's being performed, by including whatever objects are available there.

6.2 Online

As mentioned in section 5.4, peer-to-peer audio sharing over the Internet can be used to run networked Squidback performances. It has been found beneficial in this situation, to gather participants on a third-party web conferencing platform immediately before the actual performance, to give them an introductory explanation and eventual assistance as has been done in "physical" performances. It is not strictly necessary though, as instructions can be embedded on Squidback's website. Such performances can be described as participatory live-streaming concerts, where participants are at the same time attending to a shared process over which they can exert limited control, and more or less intentionally and recognizably influencing it. Sound contributions are also richer and more differentiated when participants join from their private space, allowing themselves to use more of their voices, sounds from other media (e.g. televisions, radios, music players) and even musical instruments.

6.3 Installation

As a standalone physical installation, Squidback is just an empty, dark room, with written indications (distributed as program notes, or present as the installation's description outside the room) functioning as the initial verbal explanation does for a performance. People can come and go, in any number, as they wish, but are invited to start the application before entering the room, to further characterize the installation as a performative occasion.

Squidback is also available on the Internet [1], where it is present as a permanent web installation. Differently from online scheduled performances, users can connect and disconnect at any time, and choose whether or not to share their sounds with other potentially connected users.

Figure 3. First public physical performance

7. EVALUATION, RECEPTION AND OBSERVATIONS

The process of producing artistic work is a dialogue between technological and artistic domains, for which the outcome is not measurable analytically in terms of efficiency/efficacy in solving a technical problem. Outcomes of this work are identified in activities in which the system has been used. Our preferred means of evaluation is to examine the work as an artistic process, observing performance experiences, and the receptions and comments by other artists who incorporated Squidback into their own artworks.

7.1 As a performance

Squidback has been performed several times in its prior implementation as a smartphone-native application. A short video edit from early testing stage [16], and documentation of the first public performance [17] are available online.

During these performances participants exhibited different ways to relate to devices, each other and the space through different degrees of activity, energy, mobility, sociality, collaboration and individuality. Typically, participants begin by actively engaging with their devices, then with other people, the space, its surfaces and objects. After around thirty minutes into a performance, it becomes more contemplative as people often lay down to listen to their device and the environment, intermittently changing position. 45 minutes tends to be an optimal duration, allowing for enough time to explore curiosity, excitement, boredom, relaxation and contemplation.

Each participant's own device is most often kept close to its owner, acting as a 'soloist' voice, thereby being most perceptible against the environment's background. It should be noted that leaving their devices alone somewhere in the room in order to have them 'join the choir' however, is not something most participants have been willing to do spontaneously.

7.2 As an instrument

The first author has been playing with Squidback since its first prototyping stages, performing improvised music solo and ensemble concerts as part of mixed electronic and electro-acoustic setups. In such settings, the system acts as an instrument with an autonomous generative quality, providing drones, harmonies, loud piercing frequencies, and/or a resonant reverberation effects. Its consistency and reliability as a standalone module is a strong standpoint for it to enter relationships with other instruments (e.g. no-input mixers). The lack of parametric control interfaces invites performative actions to undertake a dialogic quality, requiring receptivity for the system's own properties and developments. It also invites exploration of a control space that extends to the physical space where the performance is situated, affected by acting physically on the devices and nearby objects. As both a native and web-based application, Squidback is portable and has minimal technical requirements: a smartphone or a computer is sufficient to play it. Such a simple setup has facilitated its usage not only for staged performances, but also for more spontaneous and less planned performative actions.

7.3 As part of other artists' work

In its first incarnation as a smartphone-native application, Squidback was integrated into works by different artists. The comments below explain how Squidback fit their work and research.

7.3.1 Francesco Toninelli

Francesco Toninelli is a Copenhagen based composer, percussionist and improviser. He writes:

> My experience with Squidback starts right after its release in spring 2019, when I first tried to extend its use with bluetooth speakers and percussion instruments. After some testing I ended up with a system where a contact speaker was connected to the smartphone via Bluetooth and laid on the top of a kick drum (placed vertically on a support). This way the feedback generated by the app was affected not only by the room but also by the inner acoustics of the drum (as a combination of drum skin and wooden resonant body): needless to say, it was a very suggestive instrument

> capable of great complexity and diverse applications, such as installations or live concerts, also because of how easy it could be to access one or more smartphones and carry them around.
>
> The experiments on the instrument thus involved both tuning of the drum and use of different rooms or open spaces.
>
> As the time passed I started to be more and more focused on the harmonic material generated by the instrument, finding patterns of behavior. This brought me to create an installation then presented in Tempo Reale Festival 2020 (Florence, Italy) where three Squidback-kick drums were placed in an open space, as distant as possible from each other, to find a central point where one could hear all of them and create a small walk exploring the interaction of chords and its mutations.

A recording of Francesco Toninelli's work for Tempo Reale is available online [18].

7.3.2 Federico Corsini

Federico Corsini is a musician and dancer, based in Copenhagen. He writes:

> Limitation is invitation.
>
> When there is no control interface, that is the control interface. It comes from punk and improvisation: you play with what is there, you make a performance out of what is available. Feedback has an intrinsic property of uncontrollability, and even if not having knobs is a different thing, you accept both as epistemological truths. And it has another property: sound changes waves morphology and tone depending on dimensions and distances between speaker, microphones and the room, and also on the objects present in the room. My body in between speaker and microphone affects qualities of both my body and sounds.
>
> Squidback allows to focus on the relationships to objects and (their) movements in space. More than focusing on my body movement, I focus on objects' movements within the performative space. Adding a bluetooth speaker gives you now two objects you can move around (the speaker and the phone). I tried to interact with those movement and my body in space, at the different physical levels (floor, standing, objects above my head), accepting and reacting to information created by the feedback process.
>
> I'm fascinated by creating dynamics I've never explored before, or experiences I've never tried or rehearsed, to be explored only during a performance, and not to be studied academically.

A short video from Federico Corsini's work with Squidback is available online [19].

7.3.3 Dasha Lavrennikov

Dasha Lavrennikov is a choreographer who used Squidback in her work during an artistic residency in Copenhagen. The work was an outdoors guided walk which featured a solo performance with Squidback while exploring the surface and depths of a rocky landscape.

> Using the app really opened a place of inquisition - questioning around the notion of feedback, in sound and movement. It was a super rich finding in my research around space - sound / space - movement / sound - movement, this triangle of information in the process of improvisation.
>
> In particular, it felt like the most relevant and possible space of sound-movement manifestation at this point in the walk that I shared... as the possibility to question physical space and architectural space, the infinite and its limits, and how through sound and the body we experience these limits, contours, borders, and what that generates in terms of the concrete and the phantasmagorical.

The work in question was shared with a limited number of people as a private performance, of which there's no publicly available documentation.

8. CONCLUSION

The absence of control interfaces calls the controller paradigm into question, inviting for a more fluid relationship between individuals, the adaptive technological process and the environment. Attention flows through exploration and contemplation, curiosity and experimentation, affect and inspiration, activity and passivity. Each participant can choose a different mix between being more of a performer or an audience at any time, blending these two roles in lack of a clearly defined separation, enabling a diversity of approaches to unfold. The decentralized system also contributes to these dynamic relations by making each participant a creative agent on the collective soundscape, wherein their acoustic situation and movements affect sound contributions and perceptions at the same time. Participants create a multi-faceted soundscape, thereby listening to a particular selection and mix within the ecosystem developed between individuality and interdependence across actions and perceptions.

Squidback also works as an inspiring tool for artistic production, primarily in the fields of installation sound-art and contemporary dance. Its limited scope, generative possibilities and reactivity to space and movement, together with a relative ease of adoption and integration, have been strong points reported by artists who have used it in their works.

8.1 Future directions

Future directions will on one hand attempt to make Squidback a more accessible development platform for experimentation with feedback, by exposing a public API to the browser window so that every part of the process can be controlled via Javascript code from a browser's console, including the ability to plot graphs of historical and computed data. Also, the WebRTC implementation is still very simple, and further research could be dedicated to improving its stability and elaborate on possible processing strategies for sounds from remote peers.

The latest version of Squidback is currently a web application, and is thus able to bypass the two main commercial smartphone App Stores. However, the field of web applications is still heavily influenced by browser implementations, where the major players are the same operating commercial App Stores. As much as the authors are looking forward for more advanced features to be widely supported (primarily AudioWorklet support), Squidback still situates itself in a delicate field, where it is intended to exploit devices that people already have, but at the same time it has a strong dependency on their software updates. It could be interesting in the future to explore the construction of embedded devices.

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