Proceedings of the 5th International Conference on Live Interfaces

Øyvind Brandtsegg, Daniel Formo (editors)
Norwegian University of Science and Technology

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Contents

Introduction on behalf of the local ICLI 2020 organizing committee

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Live Interfaces conference - Trondheim 2020

We are proud to host the 5th International Conference on Live Interfaces at NTNU in Trondheim. The local organizing committee is constituted by artists, researchers and students from music technology, music performance, fine arts, acoustics, art and media studies, and computer science, all at the Norwegian University of Science and Technology. Further, the support from NTNU Art and Technology (ARTEC) lend us a strong and multifaceted platform. Last, but not least, the collaboration with Meta.Morf [1] and the theme "Digital Wild" lend us the opportunity to speculate on (among many things) the continuum from the organized and controlled to the wild and free.

The theme of Live Interfaces this year is "Artificial Intelligence – Artistic Intelligence – Automated Emotional Intelligence". With the notion of artificial intelligence(s) becoming ubiquitous in our society, we find it relevant to ask how it affects the conditions for human expression. Where is the art in artificial intelligence? Do we understand it on a sufficiently deep level that we dare allow it to mediate our deepest thoughts and emotions? Then again, can we afford to neglect the effort of trying to understand it

In an attempt to simplify: What does A.I. really do? For one, it provides a form of automation. Automation of tasks that would otherwise be impractical or impossible to complete for different reasons. By helping us probe areas that would otherwise be unattainable, A.I. serves as an interface. A means to interact with what exist on the other side of the barrier. While A.I. in itself is an interface, it is also used to build other kinds of interfaces. This nested structure complicates understanding.

Equals, not-equals

What is an interface anyway, and what makes it live? We could say it is something that allows an action on one side to have an equivalent effect on the other side. So . . . an interface is a kind of an equal sign is it? In the late 1990's I did some work with interactive dance together with choreographer Susanne Rasmussen. In providing dancers with sensors, I had the romantic idea that I could capture the expressive qualities of their movements and translate these without loss to sound and music. Perhaps a naive approach, as the richness of combining these artistic expressions may lay just as much in their opposition.

In utilizing the different possibilities of each medium rather than striving for a direct translation between them. Then, the interface does not equal? Looking at the not-equal sign ($\neq$), there is a trace of equality, as the symbol $=$ is still there. It is just protruded by a disturbance. Automatic translation programs have shown us the delicacies of translation between languages, but even with careful human authoring, we can't really say the exact same thing in two different languages. Claiming that "I love you" means the same as "Ich liebe dich" or "Jeg elsker deg", helps us approach a common understanding. But when translating a text, we more often have to rewrite the whole thing to let the text have meaning in the other language. When we say that language is an interface for human communication, also translation between different languages is an interface. Translation significantly alters the content of the message, and give it new dimensions of meaning, reflected from the culture in which each language has been developed and used. For this reason, we can hardly look at the interface as something separate from those entities it connects.

[1] http://metamorf.no/

Faces

The theme for a previous ICLI (Lisbon in 2014) was INTER-FACE, in which I read something happening between two faces. The connection point, where communication is made across a border. Thinking of it like a face, a human face, makes it so much easier to include all that lies behind the face.

The interface concerns first what happens in the meeting point, how events from one side is translated into actions on the other side. But in interfacing two environments, it also makes sense to think about the characteristics, constitution, . . . , in short: The nature of those two worlds. The piano keyboard is an interface between (usually human) limbs and the hammer that strikes a string, making it vibrate. Yet, the nature of the action being done here is not merely the physical action of producing vibrations in the string. Usually, when this action is done, we think of it as an act of making music. Making music is related to playfulness, to conveying emotions, building relations between sounds, telling a story, and many other things. It usually means that an idea is formed by one human being, and that it somehow is contained in the musical expression then made by this being, and subsequently received, (hopefully) appreciated, and (perhaps) decoded. In terms of communication theory, we have significant scope for signal loss. Noise. Misunderstandings. Reinterpretations. When we talk about a musical instrument as an interface, all these things also are entangled in the conversation.

Intelligence and representation

The field of art and technology is a meeting point of very unequal values and cultures. The technology part is often also quite naturally bound to science, to the development of new technologies. The methods and values of science meet and intermingle with the methods and values of art. In many ways, we face similar challenges in the field of artistic research. This also, is a hybrid, where the values and methods of research (sometimes confused with science) meet those of artistic exploration and expression. A potential pitfall in this meeting of cultures is the language (interface) used in the reflection, dissemination and validation of results.

Science and technology are commonly concerned with formalization, and the successful formalization of a result is measured as part of its validity. The reflections and results of artistic research (and artistic production and activity at large) are commonly less compatible with such formalizations, but when different fields and cultures meet it is all too easy to give precedence to those with the more clear-cut and unambiguous statements. The field of communication and information theory forms a basis of development for our now ubiquitous computing technologies.

One much-cited paper is Harry Nyquist's "Certain Factors Affecting Telegraph Speed". The first sentence in the abstract reads "This paper considers two fundamental factors entering into the maximum speed of transmission of intelligence by telegraph." Not intending to downplay the value of this research and this field, the use of terms could be noteworthy of a comment. The plurality of meanings associated with the term intelligence show some root of the problem of understanding artificial intelligence today. It doesn't really help that the field of AI is firmly based on the scientific use of the term intelligence in the military sense, while our expectations often stray to another and more empathic interpretation of the term. Hubert Dreyfus wrote on what computers could not do in 1972, and still could not do in 1992. AI advances in statistical machine learning have since Dreyfus' critique been successful in overcoming some of the psychological assumptions of earlier AI. It still relies, as far as I can see, on the formalization of knowledge.

What parts of cognition and intelligence can be formalized, or to aim higher, what parts of human behavior can be formalized? This philosophical question has also been researched in psychology and anthropology. Eleanor Rosh's theories of categorization via prototypes and embodied cognition is one example. Lucy Suchman's situated cognition is another, where human behavior is understood in dynamic interactions with the material and social worlds. Modern deep leaning techniques attempts to incorporate these approaches by way of learning from examples. For the most part, the algorithm is still blind, and can only use what it is explicitly given. Part of human nature is also curiosity. Can we formalize that?

What would you call an artificial intelligence that is not intelligent? With regards to the complexity of simulation, we could say artificial intelligence popularly refers to some piece of technology that we don't yet fully understand. Once we can fully understand it, it becomes a mere algorithm, a tool that we can use mechanistically for a given purpose.

Conflation and conclusion

This is also why this year's Live Interfaces attempts to combine automation and emotion, artificial and artistic. As in a hadronic collision, we hope that the photons produced may shed some light on the matter.

The contributions from all the artists and researchers to this year's conference prods these questions and many more, untangling, exploring, submitting to and conquering the transmission point, the face where worlds meet. We are indebted to your work of keeping it live.

ICLI 2020

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1

Rebecca Fiebrink

Machine learning as (Meta-) instrument

Keynote

Video of presentation can be found here

Keynote for ICLI 2020

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Machine learning as (Meta-) instrument

Computer scientists typically think about machine learning as a set of powerful algorithms for modeling data in order to make decisions or predictions, or to better understand some phenomenon. In this talk, I'll invite you to consider a different perspective, one in which machine learning algorithms function as live and interactive human-machine interfaces, akin to a musical instrument. These "instruments" can support a rich variety of activities, including creative, embodied, and exploratory interactions with computers and media. They can also enable a broader range of people—from software developers to children to music therapists—to create interactive digital systems. Drawing on a decade of research on these topics, I'll discuss some of our most exciting findings about how machine learning can support human creative practices, for instance by enabling faster prototyping and exploration of new technologies (including by non-programmers), by supporting greater embodied engagement in design, and by changing the ways that creators are able to think about the design process and about themselves. I'll discuss how these findings inform new ways of thinking about what machine learning is good for, how to make more useful and usable creative machine learning tools, how to teach creative practitioners about machine learning, and what the future of human-computer collaboration might look like.

Rebecca Fiebrink is a Reader in the Creative Computing Institute at University of the Arts London

Papers

Federico Visi and Atau Tanaka

Towards Assisted Interactive Machine Learning: Exploring Gesture-Sound Mappings Using Reinforcement Learning

Paper

Video of presentation can be found here

Towards Assisted Interactive Machine Learning: Exploring Gesture-Sound Mappings Using Reinforcement Learning

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Abstract.

We present a sonic interaction design approach that makes use of deep reinforcement learning to explore many mapping possibilities between input sensor data streams and sound synthesis parameters. The user can give feedback to an artificial agent about the mappings proposed by the latter while playing the synthesiser and trying the new mappings on the fly. The design approach we adopted is inspired by the ideas established by the interactive machine learning paradigm, as well as by the use of artificial agents in computer music for exploring complex parameter spaces. We refer to this interaction design approach as Assisted Interactive Machine Learning (AIML). We describe the architecture of an AIML system prototype, a typical workflow for interacting with the agent and obtain gesture-sound mappings. We then present feedback data collected during a demonstration and discuss perspectives for developing the AIML paradigm further, pointing out current limitations. In light of the feedback obtained and the considerations arisen following the use of the system in a multimedia performance piece, we suggest that the implementation and evaluation of new features should take into consideration established creative workflows and take place close to actual artistic practice.

Keywords. Gestural Interaction, Interactive Machine Learning, Reinforcement Learning, Artificial Agents, Sonic Interaction Design

Introduction

Gesture-sound Interaction Design and Interactive Machine Learning

Designing gestural interactions between body movement and sound synthesis is a multifaceted process. At its core, it takes place through the definition of mapping functions between input signals (usually obtained through some motion sensing device) and sound synthesis parameters (Hunt and Wanderley, 2003). Adopting an effective mapping strategy is one of the key factors affecting the expressive potential of a live interface, and as the spaces defined by input signals and synthesis parameters become more highly-dimensional and heterogeneous, designing mapping structures can be an increasingly complex task, with many possible solutions (Van Nort et al., 2014). In addition to the relatively abstract realm of designing mappings, researchers on gesture-sound interaction draw upon several fields of inquiry. The results of quantitative studies of music-related body motion based on sound-tracing experiments were indicated as a useful source for defining mappings in musical interfaces (Nymoen et al., 2013). Informed by environmental psychology, the notion of sonic affordance was introduced to look at how sound may invite action, and how this could potentially aid the design of gestural interfaces (Altavilla et al., 2013). Qualitative observations of the gestural aspects of traditional musical instruments have been looked at to inform mapping strategies (Visi et al., 2014), as well as to develop musical practices where bodily gestures are seen as fundamental compositional elements (Östersjö, 2016).

Machine learning frameworks for interacting with sound synthesis environments (Fiebrink et al., 2009) have brought about sonic interaction design approaches where mappings are not explicitly defined and manually coded, but are "shown" – or given by demonstration – to a system capable of "learning" them (Françoise et al., 2014). The widespread adoption of such interactive gesture-sound mapping approaches, facilitated by the accessibility of software tools such as the Wekinator (Fiebrink and Cook, 2010), lead to the establishment of the Interactive Machine Learning (IML) interaction design paradigm. The machine learning algorithm is thereby considered as an interface between humans and computers, a creative tool that, with its own affordances and constraints, supports the process of musicians and sonic artists (Fiebrink and Caramiaux, 2018).

The increasing detail offered by motion sensing technologies, and the complexity of sound synthesis engines creates the opportunity for exploring the numerous, non-obvious ways in which these domains can be interfaced. The user-centric interface design methods enabled by machine learning delineate a scenario in which exploring gestural mappings can be done interactively, intuitively, and with the assistance of algorithms that become part of the creative tool kit of musicians.

Artificial Agents for Parameter Space Exploration in Computer Music

Modern sound synthesis techniques are often characterised by a high number of parameters one can manipulate in order to make different sounds. Whilst these afford vast synthesis possibilities, exploring the resulting extensive parameter spaces may be a challenging task, which can be particularly difficult to accomplish by manipulating every parameter by hand. In computer music, mathematical models inspired by biological processes have long been used to explore the possibilities afforded by sound synthesis techniques. To provide a few examples, Miranda (1995) used cellular automata (a model of biological self reproduction) to generate a large amount of sonic particles that form complex sound events. Dahlstedt (2001) proposed a system based on genetic algorithms where the users listen to the sounds generated by the software and select those they find more interesting. Following an evolutionary model, the system then proposes new sounds by "mating", "mutating", and "evolving" the sounds that were selected by the user in previous generations. Genetic algorithms were also adopted later by Yee-King (2016) to explore timbre spaces in sound synthesis. The same author and collaborators later applied several machine learning and optimisation techniques to automatically programme a synthesiser to match a given target sound as accurately as possible (Yee-King et al., 2018). An approach based on sound matching and genetic algorithms informed by the work of Horner et al. (1993) was also adopted by David Griffiths and the FoAM network in a collaboration with the electronic music artist Aphex Twin.[1]

Reinforcement learning is an area of machine learning in which artificial agents are programmed to take actions in an environment defined by a set of parameters. Their goal is to maximise the positive feedback – or rewards – they are given by a human (or by another algorithm) observing the outcome of their actions. Deep reinforcement learning approaches – such as the Deep TAMER algorithm – leverage the power of deep neural networks and human-provided feedback to train agents able to perform complex tasks (Warnell et al., 2018). Recently, Scurto et al. (2019) implemented the Deep TAMER algorithm to design artificial agents that allow to interactively explore the parameter spaces of software synthesisers.

We present a system that makes use of deep reinforcement learning in the form an artificial agent to explore different mappings between an input device and a sound synthesis engine. The user can give positive or negative feedback to the agent about the proposed mapping while playing with the interface, and try new mappings on the fly. The design approach we adopted is inspired by the ideas established by the IML paradigm, as well as by the use of artificial agents in computer music for exploring complex parameter spaces. We call this interaction design approach Assisted Interactive Machine Learning (AIML).

Method

The system is designed to interactively explore the motion-sound mappings proposed by the artificial agent. This iterative collaboration can be summarised in four main steps:

1. Sound design: the user authors a number of sounds by editing a set of salient synthesis parameters;
2. Agent exploration: the agent proposes a new mapping between the signals of the input device and the synthesis parameters based on previous feedback given by the user[2];
3. Play: the user plays with the synthesiser using the input device and the mapping proposed by the agent;
4. Human feedback: the user gives feedback to the agent.

[1] The result of the collaboration between FoAM and Aphex Twin is described here: https://fo.am/activities/midimutant/
[2] If no feedback was previously given, the agent starts with a random mapping.

Steps 3 and 4 are repeated until the user has found as many interesting motion-sound mappings as they like. The following subsections will describe the system architecture and a typical workflow.

It is worth noting that, differently from most IML applications for gestural interaction, there is not a gesture design step during which the performer records some sample sensor data for training the system.[3] This is perhaps one of the most obvious differences between the IML and AIML paradigms. In an AIML workflow, the sample sensor data used for training the model is provided by the artificial agent, whereas the user gives feedback to the agent interactively while playing the resulting gesture-sound mappings.

System Architecture

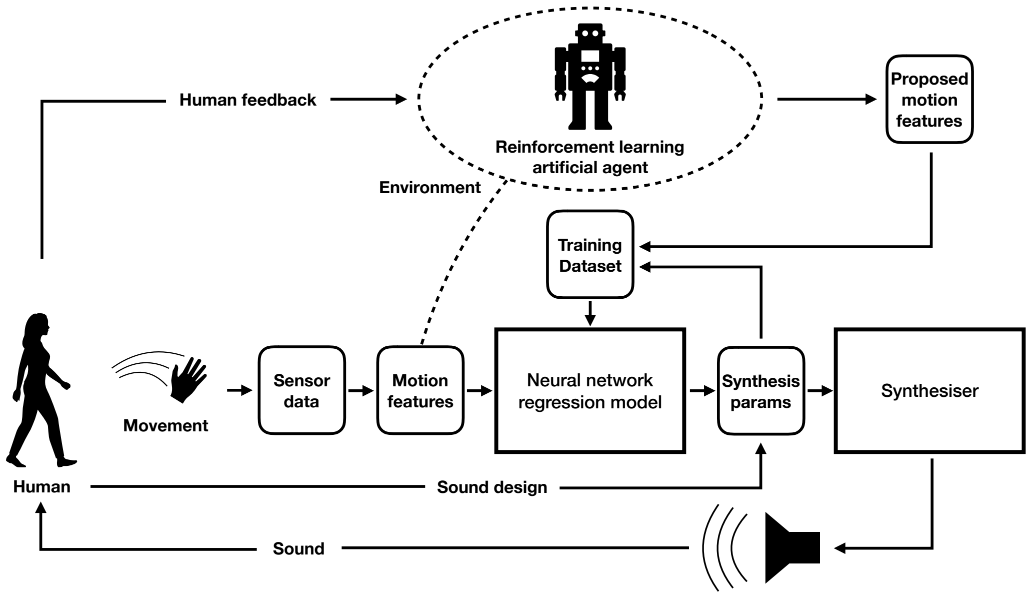

Figure 1: System architecture

The architecture of the system is schematised in Fig 1.

The movements of the human performer are captured by means of an input device. In the first prototype of the system we used the built-in accelerometers of a smartphone, while in a second version we captured gesture using a Myo sensor armband, which provides 8-channel electromyogram (EMG) muscle sensing and a 9-axis inertial measurement unit (IMU).

The motion features[4] extracted by the raw sensor data are stored in a vector and sent to a regression model created using a neural network. This was implemented in Max[5] using the `rapidmax` object (Parke-Wolfe et al., 2019), an external built using RapidLib[6] (Zbyszyński et al., 2017), a set of software libraries for interactive machine learning applications in the style of Wekinator (Fiebrink et al., 2009). These features also represent the dimensions of the environment in which the artificial agent operates. By exploring this feature space following the user's feedback, the agent proposes a set of motion features to be paired with the synthesis parameters defined by the user during the sound design step. This becomes the dataset used to train the neural network. The resulting regression model maps the incoming sensor data to sound synthesis parameters.

For the agent, we used *Co-Explorer*[7], a Python deep reinforcement learning agent implementation by Scurto et al. (2019). Bidirectional communication between the agent and Max is done through Open Sound Control

[3]For an example of gesture design in an IML workflow, see the study by Tanaka et al. (2019) carried out within the BioMusic project.

[4]The motion features may be a set of descriptors derived from the raw data and/or the raw data itself, depending on the hardware used and how the system architecture is implemented.

[5]http://cycling74.com/products/max/

[6]www.rapidmixapi.com

[7]https://github.com/Ircam-RnD/coexplorer

(Wright, 2005). Human feedback to the agent is given via a custom touch interface, which was designed in TouchOSC[8] and implemented on an iPhone (see Fig. 2).

Figure 2: The interface for playing the synthesiser and give feedback to the artificial agent.

For the first prototype of the system, we used a sample-based synthesiser to manipulate an audio file stored in a buffer. A second version of the system was instead built around the synthesiser used for the study by Zbyszyński et al. (2020), which implements corpus-based concatenative synthesis using MuBu[9] CataRT Max objects. Interaction with corpus-based concatenative synthesis was further refined by adopting the method based on self-organising maps by Margraf (2019). This method was then implemented in the piece "You have a new memory" (Visi and AQAXA, 2020).

Workflow

We will now describe more in detail the four main steps of the interactive collaboration between the human performer and the artificial agent. The whole workflow is schematised in Fig. 3.

1. Sound design

In this first step, the user defines a number of sounds by manipulating a set of synthesis parameters. This process may differ depending on the synthesiser chosen and which synthesis parameters are exposed to the user in this step. In the first version of the system using the sample-based synthesiser, the sounds are defined by manipulating six parameters (playback speed, pitch shift, start time, duration of the sample selection, filter cutoff frequency and resonance). Here, the user defines the parameters of four sounds that will be used to train a neural network in step 2 and perform regression in step 3. The sounds designed in the sound design step will thus act as timbral anchor points that define a space for interpolation and extrapolation of new sounds.

2. Agent exploration

The dimensions of the environment explored by the agent are defined by the motion features extracted from the raw sensor data for each of the sound presets. Thus, at the end of the exploration step, the agent returns a vector with a set of input features for each of the sound synthesis parameters sets defined in the sound design step. This means that in the case of the version of the system using a 2D accelerometer, the agent will return four 2D vectors. These will be automatically paired with the synthesis parameters to train a neural network and create a regression model, which will be used in the following step to map live incoming sensor data to sound synthesis.

[8] https://hexler.net/products/touchosc
[9] https://forumnet.ircam.fr/product/mubu-en/

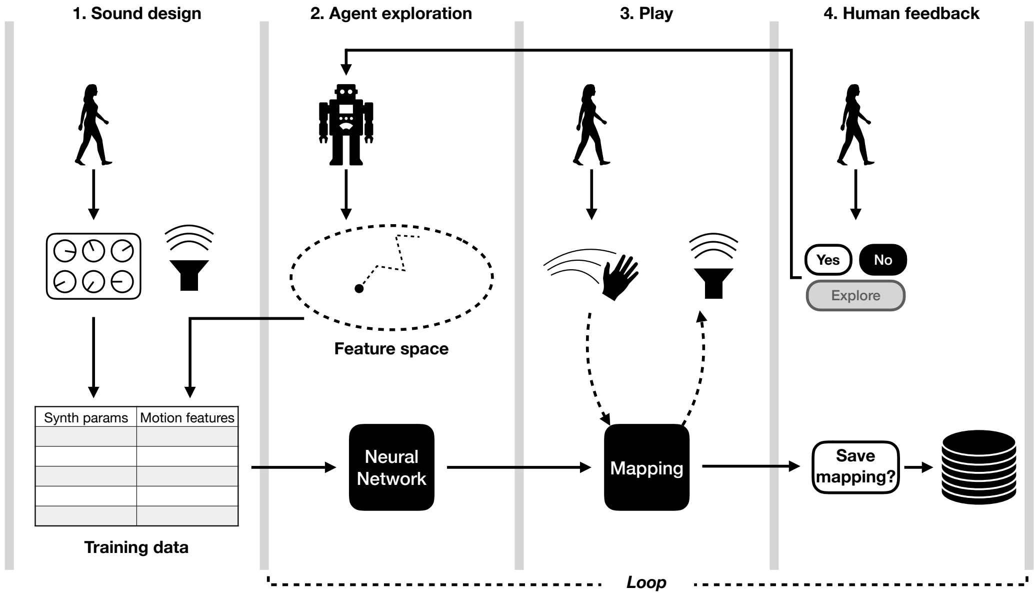

Figure 3: The prototypical assisted interactive machine learning workflow.

3. Play

In this step, the user is free to play with and explore the resulting gesture-sound mapping for however long they like. Given that the regression models allow both interpolation and extrapolation of the input sound synthesis data, this step also allows to explore the timbral possibilities of the synthesiser while playing the mapping.

In our prototype, the big button in the touch interface (shown in Fig. 2) triggers the amplitude envelope of the synth, while the movements tracked by the accelerometer axes are used to modulate the synthesis parameters through the mapping implemented in the regression model.

4. Human feedback

After playing with the mapping, the user can give feedback to the artificial agent through the touch interface (Fig. 2). We adopted the concepts of *guiding feedback* and *zone feedback* implemented in the agent designed by Scurto et al. (2019). Guiding feedback is a binary evaluation of the actions performed by the agent, or the direction of its exploration of the feature space. Zone feedback is instead an evaluation of the area of the feature space the agent is currently exploring. For example, a negative guiding feedback would change the direction of the agent's trajectory in the feature space, whereas a negative zone feedback would immediately transfer the agent to a different region of the space.

In our system, the user can give positive or negative guiding feedback to the agent about the proposed mapping. This feedback guides the direction of the next explorations of the feature space, and thus affects the next mappings proposed by the agent. In addition, the user can tell the agent to move to a different area of the feature space by using the *EXPLORE* button. This corresponds to a negative zone feedback, and will likely result in a new mapping that is considerably different from the previous one. In practice, this could be useful for trying something new once one is satisfied with the mappings proposed by the agent after a few guiding feedback iterations. In fact, whereas negative guiding feedback results in adjustments to the mappings currently being proposed by the agent, negative zone feedback triggers the exploration of a new area of the feature space, thus exploring new mapping possibilities. Users can save mappings to JSON files. Mappings can then be retrieved later for performance or as mapping material to be further refined using other approaches.

Early User Feedback

We showed the first prototype of the system during an informal demo at the Human Data Interaction (HDI) workshop *Art, AI-created content, & industrial/cultural effects*.[10] There, attendees were explained the purpose of the system and showed how to interact with the artificial agent.

The audio loaded on the synthesiser was constituted by six samples, each lasting one second and taken from a different sound source: speech, a field recording in a train station, a drum beat, a string ensemble, a whispering voice, and the sound of glass breaking. This was done in order to have some timbre variety when playing with the synth. The samples were the same for all the participants, and so were the synthesis parameters sets, so the demo focused on steps 2 to 4 of the workflow.

We collected feedback from 8 workshop attendees that tried the system in the form of a questionnaire. All the participants reported that they are active in one or more artistic discipline among music, visual arts, and performance. Additionally, three of them reported that they are developers and two of them academics. The questionnaire included five questions that the participants could answer using a five-level Likert scale where 1 corresponded to “not at all/strongly disagree” and 5 “yes very much/strongly agree”. The questions were:

- Q1: Did the artificial assistant help you discover the sounds the synthesiser can make?
- Q2: Did the feedback you gave to the artificial assistant help obtain sound interactions you liked better?
- Q3: Did the artificial assistant surprise you with sound interactions that you weren’t expecting but that you found interesting?
- Q4: If you’re a practicing musician, do you see yourself using similar AI-based procedures to explore the possibility of your musical tools? (optional)
- Q5: Was it fun to play with the artificial assistant?

We report the results in the bar chart in Fig.4.

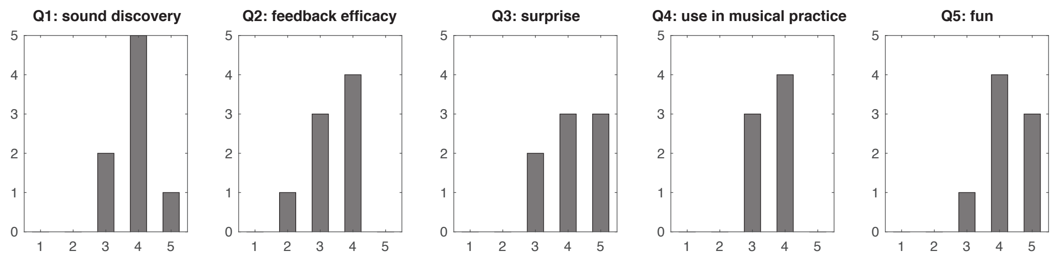

Figure 4: Responses to the feedback questionnaire. Answers were given using a ve-level Likert scale where 1 corresponded to “not at all/strongly disagree” and 5 “yes very much/strongly agree.”

In addition, participants were allowed to leave comments about their experience with the system. Four participant included some comments, two of them reported that they would have liked to have had access to a wider palette of sounds, one that the system was very responsive, and another one reported that they weren’t sure about what the system was doing.

Discussion

The feedback we collected from this small group of experienced participants (all of them reported being involved in the arts while a few were also developers and academics) led us to make useful considerations regarding the design of the first prototype, as well as on the development of AIML as a general interaction design paradigm.

Firstly, despite scoring high on all the other questions, users entered relatively low scores for the question regarding the efficacy of the feedback given to the agent. This may indicate that the mappings proposed

[10]The workshop took place on 20th September 2019 at Music Hackspace – Somerset House Studios in London, UK: https://hdi-network.org/workshop-art-ai-created-content-industrial-cultural-effects/

by the agent were fun to play and allowed the participants to explore the different ways of interacting with the synth, yet the immediate effects of giving positive or negative feedback to the agent were not always clear. As also noted by Scurto et al. (2019), for the agent to learn quickly from a small amount of feedback data provided by the users is a challenge. Despite the improved performance of recent reinforcement learning algorithms making use of deep neural networks, the system requires multiple iterations to learn from the user's feedback, especially when dealing with high-dimensional feature spaces. This is particularly challenging to the context of a short demo where participants spent a short amount of time playing with the system. The guiding feedback given to the agent is binary: yes or no. The proposed gestural interactions with the synth are often characterised by complex timbral articulations. Several participants suggested that they would have liked to be able to tell the agent *what* they liked about the mapping. This suggests that a more sophisticated way of giving feedback to the agent might be a useful feature of an AIML system. However, other participants appreciated the immediacy and simplicity of a binary feedback design, which allowed to quickly try several mappings and save those considered useful for later use. This brings to mind the design dilemma often discussed in music technology and other creative domains: sophistication and access to a high number of features vs simplicity and designed limits. The topic has been recently addressed also by the multimedia artist and music technologist Robert Henke, who discussed how the different mindsets and priorities of composers, performers, and software developers affect the design of musical tools, and described how he sees constraints and limitations as something useful in his own creative practice (Henke, 2016). This is indeed a wider, highly subjective topic of discussion, and addressing it is beyond the scope of this paper. It is however important to keep such issues in mind when developing the AIML paradigm further, given that what might be useful to improve the capabilities of an AIML system might not be what makes it more valuable in the context of actual music creation. This became more evident when the system was used by the first author for the development of the multimedia performance piece "You have a new memory" (Visi and AQAXA, 2020). Even though – compared to system shown in the demo – the sound synthesis engine used in this case was more sophisticated, the mappings obtained by interacting with the agent through the workflow described above resulted in a rewarding creative process. It is felt that more ways of giving feedback to the agent might have shifted the focus away from attentive listening and exploration of the sonic interactions. This is, once again, highly subjective and depends very much on one's creative goals.

Higher feedback on Q1 and Q3 suggest that the system has been perceived as a useful tool for exploration and discovery. A defining characteristic of the architecture we propose is that the sound synthesis space is shaped by the presets defined by the user, while the agent provides mappings between that and the input motion features. Yet, even though the synthesis anchor points are defined explicitly, the articulations between them can be very diverse and complex. Exploring such articulations through the mappings proposed by the agent allows for the discovery of sonic gestures within the synthesis space defined by the anchor points. In other words, it is like discovering different ways of performing the same sound synthesis material. We argue this has considerable musical usefulness. Varying the same source material – whether notes or synthesis parameters – is a well-established process in music making, and it is also at the centre of several other implementations of machine learning in music production, such as for example the Magenta Studio[11] plugins.

The approach we described differs from the typical IML workflow as it does not include a gesture design phase, and also differs from the study by Scurto et al. (2019) since the agent does not explore the sound synthesis parameter space. This does not mean that the approaches cannot be combined. Automated sound synthesis parameter exploration techniques can potentially be employed in the sound design phase, while mappings saved while interacting with the agent can be recalled and improved by providing additional input sample data as it is typical in the IML workflow. We therefore see AIML as a way of extending and aiding established gestural interaction design practices.

Conclusions and Future Work

We presented an interaction design approach that uses artificial agents and machine learning to interactively explore mappings between gestural input and sound synthesis. We refer to this model as Assisted Interactive Machine Learning. We implemented this paradigm in a prototype system that uses reinforcement learning and linear regression to obtain mappings between accelerometer data and a sample-based synthesiser while playing the instrument. The feedback given to the artificial agent allows to guide its exploration, thus affecting the mappings it proposes after each iteration.

[11] https://magenta.tensorflow.org/studio

After testing the prototype system internally, presenting it to an expert audience to collect feedback, and employing for the development of a multimedia performance piece, we argue that this model constitutes a useful creative tool for discovering musical interactions while actually playing the instrument. Moreover, AIML can in principle be combined with established interaction design and parameter exploration techniques, and thus be included easily in the workflow of practicing musicians and multimedia artists.

As discussed in the previous section, currently the guiding feedback given by the user to the audience is a simple binary response on the last proposed mapping. Even though the simplicity of the current version allows for a quick and intuitive interaction with the agent, a more sophisticated way of giving feedback may lead to a more rewarding experience with the system. For instance, the agent is currently agnostic of the sounds designed by the user and the output sound made while performing. By implementing machine listening and audio feature extraction techniques, the user could potentially give feedback to the agent regarding some basic timbral features of the output sound, similarly to systems that use audio analysis and genetic algorithms to define a target sound and program a synthesiser automatically (Dahlstedt, 2001; Yee-King et al., 2018). This way, the feedback given to the agent would include different weights for different timbral features. Additionally, the architecture of the current AIML prototype allows for static regression (Tanaka et al., 2019) and not for temporal modelling, which would allow interactions with more diverse dynamics.

Despite its limitations, it is worth keeping in mind that the simplicity of the current version affords a quick, fun workflow that was perceived as useful from the start, and that led to a rewarding creative process during the development *"You have a new memory"* (Visi and AQAXA, 2020). For the purpose of gathering further user feedback data, and to study how musicians would use an AIML system in their actual practice, we are aiming at carrying out a longitudinal study with a small group of professional musicians. This would allow us to situate the development of AIML systems in broader musical contexts, and thus gain insight that would be very difficult to obtain otherwise.

Grounding the research in music practice will also help with studying different ways of giving feedback to the agent and address other open design questions. For this reason, we are aiming at designing an AIML instrument using a specific input device and synthesis engine. A full system can be consistently studied and iteratively improved, by, for example, select the synthesis parameters that are exposed to the agent, try different ways of giving feedback and include other interaction design paradigms in the workflow to refine the mappings proposed by the agent. As with the longitudinal study, this will allow to spend more time with a consistent system and expose its affordances and constraints more clearly, and thus lead to a better understanding of the *ergodynamics* Magnusson (2019) of AIML as a sonic interaction design paradigm situated in music practice.

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Rene Mogensen

SomSwarm 1 computational creativity music improvisation: human-computer co-creativity

Paper

Video of presentation can be found here

SomSwarm 1 computational creativity music improvisation: human-computer *co-creativity*

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Abstract.

SomSwarm 1 is a 'computational creativity' implemented for musical improvisation performance together with human musicians, and I argue that the implementation is *co-creative* with human performers in concert music settings. *SomSwarm 1* is a first-generation hybrid system combining competitive self-organising maps with a 'swarm' algorithm: an artificial swarm moves in a dynamic topological space which is formed by the weights in self-organising networks that are trained with quantifications of features from human performances. The first concert applications of the implementation has been in two music contexts: *SomSwarm* with Big Band and *SomSwarm* in a duet with a human soloist. I analyse the implementation in relation to a formal specification for computational creativity in music and I examine the performance situation as a human-computer *co-creative* activity system. This analysis points to potential future developments for this kind of hybrid system and its 'co-creative' role as an improviser in musicking contexts.

Keywords.

Computational creativity, swarm algorithm, machine improvisation, machine learning, self-organising map, analysis.

Introduction

Previous analytical research using a formal specification for 'computational creativity' suggested a potential hybrid system which would combine Self-Organising Maps and Swarm algorithms (Mogensen, 2018a, pp. 9–12). The *SomSwarm 1* system is a first-generation network–swarm hybrid derived from some of the suggestions of the previous formal analysis, and was expressly implemented for music improvisation in human-computer *co-creative* group performances. In this hybrid technology an artificial swarm moves in a dynamic topological space which consists of the weights in self-organising networks that have been trained with quantifications of musical features from human performances; and so the networks take on a memory-like function which can be 'explored' by the swarm agents. The swarm activity is mapped onto electronic instruments and effects processing parameters which constitute the output of the improvising computer system.

To start I discuss a working understanding of computational creativity and human-computer 'co-creativity' which forms the basis for the subsequent exposition, and proceed to give an overview of a computational creativity specification previously developed. Some technical concepts of competition-based networks with swarm algorithms that form the key to the *SomSwarm* implementation architecture are introduced using the specification in Z-style notation; and some brief descriptions of implementation specifics give a sense of the implementation approach. As of this writing, *SomSwarm 1* has been active in two concert music contexts: first in *Inner Surfaces* for Big Band and *SomSwarm 1*; and secondly in *As a silence is interrupted* for *SomSwarm 1* and soprano saxophone. Both works are examined to give empirical support for the capacity for co-creativity in the first-generation *SomSwarm* technology.

A working understanding of 'computational creativity'

Creativity research has led to a variety of theories and definitions with no definitive description found yet and so 'we are still far from fully understanding what creativity really means' (de Sousa, 2008, 56). In common parlance artefacts and concepts made by humans are deemed 'creative' products even without having a clear view of what human creativity is, how it works, or whether it is computable; however, when hypothesising that it is possible, at least in principle, to make a digital computer-based 'computational creativity' then it must also be possible to make a *specification* of what a computational creativity *does* computationally, even if creativity might be an emergent result of a complex system. In other words, I take as given that anything that a current digital computer (or a Universal Turing Machine[1]) can do, can be represented in a formal specification. Therefore, if a computer can in some way be programmed to perform creative output, then it must be possible to define such a computer program in a formal specification of 'computational creativity'. Below I give an overview of such a specification and subsequently apply it as an analytical tool in order to compare implementations.

I submit computational creativity and human creativity as logically distinct categories, both of which may be members of a 'creativity concept family'. In developing a working specification for computational creativity the vaguely defined 'human creativity' can serve heuristically as a prototype for the creativity concept family, but only in the sense that terms adopted from ideas about human creativity can be used to name and to guide the conceptualisations of components in the specification for computational creativity. Such use of terms does not imply any identity between human creativity and computational creativity.

I use a notion of *creativity* not as a process, but instead as a *product* (which echoes Glickman (1976)) of a *learning* process; for example an *experiential* learning process: in Kolb's (2015) interpretation of Dewey (1938) experiential learning is an iterative process with cycles of 'Impulse' leading to 'Observation' and to 'Knowledge' and 'Judgement' which result in what Dewey calls 'Purpose' (Mogensen, 2018b, 65–67). Such *purpose* is directed towards achieving or outputting particular *produced* artefacts and/or ideas. In order to formulate a specification for *production* by computational creativity, a necessary condition will be the inclusion of a learning process which may (or may not) result in creative outputs. In the recently developed *SomSwarm 1* implementations of computational music improvisers, such a learning process is interpreted as the process of building a 'memory' of patterns (in the form of self-organising maps) that is 'learned' through performance with humans, and which is explored as a possibility space by 'swarm agents'.

Human-computer 'co-creativity'

When we concede improvisation to be a creativity *product*, and allow that computer systems may 'co-improvise' with human performers, then the implication is that the computer systems are computationally 'creative'. Given *computational creativity* in a co-improvising relation with the human performers, the resulting human-machine 'co-creativity' is inclusive of human creativity and computational creativity, and so the relation between human and machine improvisers may be one of partnership, rather than one of user and tool.

In other words, co-creativity is an approach to human-computer relations which may transcend concepts of Human Computer Interface (HCI) as a human-centric user-tool paradigm giving hierarchical preference to the human and the goal-oriented activities of the human user of a computer system (Dix et al., 2007). Robert Rowe (1993) proposed a taxonomy which polarised what he called the 'instrumental paradigm' and the 'player paradigm' in computer interactivity. Using Rowe's categories the area of HCI is an 'instrumental paradigm' in the sense that the computer systems extend the human musical activities. On the other hand, human-computer *co-creativity* may be similar to Rowe's 'player paradigm' where the computer exhibits more independence as 'an artificial player, a musical presence with a personality and behavior of its own, though it may vary in the degree in which it follows the lead of the human player' (Rowe, 1993, 8). The 'human activity system', in the Soft Systems Analysis sense (Wilson, 2001), that engages in improvisation, and which includes computational creativity as a co-improviser with humans, has a potential emergent creative performance output that is wider in scope than either purely human improvisation or purely computational improvisation systems; and such creative output is a result of human-computer co-creativity (Mogensen, 2019).

Overview of the *computational creativity* specification

I am developing a formal specification of computational creativity for music. The specification is a generalised model of computational creativity for music in the sense that it does not indicate specific technological

[1] The Universal Turing Machine as presented by Alan Turing (1936). 'The [Universal] Turing Machine not only established the basic requirements for effective calculability but also identified limits: No computer or programming language known today is more powerful than the Turing Machine' (Petzold, 2008, 330).

solutions; the specification is concerned with *what* the computational creativity does, not *how* this would be implemented in software. An implemented system such as *SomSwarm 1* can then be analysed by identification of the functions of the system which correspond to components of the specification. Components of the specification include dynamic *Possibility Spaces* (Mogensen, 2018b), *Memory* and *Context* (Mogensen, 2020b), as well as *Motivations* (Mogensen, 2017). Initial ideas for the specification were built on the earlier framework proposed by Wiggins (2006). Figure 1 gives a condensed and diagrammatic overview of the formal specification which indicates the more significant components necessary for the present discussion (where t represents discrete time).

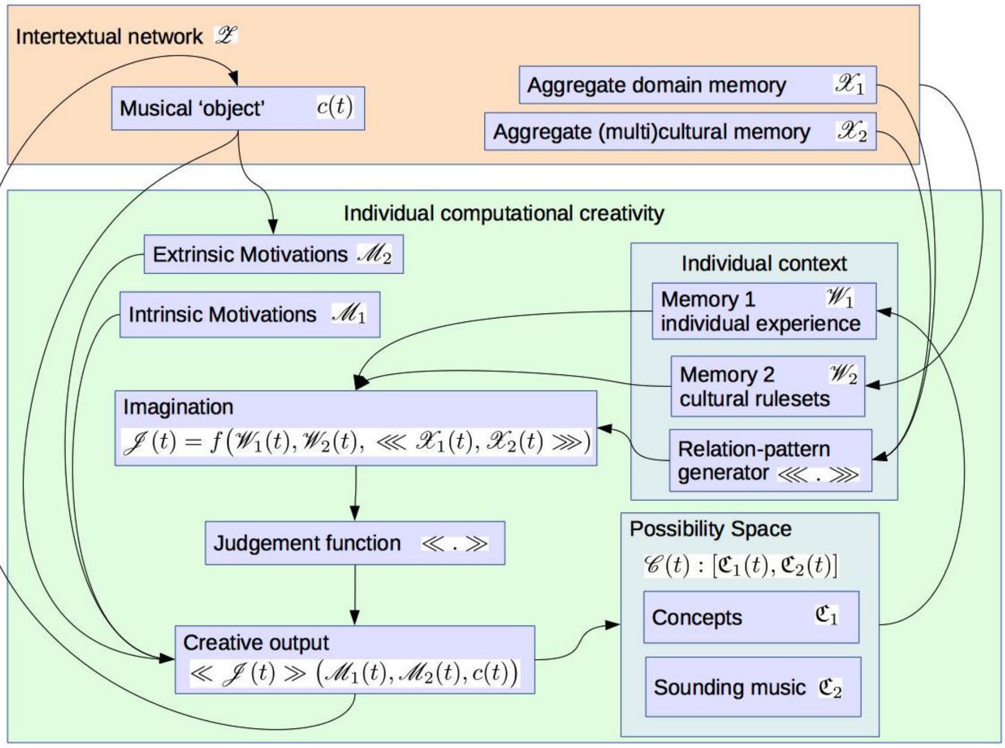

Figure 1: Diagram overview of the specification for computational creativity.

The individual computational creativity has memory which encompasses several categories of components: individual agent experience $\mathscr{W}_1$, cultural rulesets $\mathscr{W}_2$, aggregate domain memory $\mathscr{X}_1$ (idiomatic to styles or genres of music), and aggregate (multi)cultural memory $\mathscr{X}_2$ (larger cultural baggage). I proposed the *Individual context* $[\mathscr{W}_1, \mathscr{W}_2, \lll . \ggg]$ as well as the *Intertextual* network $\mathscr{L}$ that enter the memory of the computational creativity as feeding an individual *Imagination* function $\mathscr{J}(t)$ (Mogensen, 2020b). *Imagination* and *Motivations* $[\mathscr{M}_1, \mathscr{M}_2]$ enter into a *Judgement function* which shapes the possibility space and may result in a *Creative Output*. In the present context this *Creative Output* is improvised music. I have applied the formal specification in analyses of computational creativity implementation architectures, and the first version of the *SomSwarm* computational creativity was derived as a hybrid of two earlier implementation architectures. In the next section I turn to details of *SomSwarm 1*, with references to the specification outlined in Figure 1.

SomSwarm 1: competition-based network as topological space for swarm agents

The key concept in the present version of *SomSwarm 1* is the idea of a swarm algorithm which is active within a topological space, where the space is based on the weights of a self-organising map: these weights represents a kind of distributed 'memory' of the musical features of a performance, and the swarm *agents* moving around in this memory are then a second-order algorithm that superimposes, or nests, into the first-order weight network. The swarm agents can in this setting 'move within' the memory space of the network, reacting to the network weights as features of a topological space. In this system the swarm agents which move according to simple rules may contribute to potentially 'creative' musical results when the movements and positioning of the agents are mapped to sound control mechanisms. This idea is outlined formally using Z-style notation in Figure 2 with references to the specification for computational creativity outlined in Figure 1.

SomSwarm 1

$t : time$
$\mathscr{C}(t) : Possibility\ space\ [\mathfrak{C}_1(t), \mathfrak{C}_2(t)]$
$N_i(t) : Network\ of\ weights\ (\mathfrak{C}_2(t))$
$A_k(t) : Swarm\ Agent(k)\ position$
$\mathscr{R}_k : Agent\ behaviour\ rule\ set$
$\mathscr{C}_k(t) : Possibility\ Space\ visible\ to\ Agent(k)$
$M(t) : Musician\ performance(input)$
$c(t) : Musical\ object\ (sounding\ music)$
$\mathscr{M}_1(t) : intrinsic\ motivation$
$\mathscr{M}_2(t) : extrinsic\ motivation$

$$M(t) \in c(t)$$
$$N_i(t) = f[N_i(t-1), c(t)]$$
$$\mathfrak{C}_2(t) = N_i(t)$$
$$\mathscr{C}(t) = [\mathfrak{C}_1(t), N_i(t)]$$
$$\forall\, k : \mathscr{C}_k(t) \in \mathscr{C}(t)$$
$$\forall\, k : \mathscr{C}_k(t) = \mathscr{R}_k[N_i(t)]$$
$$\forall\, k : A_k(t+1) = f_k\big(\mathscr{C}_k(t), \mathscr{R}_k, A_k(t)\big)$$
$$\mathscr{M}_1(t) = \textstyle\bigcup_k \big[\mathscr{R}_k[N_i(t)]\big]$$
$$\mathscr{M}_2(t) = f[c(t)]$$

Figure 2: *SomSwarm 1* central idea: weight networks as topological space(s) providing the environment for swarm activity.

Briefly, in Figure 2, the network weights N_i encode the music phenomenon space $\mathfrak{C}_2$. At time t, the possibility space $\mathscr{C}(t)$ then consists of $\mathfrak{C}_2$ and a statically encoded concept space $\mathfrak{C}_1$. Each $Agent(k)$ in the group of k swarm agents can observe and move according to a ruleset $\mathscr{R}_k$ in the agent's visible possibility space $\mathscr{C}_k(t)$ which is a subset of the possibility space $\mathscr{C}(t)$. For each $Agent(k)$ the function f_k processes the visible possibility space $\mathscr{C}_k(t)$ according to its ruleset $\mathscr{R}_k$ and present location $A_k(t)$ to calculate its movement to the next position $A_k(t+1)$. Intrinsic motivations (at time t) of the system $\mathscr{M}_1(t)$ can be understood as the set of k agent rulesets $\mathscr{R}_k$ each of which is interacting with the network weights $N_i(t)$. Extrinsic motivations (at time t) of the system $\mathscr{M}_2(t)$ can be understood as a function of the current sounding music $c(t)$.

The self-organising network which contains the weights (or topological space) in *SomSwarm 1* is organised as a set of matrices. The set of matrices is cumulative and can be expanded so there is a time-based dimension to the memory where memory from earlier performances can affect later performances. The network weights are adjusted based on competition, as a version of a Kohonen Self-Organising Map (Fausett, 1994, 169–187). The inputs to the network are features of the performed music, primarily the sound of the human musician(s) captured through microphones. In the first implementations the feature extraction process has been focused on encoding pitch, rhythm, and attack intensity; but future work will expand this process to include more feature dimensions.

Because the network is competitively self-organising, where training continues during performance time, mapping is automated and the musical patterns mapped to the computer sound are based on characteristics of the network node weights: rhythmic dynamic patterns are generated from the weight value sets of clusters in the self-organising map. These patterns are associated with pitches derived mostly from a relatively short-term 'memory' matrix of pitch classes that were captured via one or more microphone inputs. The parameters generated by the swarm agents' positioning in the matrices are mapped to midi instruments, audio-file manipulations and 'gating' of audio processing.

Inner Surfaces for Big Band and *SomSwarm*

Inner Surfaces for Big Band and *SomSwarm* was premiered on September 3, 2019 in Aarhus Musikhus, Denmark by the ensemble *Blood Sweat Drum and Bass* under the direction of Jens Christian 'Chappe' Jensen.[2] The work is encoded in a written score for the instrumentation of the ensemble and as a sequence on the computer which enables playing of several electroacoustic sound constructs at various points in the score as well as timed enabling and disabling of the *SomSwarm 1* improvising output in coordination with the score. The computer improviser is limited to three segments in the score; and the computer output is mapped to midi-instruments that have timbres that stand in contrast to the ensemble sounds. The three segments where *SomSwarm* plays there are also saxophone soloists improvising, and there is improvised interaction between *SomSwarm* and the soloists so that those segments add distinct ideas to the ensemble sound and to the shape of the musical work.

After rehearsals (September 1–3, 2019) I asked the saxophone soloists from the ensemble *Blood Sweat Drum and Bass* what their impressions were of interacting with the computer in the solo sections. One of them felt quite confident and said he found it fun to play with and interesting that the computer part was different every time the piece was played. The other saxophonist felt somewhat less confident about interacting with it but nevertheless came across in a musically convincing way during the rehearsals and concert performance.

The intention with *SomSwarm 1* in the work *Inner Surfaces* was to integrate a system that could be *co-creative* with human performers in an improvisational setting. The contribution of *SomSwarm 1* in this music work clearly challenged the soloists to improvise interactively with the computer sound. I propose that the resulting music was *co-created* by the human-computer ensemble. While the musical ideas played by *SomSwarm 1* were based on feature extractions from human performance, and technically could have been performed by humans, the machine generated music was unique to each rehearsal/performance and included both predictability and surprise within constraints demanded by the scored parts of the music. Therefore I argue that the parts 'improvised' by *SomSwarm 1* contributed co-creatively to the music.

As a silence is interrupted for soloist and *SomSwarm*

In the improvised duet entitled *As a silence is interrupted*[3] for *SomSwarm* and saxophone, the role of *SomSwarm 1* is more extensive than in the Big Band piece *Inner Surfaces*. The duet is used to develop the capabilities of *SomSwarm* further after the initial success of its part in *Inner Surfaces*. In the duet a structure for improvisation is planned before performances, through a sequence of mappings, so that the orchestration of the *SomSwarm* output changes in a predetermined sequence over the time of the performance. Structural points of the changes in mappings are activated mostly by the human performer who thereby controls the timing of these changes. Within the orchestration structure, *SomSwarm* plays gestures with pitch and rhythmic qualities that are derived from the weights in the network; these weights are trained whenever the system is active.

In this version of *SomSwarm 1* the memory matrices from *Inner Surfaces* are also included as part of the topological space in which the swarm agents act and interact. I expect that with more performances and involvement with more music works, the *SomSwarm* memory network can be expanded, and will be limited only by hardware capacities. The first public concert performance of *As a silence is interrupted* was at the Royal Birmingham Conservatoire, UK, on November 6, 2019, with me on saxophone; rehearsals for this performance as well as the performance has added further training and implementation development has also enlarged the size of the memory network. Future plans call for performances with other soloists and ensembles.

[2] As of this writing, a concert recordings of *Inner Surfaces* is available online at: http://soundcloud/renemogensenmusic/20190903-innersurfaces

[3] As of this writing, a recordings of *As a silence is interrupted* is available online at: http://soundcloud/renemogensenmusic/as-a-silence-is-interrupted-20190925

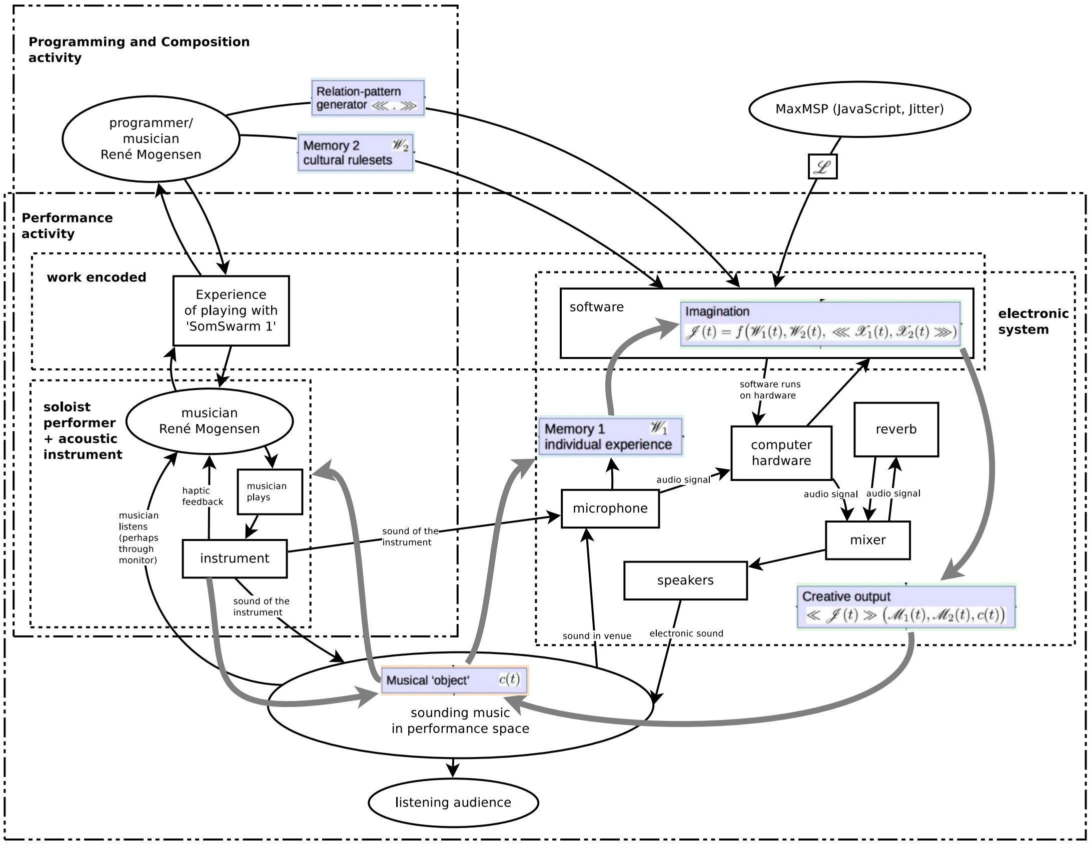

Figure 3: Soft Systems analysis of *As a silence is interrupted* for *SomSwarm* and saxophonist.

In Figure 3 a soft systems analysis of the performance situation of *As a silence is interrupted* shows both physical components and abstract specification components (boxes and/or ovals), where arrows indicate flows of influences and/or information. For now I will bypass a detailed narrative about this analysis, but the parallel and interacting development of two individual 'memories' suggest that it is a system that can result in *co-creativity*; by two individual 'memories' I refer to: 1. the programmer/musician gaining *Experience* of interacting with the system; and 2. the development of the *Memory 1* ($\mathscr{W}_1$) in the Computational Creativity *SomSwarm*. I suggest that these memories enable transformations of references in the human, and transformations of inputs to outputs in the software; and that capacities for these kinds of transformations are necessary for the respective music improvisation categories.[4]

As was the case in the Big Band piece, the intention with *SomSwarm 1* in the work *As a silence is interrupted*, was to make a system that could be *co-creative* with a human performer in an improvisational setting. In my own performance interactions with the system I have found that training the system makes the musical output more interesting to me as an improviser; and my construction of the structure (sequence of mappings) grew out of improvising with the system. Also, I found that improvising with the system gradually made me adapt some of my musical choices to better interact with the output of the system: so an iterative process, of improvising and adjustment, provided learning for me as well as training for *SomSwarm 1*. I suggest understanding this as a development based on improvisation and interaction between me (as the programmer/improviser) and the software (as a computational creativity).

My own introspective impressions of improvising with the system are possibly biased; since I am both programmer and performer I have in-depth knowledge and influence in the software development. Lewis's *Voyager* system (Lewis, 2000) has been criticised as being 'a system that is designed by Lewis, for Lewis, and would not work for all musicians' (Magnusson, 2010, 46); and a naive evaluation of *SomSwarm 1* might

[4]This leads to work on computational prospection (Mogensen, 2020a).

raise a similar criticism given my introspective observations. However, the performances by *SomSwarm* in the *Inner Surfaces* Big Band setting, where I was not involved as a musician, gives some preliminary indications that the approach to implementing *SomSwarm* has some potential as a 'computational improviser' in a wider range of contexts. More work is needed to gather information about human improviser perspectives on how *SomSwarm* implementations interact in improvisational contexts. For this research direction I am planning a number of new work structures which will engage with various improvising soloists, and in parallel make further developments in the specification and implementations of future generations of *SomSwarm* as computational improvisers.

Comparative analysis of *SomSwarm 1* as a hybrid

SomSwarm can be aligned with the computational creativity specification and the resulting component representations are indicated in Table 1. I refer to Mogensen (2018a) for a more detailed narrative on the previous comparative analysis of my *Favoleggiatori 2* and *MASOM* by Tatar and Pasquier (2017); here the focus is on the comparative analysis of *SomSwarm 1* and its qualities as a hybrid of the two previous implementation architectures.

Reading Table 1 we can observe some similarities and some differences between the three implementations: the most obvious similarities being that all three have static concept spaces $\mathfrak{C}_1(t)$, as well as implicit and constant cultural memory $\mathscr{W}_2(t)$ which implies a somewhat static mapping of computation output to sound. Differences in the phenomenon spaces $\mathfrak{C}_2(t)$ are therefore central to differences in the implementations' memories of possibility spaces $\mathscr{W}_1(t)$, and are significant: in *Favoleggiatori 2* there is a performance time memory matrix $\mathscr{W}_1(t)$ of pitch and rhythmic features, whereas in *MASOM* the memory $\mathscr{W}_1(t)$ is trained before performance time ($MASOM_T$ training $(t < 0)$). In *SomSwarm 1* the $\mathscr{W}_1(t)$ memory can be divided into three categories $N_i : [N_0, N_1, N_2]$ where N_0 is a short-term memory version from *Favoleggiatori 2*, N_1 is self-organising network that is trained during performance time, and N_2 is a collection of self-organising networks that have been trained in previous performances/rehearsals and may represent a longer-term memory of phenomenon spaces that have been input (as 'training') in the past. So in *SomSwarm 1* this $\mathscr{W}_1(t)$ has multiple components that resemble the $\mathscr{W}_1(t)$ functions in both *Favoleggiatori 2* and *MASOM*.

I have discussed (2020b, 2018a) the potential significance of memory attenuation as a factor in computational creativity, and in *Favoleggiatori 2* the memory matrix $\mathscr{W}_1(t)$ is degraded gradually at a constant rate Q_1, whereas in *MASOM* there does not seem to be any explicit Q_1; in *SomSwarm 1* the three categories $N_i : [N_0, N_1, N_2]$ have differing attenuation and growth characteristics. The specification *Imagination* function $\mathscr{I}(t)$ has varying characteristics over the three implementations as a result of the different possibility space representations: in *Favoleggiatori 2* it is dynamic $N_0(t)$, *MASOM* with a static $MASOM_T(t)$, and *SomSwarm 1* with a dynamic and cumulative $N_i : [N_0, N_1, N_2]$. Finally, the *Intrinsic Motivations* in *SomSwarm 1* and *Favoleggiatori 2* are intertwined with agent behaviour rules $\mathscr{R}_k$ which are constant in these systems, whereas the (constant) *MASOM* strategy is to use random choices within a node classification of the self-organising map. In summary: *SomSwarm 1* includes components that are similar to components found in both *Favoleggiatori 2* and *MASOM* and may be considered a hybrid which I propose as being potentially more flexible, responsive, and adaptable than either of its predecessors.

Specification component	***Favoleggiatori 2***	***MASOM***	***SomSwarm 1***
$\mathfrak{C}_1(t)$: concept space	static	static	static
$\mathfrak{C}_2(t)$: phenomenon space	$\mathfrak{C}_2(t) =$ $\mathfrak{C}_2(t-1) \cdot f_{\mathfrak{C}_2}\big(c(t), \mathfrak{C}_2(t-1)\}$	$MASOM_T$ constant $(t \geq 0)$ $MASOM_T$ training $(t < 0)$	$N_i(t) = f[N_i(t-1), M(t), c(t)]$ ongoing training $(t > 0)$
$\mathscr{W}_1(t)$: memory of possibility space $[\mathfrak{C}_1(t), \mathfrak{C}_2(t)]$	$N_0(t) : \bigcup_{p=1}^{t-1} \Big(\mathscr{C}_F(p) \cdot Q_1\Big)$	$MASOM_T$ constant $(t \geq 0)$ represented by SOM	represented by $N_i(t) : [N_0(t), N_1(t), N_2]$
$\mathscr{W}_2(t)$: cultural memory	S_3: implicit and constant	T_1: implicit and constant	S_4: implicit and constant
Q_1 : attenuation of $\mathscr{W}_1$	N_0 degrades at constant rate $(t > 0)$	none	N_0 degrades at varying rates N_1 learn rate attenuates $(t > 0)$ N_2 increases outside time t
Q_2 : attenuation of $\mathscr{W}_2$	none	none	none
$\mathscr{I}(t)$: Imagination	$f\big(N_0(t), S_3,$ $\lll N_0(t), S_3 \ggg \big)$	$f\big(MASOM_T, T_1,$ $\lll MASOM_T, T_1 \ggg \big)$	$f\big(N_i(t), S_4, \lll N_i(t), S_4 \ggg \big)$
$\ll . \gg$: *Judgement* function	$\ll . \gg_{agent}$ agent behaviour rules	$\ll . \gg_{VOMM}$ VOMM $\rightarrow$ random selection from cluster	$\ll . \gg_{agent}$ agent behaviour rules
$\mathscr{M}_1$: *Intrinsic Motivation*	agent behaviour rules	$MASOM_{GR}$ Random audio from SOM node	agent behaviour rules
$\mathscr{M}_2$: *Extrinsic Motivation*	feature analysis	$MASOM_{GR}$ feature analysis	feature analysis

Table 1: Comparison chart of specification components in *Favoleggiatori 2*, *MASOM*, and *SomSwarm 1*, where performance time is represented by discrete time t.

Conclusion

Analytical use of the computational creativity specification outlined in Figure 1, in conjunction with the experiments of integrating the *SomSwarm 1* implementation as an improviser in *Inner Surfaces* and *As a silence is interrupted* have arguably resulted in satisfying music as creativity products. The musical challenges and surprises that create rich interactions for human improvisers in the two concert works mean that *SomSwarm 1* contributes to the creative product and I argue that it is potentially *co-creative* with the human performers. The analytical work related to *SomSwarm 1* has also given rise to ideas towards future *SomSwarm* versions for deeper co-creativity with human performers. However, further discussions about these possibilities await future work.

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Matthew Hughes, Jaime Garcia, Felicity Wilcox, Robert Sazdov, Andrew Johnston and Andrew Bluff

Immerse: Game Engines for Audio-Visual Art
in the Future of Ubiquitous Mixed Reality

Paper

Video of presentation can be found <u>here</u>

Immerse: Game Engines for Audio-Visual Art in the Future of Ubiquitous Mixed Reality

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Abstract. Through the context of the mixed-reality performance work 'IMMERSE', this paper discusses the use of game engines as a practical medium for the creation of audio-visual art. The game engine's metaphorical and spatial consistency with reality, flexible deployment options and capacity for high-fidelity graphics make them a perfect tool for constructing the artworks of the twenty-first century.

Keywords: mixed reality, audio visual art, composition, game engines

Introduction – The science fiction of a mixed reality

Nested in the footer of designer and film-maker Keiichi Matsuda's website sits a randomly selected quote. Today it presents a gem from J.G. Ballard:

> Everything is becoming science fiction. From the margins of an almost invisible literature has sprung the intact reality of the 20th century.

It accompanies Matsuda's concept works that explore a future where technology is immersive, pervasive and ubiquitous. His 2016 short film 'Hyper-Reality' (Matsuda 2016) transports the audience to a point-of-view bombarded by mixed-reality media (figure 1). Virtual objects are planted inside the day-to-day and appear as integrated as any physical object. It is not clear what technology is rendering the holographic imagery, but as Ballard noted for his own century, science-fiction literature is charged with the task of discussion – scientists will find the necessary techniques to transform the fiction into reality.

Much of what is described in 'Hyper-Reality' is materialising itself right now. Computer-generated cat-ears already crown our heads and 'Pokémon' roam our streets. Mobile and headset-based augmented reality is transforming the once immovable window to the virtual world into an interactive viewport. CAVE environments and AR headsets provide researchers and artists with mixed-reality play-spaces, and numerous technologies are sure to follow that continue to liberate us from the flat-panel.

To researchers, the concept of creating a ubiquitous computing environment is becoming increasingly important – and to artists, these developments in technology offer an exciting opportunity; a new medium in which to produce work, entangled with questions of how to present the imagined and the synthesised among us.

In this paper, we present 'IMMERSE' – an audio-visual work that combines live music and spatialised sound design with audio-reactive visuals in a CAVE-like (Cruz-Neira et al. 1992) environment. The work wraps the performance area in 360-degree projections, with the audience onlooking from inside the cylindrical space. In this mixed-reality performance piece, musicians interact in real-time with the virtual environment that surrounds them. At the core of the system's architecture is a video game engine, housing virtual objects manipulated by the music in real time.

Figure 1. Caption: A still from Keiichi Matsuda's short film 'Hyper-Reality' (2016).

The game engine is becoming a key tool for carving out the immersive, pervasive and ubiquitous future of computing described by Matsuda and his science-fiction contemporaries – its place in our media is stretching far beyond what its name suggests, and the features of a game engine make it a versatile medium for those exploring the nexus of art and technology. This paper will explore the benefits of using the game engine as a medium, and through the context of our live performance piece 'IMMERSE', seeks to demonstrate that the object-based, spatially consistent, and widely deployable nature of game engines make them a perfect tool for constructing the interactive artworks of the 21st century.

Usual systems for audio-visual art

There are several approaches used by artists to create audio-visual works, although one of the most commonly used methods is to construct the system using a combined multimedia programming environment such as Max or its open-source cousin Pure Data (Pd). Max is a graphical environment in which applications are "patched" together by visually drawing connections between independent nodes (figure 4). Its component libraries MSP and Jitter contain nodes to construct and manipulate sound and visuals respectively. By combining audio and graphical development in the same environment, an artist who uses this type of system can easily achieve a high level of integration between the audio and the visuals. Visualisations of audio can be constructed by feeding sound directly into graphical nodes, and sonification of visuals can be achieved by doing the opposite (Jones & Nevile 2005).
The Cosm toolkit (Wakefield & Smith 2011) uses Max to design for CAVE environments, and the authors chose the highly integrated system over alternatives to ensure tight coupling between modalities. They

do concede however, that the power of Jitter's graphical engine is not able to match that of a game engine – a point which is echoed by audio-visual composer Tadej Droljc (2017). Droljc uses Max to produce his compositions, and praises its immediacy, but the lack of fidelity available in its graphics engine forces him to use Max primarily as a compositional tool. For finalising visuals in high-quality, his animations are rendered offline using more traditional 3D animation techniques. He presents many pain points when using a system based on Max, including limited support for processing 3D meshes and inconsistent surface lighting, and also implies that a high degree of technical and programming skill is necessary, describing the process of importing usable 3D models into Max as "very complicated".

Acknowledging these factors, audio-visual artists can combine the strong audio engines of Max/PD or alternative digital audio workstations with environments focused on graphics. VVVV and TouchDesigner are two examples of popular software environments used to create graphics for interactive artworks, and some artists even create their own graphical engines using languages like C++ along with creative coding libraries such as OpenFrameworks and Cinder (Johnston 2013; Correia 2015).

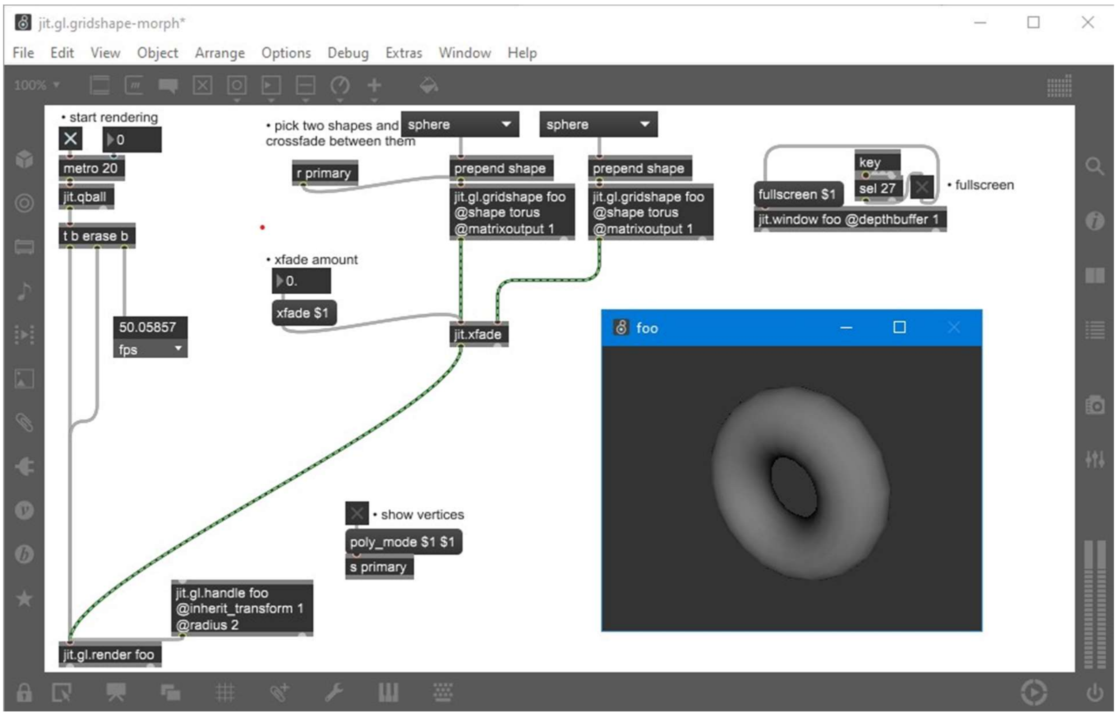

Figure 2. Cycling '74's Max software environment and its 'patcher' interface.

Benefits of a game engine

A video game engine, in comparison to the methods previously outlined, offers artists a high fidelity, real-time graphics pipeline without needing to write low-level code – perhaps even no code at all.

Today, the video game industry is more profitable than the film and music industries combined (LPE 2018), and consequently, a great deal of high-quality tooling has been developed in the form of feature-rich game engines such as Unity and Unreal. These engines provide the user with high level control over meshes, lighting, physics, particle systems, fluid and cloth simulations, with huge communities (and corporations) furthering the state-of-the-art in these technologies and their interfaces. Without diminishing the welcoming communities of the alternative software environments, it is worth noting the company behind the free-to-use Unreal game engine, Epic Games, earned $3 billion in profits for 2018 (Kain 2018) – money which can be seen in the numerous features added in each of the engine's frequent new releases.

Indeed, commercial game engines offer a higher-quality and more flexible graphics pipeline out-of-the-box as opposed to the alternatives audio-visual artists often use – but the most vital change is not this upgrade in fidelity. Game engine's present a conceptual advantage to the process of audio-visual composition through their strong focus on the concept of 'game objects'.

The vision of the future painted in Matsuda's 'Hyper-Reality' is not one where creators design for the limitations of screen-space. You won't find a flat screen throughout his entire short. In this future, the existence of the virtual is bound to the citizen's own world-space, where each digital experience – be it a game, an advertisement, or in our case a work of art – exists as a 3D entity inside the real world.

In a game engine, everything presented within the environment exists as an object made from *attributes* – representing the object's current state – and *behaviours* – defining how that state should change over time and in response to events (Gregory 2017). These objects are typically referred to as entities, agents, or 'game objects', and can be easily manipulated within a 3D scene that is analogous to our real world.

As mixed-reality experiences become more prevalent and the science-fiction future emerges in front of us, the world-space canvas presented to game designers along with its game object metaphor is highlighting itself as a practical medium for a variety of real-time media – not just gaming. Game engines have always been designed to resemble the world of our own, and modern game engines include an 'editor' that allows for manipulation of game objects in ways that remain within this world/object metaphor. The metaphorical consistency with our own experience is important, because it is notably absent or convoluted in some of the alternative software environments used by audio-visual artists.

As an example of this metaphorical consistency between the world in a game engine and our reality, let's take this paper you're reading (and foolishly assume you're not doing so on a screen). You're probably reading it inside a room – or perhaps you're enjoying it outside in the sun – either way, it exists, and it does so inside a unique environment. You can place this paper down in front of you, inside your unique environment very easily. Now if you have a second paper, you could easily take that and stack it on top of this one. With a game engine, the process is analogous. If you were to load a model of this paper as a game object, you could insert it into the game world and stack more on top by adding additional "paper" objects into the scene – moving them about as you please by dragging them within the editor's interface.

If you attempted this same feat in Pd's GEM, the process is less intuitive. You would connect a "gemhead" node (which represents the rendering world) into a 3D model node. Immediately this metaphor is at odds with reality, because the connection order insists we connect the world to the object and not vice-versa. Adding a second 3D model, you'd need to create a "separator" to tell GEM the objects must exist in separate locations. Max's Jitter environment is closer to reality. You can create a world node and populate it with object nodes. Each object can be moved about the virtual world independently, but being able to manipulate the object's position interactively isn't available to us without additional programming. These details may seem insignificant, but the game engine's ability to navigate, populate and visualise a 3D scene with its editor – whilst being able to manipulate its contents intuitively – demonstrates the medium's immediacy and suitability for creating works that exist in a world of mixed-reality.

Audio-visual artworks that utilise video game engines for graphics typically don't use the game engine for audio as well though. The maturity of Max and Pd, and their unquestionably greater focus on sound manipulation make them far better candidates for handling audio than anything built into a game engine itself. Therefore, it is common for Max, Pd or similar software to be used as an audio backbone bound to a game engine handling the graphics. The most common way to unify the two engines – facilitating the binding of sound and game object attributes – is with an internal network connection, as demonstrated in (Dolphin 2009), and often through use of the Open Sound Control (OSC) protocol (Hamilton 2011).

This type of system that introduces a network layer in order to bind two separate engines has been denounced by some creators due to its implicit looser coupling between modalities (Wakefield & Smith 2011), but projects like Chunity (Atherton & Wang 2018) and Libpd (Brinkmann n.d.) offer solutions to embed the external audio engines inside the game engine itself, allowing for shared memory and simultaneous event handling without introducing the latencies of a network. Additionally, at the time of writing, Epic Games' latest Unreal engine release has enabled by default a new built-in audio engine – one that could potentially rival external alternatives, and as a first-party integration, may offer the most unified approach moving forward (Lerp 2019) .

Figure 3. A dress-rehearsal for 'IMMERSE' inside the data arena.

IMMERSE

Our project, entitled 'IMMERSE', is a mixed-reality audio-visual performance work that combines chamber music, spatialised sound design, and interactive visualisations. It was presented as part of the 2019 Sydney Festival inside the University of Technology Sydney's 'Data Arena' – a CAVE-like environment that projects images in 360-degrees, and houses a sixteen-channel surround sound system (figure 3).

Like many of our contemporaries, we chose to build a hybrid system that couples a game engine with an external audio engine over a local network (figure 4). Live audio from two performers, on viola and cello respectively, is fed through wireless microphones into Pd, where it is combined with spatialised electronic sound compositions controlled by a third performer. The Pd patch performs spectral analysis, pitch detection, and transient detection on both live audio sources, as well as for the 16-channel electronic sounds. The electronic soundscapes feature the surround speaker system heavily, swirling noise around the audience seated in a ring facing the performers in the centre. The volume of each of the 16 speaker channels is also monitored, and the location of the loudest speaker is calculated in terms of its position on the room's circumference, so that the aforementioned swirling can be tracked.

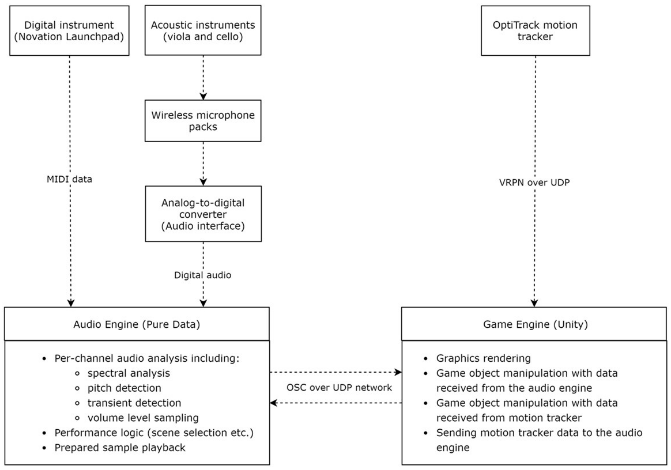

Figure 4. The system architecture of `IMMERSE`.

Each of these data streams created by Pd is piped to an instance of the Unity game engine running on the Data Arena's graphics server, which houses an array of graphics cards and is connected to six projectors. Game object attributes in Unity are bound to the incoming network messages, allowing the performers direct manipulation over the virtual environment through their musical gestures. For one scene, an OptiTrack motion tracking system is also utilised, and the position of some game objects are set to follow the viola player as he bounds throughout the performance space and around the audience.

A recurring pattern throughout the work is a motif we call the "connective tissue", which is composed of a particle system that reacts to abstract electronic sounds. Spectral data is used to animate the particle system's attributes, and the position of the particle system is guided by the surround sound position of the audio. Figure 5 shows this visualisation inside the Unity editor, alongside a representation of the physical performance area in proportional scale, where one spatial unit in Unity is equivalent to one metre in real life. The black circle represents the floor of the Data Arena, and the pink cubes are markers which orient the visualisations during the design process. The game engine's editor – being easily navigable and spatially consistent with reality – allows the designer to comprehend the experience of the Data Arena without needing to be inside the space itself. In fact, the principal designer of 'IMMERSE' was able to generate a series of game objects like this one on a laptop from the opposite side of the world, and be confident that they would present themselves as intended inside the Data Arena. Of course, the impact of the Data Arena's scale does not translate to a laptop screen, but the fact this virtual object is transferrable to a highly specific environment highlights another advantage to composing artworks in a game engine – flexibility over the technological system used for presentation. Unity can be used to build experiences for PCs, consoles and mobile. It can target VR headsets or AR glasses, and all that's necessary for us to deploy to the Data Arena is to insert a virtual "camera" suitable for our projector configuration.

As we close in on Matsuda's "hyper real" future, numerous techniques are being bred that allow the virtual to coexist in our spaces, but there isn't a singular presentation mechanism that's assumed for mixed reality artworks. CAVE environments like our Data Arena are fundamentally site specific. Headsets are – at this point in time – expensive and unergonomic, and their intermediary – the smartphone – requires users to fumble with screens in front of their face.

Holograms as depicted in Hollywood are a far-cry from reality, and it's unlikely there will ever only be one technology to account for all mixed-reality presentations. By composing audio-visual artworks within a scene of component game objects, the presentation technology is distanced from the composition itself. 'IMMERSE' has been designed so that the audience is encircled by visualisations – quite obviously because the Data Arena is constructed this way – but now the work is completed, it would be trivial to present the same production inside a VR headset because it is offered by Unity as a deployment target. We could build our show's scenes for a different CAVE space at another institution, or we could tell Unity to build for iPhone and deploy it as an augmented reality app. Because the game object's attributes and behaviours, along with the world's scale remains consistent no matter the deployment target, each experience would still effectively showcase our artistic intentions. When designing for mixed reality – a new artistic medium whose mechanisms for presentation are not standardised – the technological agnosticism provided to us with game engines can simplify development, allow exploration in multiple presentation methods, and in theory extend the lifetime of the artwork itself.

Future development

In future works of this nature – contrary to how we approached the 'IMMERSE' system – an architecture that allows the audio engine to be embedded within the game engine would certainly be an improvement. Instead of networking with an external audio software, an embedded approach (like some mentioned in section 3) would allow us to bind sonic parameters more directly to game objects. The improved audio engine present in Epic Game's new Unreal engine releases would simplify this even further – so we are watching with interest to see if it presents a competitive first-party alternative. For 'IMMERSE', the networked approach didn't present itself as an obstacle per se – and we are perfectly satisfied with the level of audio-visual integration we have been able to achieve – but in order to further explore the game engine's use as an artistic medium, focusing on integrating modalities within the game objects themselves seems like a logical path forward.

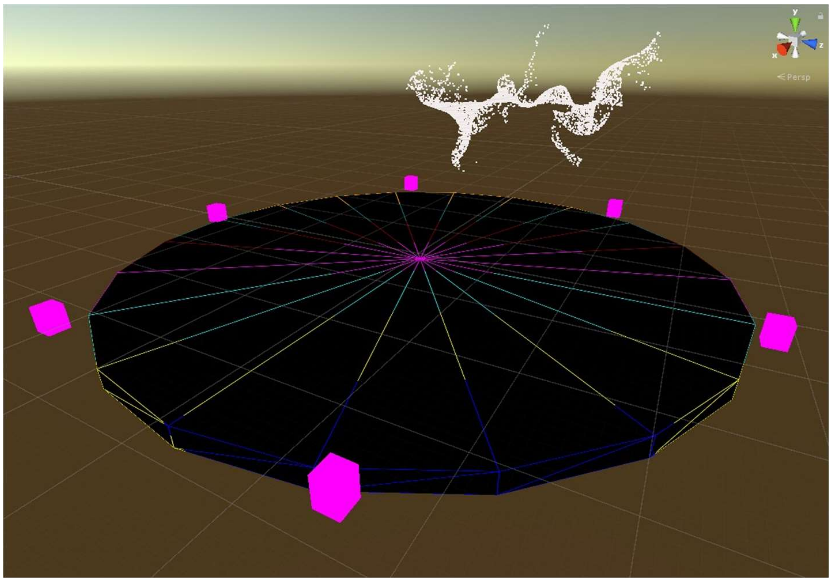

Figure 5. The “connective tissue” visualisation inside the Unity editor. The black circle is the floor space of the Data Arena, and each pink cube marks the centre of a projection screen.

Conclusion

In this paper, we started by describing a future of mixed reality. An imagined future indeed – but as is the nature of science fiction, time transforms the author’s work into something less resembling fiction as it passes. A recent surge of interest in mixed reality – along with advancements in technologies that seek to make its presentation possible – is set to deliver us a virtually augmented world sooner than one might think. Compared to the alternative approaches

in audio-visual software, game engines offer a flexible approach to high fidelity development, whose metaphorical consistency with our own world make them apt for mixed reality works. Through discussing the development of ‘IMMERSE’, we hope to have demonstrated this suitability, and propose that game engines – as tools long used to prepare virtual worlds – are a means of content creation particularly suited for the future of mixed reality upon us. We implore audio-visual artists interested in exploring this future to consider the game engine’s use as a compelling medium for artistic expression.

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Karolina Jawad and Anna Xambó Sedó

How to Talk of Music Technology: An Interview Analysis Study of Live Interfaces for Music Performance among Expert Women

Paper

Video of presentation can be found here

How to Talk of Music Technology: An Interview Analysis Study of Live Interfaces for Music Performance among Expert Women

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Abstract. With the aim of making women's work in music technology more visible, the organization Women Nordic Music Technology (WoNoMute) has originated conversations with expert women in the form of seminar talks and interviews that are archived digitally. This paper analyses the first seven interviews and seminar talks with women from this online archive using thematic analysis. We explore whether and how their gender determines the shape of their tools focusing on *live interfaces*. From our findings, we propose to investigate alternative usage of the technical term 'music technology' to accommodate more diversity and fluidity into the field. This can inform the revision of the language used in education and human-computer interaction in order to be more inclusive but also to become more conscious about the creation of professional and academic environments that involve music technology.

Keywords: Human-Computer Interaction, live interfaces, physical virtual communication, interviews, digital archive, performance, women in music technology, gender

Introduction

As studied in previous research, women are underrepresented in the field of music technology (Gadir, 2017; Xambó, 2018), which aligns with the broader issue of the underrepresentation of women in science, technology, engineering and math (STEM) fields (Nimmesgern, 2016; Sax, 2012). It has been highlighted the importance of creating all-female communities of learning, mentoring, and the promotion of women role models in music technology related fields as strategies to raise awareness and broaden participation (Armitage, 2018; Dobson, 2018; Xambó, 2018). Beyond that, it is important to investigate and discuss the mechanisms and reasons behind the absence of women in these fields.

With the aim of making women's work in music technology more visible, the organization WoNoMute has originated a series of seminar talks and interviews with expert women in the form of live events and a digital archive (http://wonomute.no). The events are organised around the cross-campus master program Music, Communication and Technology (MCT), a co-joint master between the Norwegian University of Science and Technology (NTNU) and University of Oslo (UiO). The master's activities are located in an audiovisual networked space, the Portal, which connects the two universities and has streaming facilities to also communicate with online viewers. WoNoMute is reimagining the *cyberspace*—a term that refers to interconnected digital and physical spaces that promote other ways of participation and communal life (Schwartz, 1999)—by creating a forum where women in music technology are visible and discuss about their work and experiences with technology.

This article addresses the following research question: *How can interview analysis with women who work with live interfaces in music inform about whether and how their gender determines the shape of their tools?*

We analysed the first seven interviews published in this online archive using thematic analysis. One of the themes identified is the use of the term 'music technology' in their work, and how gender shapes their tools, particularly live interfaces. Thus, the research question includes gender as a key factor. However, it is noteworthy that we adopt a stance as descriptive and ethnographic as possible in regards of how we approach the term of 'music technology'. The term is defined by the interviewees' voices and then linked to the literature, which we found especially connected to the notion of musical interface as a gendered metaphor (Essl, 2003). From this perspective, this research contributes to rethink the term of 'music technology', which can inform future steps in education and human-computer interaction. Although music technology received such a prominent place in the discussion through the thematic analysis, it is out of the scope of this research to provide a more profound historical overview on the terminology.

Interface as a Gendered Metaphor

> *"Knowing how interface structures our relation to knowledge and behaviour is essential... today we perceive our environment through interfaces."*
> Monteiro (2017, p.7)

In order to stress live interfaces as possibly gendered artefacts, we highlight the communicative aspects of interfaces in general. Monteiro (2017) is describing interfaces as a cultural moment in which a specific relationship between human user and technological artifact is being established. Accordingly, its connotations of advanced technology and contemporary forms would suggest both immediacy and engagement. Further on, interfaces would represent and convey ideological meanings, therefore capable to produce false consciousness. Monteiro expresses the notion of interface as a series of actions between human and machine in time and space: *"embed choices, conduct, languages, and ultimately values, worldviews and aesthetics into technical infrastructures."* (Monteiro, 2017, p.8)

Georg Essl (2003) regarded new music interface technology as concerned with using technology for musical performance and highlighted how women authored gender as an issue in their performances. Essl describes *new music interface design* as an academic field involving electrical components for musical performance, and *music technology* as any mechanical device that generates musical sound. Georg Essl's definition of new musical interface technology involves usually electrical components and sensors, a workable definition in this paper because it echoes with our findings.

Along other practises, often summarised as 'music technology', the design of live interfaces has multi-disciplinary dimensions. Historically it has been a little diverse subject, especially women were rarely involved in interactive audio design with traditional engineering tools such as microprocessors (Stewart et al., 2018). However, there is enough evidence that indicates strongly that gender imbalance exists in creating interfaces for music and performance. This can be traced to external factors in the practise environment rather than in the technological subject itself, which has been addressed and showcased by several authors and practitioners with different methodologies (Cheryan et al., 2009; Stewart et al., 2018; Sørensen, 1992). The analysis of the interviews presented in this paper is done from the perspective of using the term 'music technology' as an interface that can communicate gender issues.

The Interview Process

In this section, we present the context of this research in terms of the MCT master and Portal, the organization Women Nordic Music Technology (WoNoMute) and the interview analysis process.

The MCT Master and Portal

The NTNU-funded project Student Active Learning in a Two Campuses Organization (SALTO) aims to promote cross-campus teaching and learning as an open laboratory (Støckert et al., 2017). A new international master has been launched within this educational scheme: Music, Communication, and Technology (MCT), which is a master's program in collaboration between the NTNU in Trondheim, Norway, and UiO in Oslo, Norway. The master's program centres around the field of music technology from a research perspective in a cross-campus setting. The students have interdisciplinary backgrounds and work in teams. The master has a dedicated physical space in both sites, the Portal, with a real-time low-latency audiovisual network and audiovisual technologies.

Women Nordic Music Technology (WoNoMute)

The organization Women Nordic Music Technology (WoNoMute) has been founded by the second author in August 2018 at NTNU, in partnership with UiO, and in alignment with the NTNU Department of Music's and Faculty of Humanities's will to improve the underrepresentation of women in techno-scientific fields. WoNoMute is an horizontal network that promotes the work of those identifying as women in the interdisciplinary field of music technology. The organization aims to promote and connect the work of women in music technology at local, national and international levels. During the first year of the organization, a small group has constituted the core WoNoMute team, with the help of a number of contributors and advisors, in particular with invaluable contributions from the MCT students and teachers.[1]

WoNoMute is an open space defined and discussed by its members and produces content that is publicly available. During the first year, the organization has coordinated seminar series,[2] which is a monthly series of lectures by women who work around music technology and who present their work in the MCT portal, connecting the two campuses of NTNU in Trondheim and UiO in Oslo and streaming to the world. The seminar series have been curated by the second author in conversation with the organization's advisors. In connection with the seminar series, WoNoMute has also conducted interviews,[3] mostly led by the first author. The interviews have been conducted typically in the form of both a short biosketch interview video and a written interview, which are published on the organization's website.

Interview Analysis

Over the period of 8 months, WoNoMute invited 7 women figures active in music technology related fields, to give a lecture in the Portal, in chronological order: Miranda Moen, Alexandra Murray-Leslie, Tone Åse, Tami Gadir, Angela Brennecke, Pamela Z and Sofia Dahl. The live streams of the presentations and interviews are stored in the online archive. The interviews are semi-structured and have been conducted by the first author (except for the interview with Pamela Z where Tone Åse was also an interviewer). The interviews had questions related to the interviewees' background, mentors and role models, their work, and advice to women interested in pursuing their careers in music technology. The questions were inspired by the previous experience of the second author while conducting and supervising similar interviews when she was at the organization Women in Music Tech at Georgia Tech.[4]

Both seminars and interviews were generally programmed in the Portal. While the seminars were open to public and accessed from two cities and online viewers, the interviews were captured in a more intimate ambience. Driven by the interview questions, we applied thematic analysis (Braun and Clarke, 2006) to identify emerging patterns on the WoNoMute's published online material i.e. the short biosketch interview videos, the written transcribed interviews and the video recordings of the presentations. We used the software NVivo (Bazeley and Jackson, 2013) to unfold themes from this material, annotating the text snippets from each interviewee. For the written interviews, the nomenclature used includes the name of the interviewee and the reference number (e.g., *"Miranda Moen, Reference 1"*), and for the videos we give the timecode and distinguish between the presentations (e.g., *"Miranda Moen, Presentation Video, 01:12"*) and the biosketch videos (e.g., *"Miranda Moen, Video Interview, 01:12"*). In the next section, we discuss in detail the main findings from this interview analysis process, focusing on how the term 'music technology' is used.

Live Interfaces, Sonic Arts, Circuit Bending. . . Is Everything 'Music Technology'?

In this section, the musical interface is being inspected, based on the statements of four of our seven interviewees, when discussing about their backgrounds and experiences. In particular, we explore how the term 'music technology' is used when talking about instruments and applications. We sketch a casual frame in order to understand in what way the term is genderised according to Essl's (2003) definition. We seek for reasons and come up with interpretations, which indicate that there does not seem to be a universal statement.

According to Tami Gadir's presentation "The Music Technological Body", every form of musical expression, including all forms of bodily, classical and computer engineered instruments, are declared as 'music technology':

> *"Music is always technological. And music is always affected by gender. Or sometimes it helps to use negative formulations, we can say that there is no music that is non-technological and no music that is unaffected by gender."* (Tami Gadir, Presentation Video, 04:42)

[1] http://wonomute.no/committee
[2] http://wonomute.no/seminars
[3] http://wonomute.no/interviews
[4] http://womeninmusictech.gatech.edu

Asking what kind of images would rise when thinking about the “music technological body”, Tami Gadir presented different photos and video excerpts with content that is distantly or closely related to the term. In her interview, she would affirm this position, based on her own practice:

> *“The piano was my first music technology. [. . .] I tried to teach myself that people have different skills with various types of technologies.”* (Tami Gadir, References 1, 2)

Independent from that, another interviewee stated in her interview that everything is ‘music technology’ as well:

> *“Because it is all technology. Even somebody who just plays a concert grand piano, that is probably one of the most technologically sophisticated instruments that you can imagine. It is all about the well balanced and designed mechanical thing.”* (Pamela Z, Reference 1)

In Tami Gadir’s presentation, she also states that technology would not be an item that exists apart from music in a pure, pre-technological form (Tami Gadir, Presentation Video, 17:46). A number of the answers to the question “What brought you to the field of music technology?” are able to reveal preconceptions that come along with the term ‘music technology’ and show that the intended detachment notion between music and technology is quite strong. The term evoked partly discontinuous reactions when two of the interviewees expressed their disconnection with ‘music technology’ when referring to their own work, even though their musical practice included several technical layers and items. An indication for this can be inspected in the following vignettes:

> *“I don’t like to describe what I do as music technology, for me, that’s more the system behind the instruments.”* (Alexandra Murray-Leslie, Reference 1)

To the same question, Pamela Z answered:

> *“There is an introduction of technology into the arsenal of tools that I’m using but I don’t think of it as the technology part being the prominent thing. The aesthetic and the adventurousness of the work is more important to me than whether or not there is technology involved.”* (Pamela Z, Reference 1)

Although Pamela Z stated earlier that the exposure to technology provoked a change in her artistic voice, when we asked her “What advice would you give to women interested in pursuing a career in music technology?”, the term music technology seems to become a detached and irrelevant artefact:

> *“Again, to me ‘career in music technology’ sounds a little bit like you’re talking about circuit benders or that they are writing and designing software. I see myself as an artist and so I can only speak from that, what my advice is about trying to be an artist. Then it doesn’t matter rather you are using technology, and what kind of technology you’re using.”* (Pamela Z, Reference 2)

There seems to be an echo between these statements and the approaches to music technology regarding the nature of the technological or engineering part in music. Sofia Dahl, who holds an engineering degree, distances herself from the role of the engineer even though she applies engineering methods in her research:

> *“Now I can say I am an engineer, but I am not a typical engineer. I wouldn’t feel comfortable working as an engineer in a company.”* (Sofia Dahl, Reference 1)

Alexandra Murray-Leslie mentions international conferences on music technologies such as the New Interfaces for Musical Expression (NIME),[5] which namely fuse music and technological practice. Although her music instrument *Computer Enhanced Footwear* is mentioned in relation to it, ‘music technology’ is not present in the language:

> *“[T]o 3d print the prototype instruments, creating a live costuming on stage that could be actuated through gesture led my group [. . .] to new interfaces for musical expression. When I started my PhD I suddenly realised this whole incredible world of people working with their digital DMI [digital musical interface/instrument] controller or connecting virtual with classical instruments.”* (Alexandra Murray-Leslie, Reference 2)

[5] https://www.nime.org

Discussion

Here, we analyse how the term 'music technology' should be reimagined to include the missing plurality and fluidity revealed by our interviewees, which is beyond the acknowledged interdisciplinarity of the field.

According to the above conversations, the interviewees with the strongest artistic practice see their work not necessarily regarded as part of music technology. The attributed expressions like "circuit bending" and "designing software" (Pamela Z, Reference 2), and "the system behind the instruments" (Alexandra Murray-Leslie, Reference 1) suggest that the *ambient belonging* (Cheryan et al., 2009) that accompanies the term 'music technology' rather associates with stereotypical environments and characteristics of engineered products.

The scholars that we discuss next propose ideas that are part of our agenda on how to reveal the stereotypical biases of technology in the academic field of music technology. For example, Sørensen introduces in "Towards a Feminised Technology?" (1992) the notion of *translation problems* from values to technology, for example values such as usefulness and efficiency. Human practice would be difficult to relate with these concepts. Similarly, Sørensen explains how humans and their activities would be gradually removed from the vocabulary in technological texts. Accordingly, Sørensen wonders whether there is the possibility that the aforementioned values could be seen as a translation into physical characteristics of an artefact (Sørensen, 1992, p.13). This could explain why many of the interviewees, even those with engineering background, do not seem to see themselves aligned with 'music technology' or engineering.

Cheryan et al. (2009) examined how material objects in environments can communicate characteristics of the inhabitant group. Environments could therefore act like gatekeepers by preventing people who do not feel they fit into those environments, from joining them. The goal of their paper was *"to demonstrate that stereotypes of a domain should be taken into account when attempting to diversify that domain"* (Cheryan et al., 2009, p.2). In Stewart et al. (2018), the researchers demonstrated that women and girls want to learn how to work with electronics and code to build audio interfaces of their own design (Stewart et al., 2018). However, they are underrepresented within established audio and music technology communities and academia (Stewart et al., 2018, p.8). Accordingly, by introducing e-textiles to audio technology women would persistently outnumber men in the gender representation.

Even though the design of interfaces in all its artistic and sonic nuances might be seen as inherent to the academic field of music technology, 'audio and music technology' terminology still resonates with STEM disciplines, as we learned from interviewing diverse practitioners, in a way that cannot resemble those practices. By designing their artistic items and technically tailoring them to their own needs, the idea of the implicated attributes that come along with the imagery of engineering and programming is transformed and often reversed. Consequently, music technological practices can be 're-written' and, in doing so, can alter our perception of technology itself. This has the potential for a 'female narrative' (Armitage, 2018) in engineering or what Sørensen calls 'feminised technology' (Sørensen, 1992).

All the above examples show that the context in which STEM methods are applied is crucial for the presence or absence of women. In the moment a gendered tool can act excluding, termed as *ambient belonging* in Cheryan et al. (2009), a gendered tool can become inclusive as well, as seen with the e-textiles. And this is also reflected in the statements of the expert women in our interviews, who do not like to describe what they do as 'music technology'.

Implications and Future Work

This article sought to answer the research question *How can interview analysis with women who work with live interfaces in music inform about whether and how their gender determines the shape of their tools?*

From our analysis we observed that the established terminology in the academic environment of music technology fails to address the diversity of practices, especially with gendered tools that can act as gatekeepers for women. We thus propose to investigate alternative terminology that is suitable to accommodate a diversity of uses and practices. This is an important finding that was possible through the analysis of the publicly available material from the WoNoMute online digital archive. In turn, it has been crucial the creation of both a public and a private cyberspace for forum debate and dissemination of a variety of women's work in music technology in a connected and modular venue, the Portal, in order to promote these initial conversations. When attempting to diversify the music technology domain in academia, education and industry, it should be taken into account that not only language but the design of the environment are relevant factors to be considered (Cheryan et al., 2009).

We acknowledge that this research is limited to a specific group of practitioners, academics and professionals who identify as women, and that more research needs to be done in order to provide a more generalisable representation. For example, it is an open question whether similar reflections could be found among practitioners, academics and professionals who identify as men or non-binary. Here we focused instead on an in-depth qualitative analysis of a small but diverse group in terms of backgrounds and experiences to initiate this debate. As future work, we foresee the need of establishing working groups, where multiple stakeholders take part into discussions with the aim at revising the terminology in order to be more inclusive and move the field forward.

Conclusion

In this article, we noticed that interfaces for music performance are not only artefacts, but ideas. The term 'music technology' alone is not capable to encompass the existing diversity of practices as it carries ideas of activities related to the term that are stereotypically gendered. The discussion showed, with a number of examples from women who work with topics related to music technology, that the context in which STEM methods are applied is crucial for the presence or absence of women. Finally, we discussed the implications and future work of this research, namely rethinking the terminology in academia, education and industry, related to the term 'music technology', so that it becomes more inclusive and environment-aware. We acknowledge that gender is one of the dimensions in diversity, and we hope that this research can encourage to reflect new perspectives on the techno-scientific terminology.

Additional Information

The following list includes the links to the written interviews, biosketch video interviews and presentation videos discussed in this paper, which are part of the WoNoMute online digital archive:

Miranda Moen
– **Written interview**: http://wonomute.no/interviews/miranda-moen
– **Biosketch interview video**: https://youtu.be/xdMMQiUG7mU
– **Presentation video**: https://youtu.be/QJBmbiEb8dc

Alexandra Murray-Leslie
– **Written interview**: http://wonomute.no/interviews/alexandra-murray-leslie
– **Biosketch interview video**: https://youtu.be/VPpy01W0fAw

Tone Åse
– **Written interview**: http://wonomute.no/interviews/tone-aase
– **Biosketch interview video**: https://youtu.be/SRX81BHTWbc
– **Presentation video**: https://youtu.be/y8PI-E0o6Wc

Tami Gadir
– **Written interview**: http://wonomute.no/interviews/tami-gadir
– **Biosketch interview video**: https://youtu.be/DoO9mq3khGQ
– **Presentation video**: https://youtu.be/okEgjIjpJkY

Angela Brennecke
– **Written interview**: http://wonomute.no/interviews/angela-brennecke
– **Biosketch interview video**: https://youtu.be/OV8A98-HRIk
– **Presentation video**: https://youtu.be/mpFSF2PHcFo

Pamela Z
– **Written interview**: http://wonomute.no/interviews/pamela-z
– **Biosketch interview video**: https://youtu.be/DQMF2ABrJvs
– **Presentation video**: https://youtu.be/v3ql6QMNi4U

Sofia Dahl
– **Written interview**: http://wonomute.no/interviews/sofia-dahl
– **Biosketch interview video**: https://youtu.be/SV42EZF3Gx0

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Filipe Cunha Monteiro Lopes and Paulo Maria Rodrigues

Plantorumori - first report

Paper

Video of presentation can be found here

Plantorumori – first report

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Abstract. *Plantorumori,* our research and art work, is about complicity with plants. Our aim is to use music as a conciliator to create subjective communication channels with nature, particularly with plants. The communication channels that we want to "open" with plants are, however, a utopia. We are dealing with entities that do not manifest themselves in ways we humans can easily perceive. We are atempting to understand how relationships could be outside the realm of logic, numerical truths or intersubjectivity. To accomplish this desire, we want to explore the opening of "communication channels" with plants using a wide range of technologies and interfaces to nurture a subjective relationship with nature and to integrate that "contribution" in musical performances.

Keywords: Music Performance, Plants, Interfaces.

Introduction

The general purpose of the *Plantorumori* project is the creation of sonic worlds emerging from symbiotic relationships between humans, plants and digital interfaces. This is a path that we have been pursuing in our artistic work over the last few years, both individually and together[1 2 3 4]. We share a common philosophical and technological ground that, we believe, could give rise to innovative artistic questions and artistic experiences that could be beneficial not only for the arts community but also for public awareness. Looking at plants and nature and creating art that also raises awareness is especially important at this moment in the history of our planet, considering the immense challenges of global warming, pollution, public health or sustainability. The main outcome of the *Plantorumori* will be a performance (and its ideas) supported by a hybrid symbiotic installation. We believe, nonetheless, that this research can really open up a series of possibilities that will transcend the timeframe of that particular event, both for the scientific project and to our own artistic activity. To support and structure the performance, we are developing a "sonic language", (i.e. technological tools, sonic vocabulary, theoretical ideas) made of sonic gestures that could work as the "idiom" of a communication process to bond plants, interfaces and humans.

We have referred to some of our previous work has "tuning people, birds and flowers" and some of our projects, artistic and educational, have addressed the concept of "soundscape" proposed by Murray Schaffer (1980)[5]. We also have worked in the development of tools to allow artists, educators, the "common person" and the "not so common person"

[1] Lopes, F. and Paulo Rodrigues. 2014. "POLISphone: Creating and performing with a flexible soundmap." *ICMC*. pp. 1719-1724.
[2] Lopes, Filipe, Paulo Rodrigues and Helena Rodrigues. *Pensamentos POLISphónicos*. (Lisboa: Fundação Calouste Gulbenkian), 145-171
[3] Filipe Lopes, "LabJázzica: Afinação das sementes", *Revista Portuguesa de Educação Musical*, nº 142 -143 (2017): 78-89.
[4] Lopes, F. and Rui Ferreira. 2017. "Cant(a)eiro: A program for music creation in schools". *X International Research in Music Education Conference*. pp 66-67
[5] Schafer, R. Murray. *The tuning of the world: Toward a theory of soundscape design*. Philadelphia, PA, USA: University of Pennsylvania Press, 1980.

(the disabled) to express themselves musically[6]. In the *Plantorumori* project these work experiences are regarded as our background which we wish to expand, thus, *Plantorumori´s* challenge will be to deal with "soundscapes" that are still unknown to human ears.

Plants were regarded, for centuries, as primitive beings, until fairly recently we started to understand that they have sophisticated communication strategies that allow them to communicate between themselves and with the environments they live in. For instance, it is now widely known that the roots of plants and trees behave as the plant´s "brain" because they talk, trade and wage war on one another to survive[7]. In fact, plant bioacoustics is becoming a field of study and we are gradually realising that the paradigm of plants as passive beings with which humans cannot communicate is gradually changing. Whether it is sound as we know it (audible vibrations) that will allow us in the future to communicate with plants is unknown and it is possible that the main problem in bonding humans and plants might be that we seem to live in "different time scales". We humans seem to live at a much higher pace when compared to plants (i.e. we move faster, we talk faster), an idiosyncrasy probably related to the advancement and survival of our species (plants and humans). The purpose of our project is not clarify this, our proposal is intrinsically artistic, i.e., we want to "create the possibility" of communication between humans and plants by developing sounds that can relate to each other in a manner that is simultaneously musical, as we humans understand it, and functional or "organic" as we tend to perceive the natural sounds that surround us. Our vision of the *Plantorumori* project is of a system composed of sensors and actuators that will allow us to make music with people and plants in a wide range of situations: in cultural spaces, in the open air, in schools and community facilities. Lastly, our project has a clear allusion to Russolo´s Intonarumori, a group of experimental musical instruments, created by the Italian futurist Luigi Russolo to perform the new music that he had envisaged and proposed in his *The Art of Noises Manifesto* (1913)[8]. Like Russolo, we think that current technology offers great opportunities for musical creation and we regard the sounds around us as an important part of the sound vocabulary we consider when creating musically. Unlike Russolo, we are not mesmerized by technology itself or by sounds of its intrinsic working, but by the tools it provides to allow us to relate to other beings in a deeper, meaningful way.

The Art of Human to Plant interaction

Plants have been present in the artistic world since immemorial times and the particular case of music is not an exception. The distinction between popular, traditional or classical certainly does not segregate plants: in music, plants seem to be as ubiquitous as in real life taking into account the varieties of approaches ranging from pure inspiration, imitation or using sources of data retrieved from nature. Translating plants features (their morphology, pattern of growth, etc.) into organizing principles for music creation with "real musical instruments" was, in the past, the closest possible musical relationship between plants and humans. In the late 20th century, increasingly sophisticated and available technology allowed to diversify both the features that could be "observed" and the sounds to be used in the "translation" of these observations. Living plants became interfaces for human-computer interaction in artistic projects at the time when human-computer interaction was heavily based on very specific technical devices, a very different scenario from the current IoT[9] world we live in today, where all daily objects are candidates to mediate the interaction between humans, computers and the world. The work of bio-art pioneer Richard Lowenberg in the seventies is undoubtedly at the root of these developments as well as the controversial book *The Secret Life of Plants*[10] by Peter

[6] Gehlhaar, R., Paulo Maria Rodrigues, Luis Miguel Girão, and Rui Penha. "Instruments for everyone: Designing new means of musical expression for disabled creators." In *Technologies of inclusive well-being*, pp. 167-196. Springer, Berlin, Heidelberg, 2014.
[7] https://www.youtube.com/watch?v=yWOqeyPIVRo, accessed on the 5th of November
[8] Russolo, L. "The art of noises: Futurist manifesto." (1913). *Audio culture: Readings in modern music* (2004): 10-14
[9] Internet of Things
[10] Tompkins, Peter, and Christopher Bird. *The secret life of plants*. No. QK50. T65I 1973. New York: Harper & Row, 1973.

Tomnkins and Christopher Bird. Some years later the work of Christa Sommerer and Laurent Mignonneau, also influenced by the same book, was determinant in the emergence of the idea of human-plant interfaces as a tool for artistic creation by media artists, rapidly inspiring not only the visual culture but also the sonic culture, frequently both. With their 1992 installation *Interactive Plant Growing* they contributed decisively to the consolidation of the emerging field of art, science and technology. Sommerer and Mignonneau's stated that their "artistic objective was to create a link between humans and plants and thereby challenge our relationship to the vegetal world through an artistic and engaging experience"[11]. In the essay *The Art of Human to Plant Interaction*, Sommerer, Mignonneau and Weil cover the main aspects of this "short time history", analyzing the technological present-day approaches as well. These authors acknowledge that scientific evidence is increasingly supporting the view that plants "do feel their environment and that they are more intelligent than has been was commonly believed"[12]. This point of view is shared by scientist Stefano Mancuso, the founder of the study of plant neurobiology and widely known for his recent books *Brilliant Green: The Surprising History and Science of Plant Intelligence*[13] and *The Revolutionary Genius of Plants: A New Understanding of Plant Intelligence and Behavior*.[14] In both books Mancuso narrates and discusses how plants have evolved in our world when compared to humans, how plants communicate and many specificities about plants which, until recently, were considered an absurd.

We will now give a very brief description of the technologies to perform bio-sensing, as well as examples of art works. Both aspects are described in detail by Sommerer, Mignonneau and Weil.

Resistance

Using plants as resistors has been one of the most common approaches and it is often used in musical interfaces. This approach measures how conductive a plant, which is then used to produce a specific task. Some examples of artworks using this approach include *Plantas Parlantes* (2010) by Ricardo O'Nascimento, Gilberto Esparza, Javier Busturia, and Jigni Wang, *Baumark- tmusik* (2011) by MSHR, *Kraft Test Drummie and Robert Plant* (2012) by Cristian Martínez,, *Mosszillator* (2012) by Stefanie Wuschitz or *Genesis of Biosynthia II* (2011) by Benjamin Kolaitis.

Contact microphones

The use of contact microphones (piezoelectronic sensors) is another simple approach in using plants as biosensors. Contact microphones can detect vibrations in solid objects, useful to trigger events and amplify sound. Some examples of artworks include *Mogees* (2012) by Bruno Zamborlin, *From the Hills* and *Frishasin Pijamas* (2013) by Cristian Martínez and *Tree Listening* (2012) by Alex Metcalf.

Capacitive sensing

Capacitive sensing is a technology based on capacitive coupling that can detect and measure anything that is conductive. It is particularly useful to measure touch, proximity and humidity. Many spatial sound installations use this technique, like *Akousmaflore* (2007) by Scenocosme, *Baumarktmusik* (2011) by MSHR, and *The Plant Orchestra* (2013) by Alexandra Duvekot.

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[11] Bristow, Tom, Pansy Duncan, Andrew Howe, Michael Marder, Laurent Mignonneau, Guinevere Narraway, Alan Read et al. *The green thread: dialogues with the vegetal world*. Lexington Books, 2015.

[12] Ibid.

[13] Mancuso, Stefano, and Alessandra Viola. *Brilliant green: the surprising history and science of plant intelligence*. Island Press, 2015.

[14] Mancuso, Stefano. *The revolutionary genius of plants: a new understanding of plant intelligence and behavior*. Simon and Schuster, 2018.

Electric field measurement and biopotential measurement with electrodes

This technique is similar to capacitive sensing, however, measuring the electric field with electrodes provides more accurate sensor values in terms of electrical changes. Some of the art works done using this technique include *Plantron* (1993) by Yuji Dogane, *Anthroposcope* (1993) by Sommerer and Mignonneau, *Yucca Invest Trading Plant* (1999) by Ola Pehrson, *Pieces for Plants* (2002) by Miya Masaoka, *I/O Plant* (2007) by Satoshi Kuribayashi, Yusuke Sakamoto, and Hiroya Tanaka, *Jurema Action Plant* (2011) by Ivan Henriques, *Pulsu(m) Plantae* (2012–13) by Leslie Garcia and *Plant Cyborgs* (2020) by Daniel Slattnes.

Recent developments

Nowadays there are many sensors available to be used in sensing plants activity, plants environment and even ways to generate electricity using plants[15]. It is not uncommon to see Arduino projects to automate house gardening, for example. Some of these new technologies, usually mixed and updated based on the ones previously mentioned, have been transformed in commercial products. Some of these products include the Midi Sprout[16], Makey-Makey[17] or the The Plant Spiker Box[18]. These products are almost "plug and play" in the sense that one does not need to build any circuit or have any kind of knowledge on electronics, and quickly can interact with plants and play music. The availability of many of these technologies has prompted the possibility to imagine larger projects that are not exclusively about a certain technology or technique. Just like music, at least in a way, one is now able to devise projects with plants, technologies and art that aim more generic holistic approaches. Some projects like the one carried out by the artist Mileece [19] or Flora Robotica[20], relate different analogue technologies, digital technologies and poetics to develop a certain approach to life, art and nature. These projects are quite inspiring for our *Plantorumori* project.

Plantorumori

Plantorumori is a part of Xperimus, a larger project about musical experimentation. *Plantorumori´s* main goal is to develop a hybrid system based on plants, electronics and acoustical sound sources to create and perform music. In addition to this main goal, there are some complementary objectives we wish to achieve, namely: to develop systems to create automatic soundscapes based on plants data; to develop means to listen to plants (e.g. underground microphones) and, finally, to develop means to share over the internet any garden's "soundscape and music". This paper is mostly concerned with reporting our main goal.
The analysis we performed on artistic works relating music, plants and electronic music, showed us that there are two main approaches to plants being employed: 1) plants as *listeners* and 2) plants as *producers*. While there are many examples of music for plants (e.g. to promote health), we are not looking at these studies and approaches. We do care about plants as *listeners* but not plants as sound recipients *per se*. We are more interested in plants as *producers* and, within this view, we believe that there are two main approaches being applied: 1) plants as interfaces and 2) the sonification of plant's bio-signals. In either approach, roughly speaking, we feel that plants are used in a "passive" way. In other words, they are not contributing actively to what is being played/created, but, instead, they are triggers or just a source signal to be transformed into sound (i.e. sonification). Our aim is to design a system which retrieves idiosyncratic signals of plants (e.g. galvanic measurement, electrical changes) and signals from its environment (e.g. sounds, light measurement, moisture measurement) in order to devise a holistic approach to natural environments to create and perform music. In addition to this, we want devise custom acoustic

[15] https://www.plant-e.com/en/, accessed on 5th of november
[16] https://www.midisprout.com, accessed on 5th of november
[17] https://makeymakey.com, accessed on 5th of november
[18] https://backyardbrains.com/products/plantspikerbox, accessed on 5th of november
[19] https://www.mileece.is, accessed on 2th of november
[20] https://www.florarobotica.eu, accessed on 2th of november

sound sources (e.g. bowls, bells, bambus) to complement the electronic sonic system, thus, producing more exciting soundscapes/music. Finally, and quite important, we want to be as precise as possible regarding the measurement of plant biological data (e.g. read voltages, observe leaf growth) but we will be mainly concerned with the poetics of the project. In this sense, some of the instruments we will use to make the measurements will be of low cost (i.e. diy) which means, of course, that they could not be used to report and conduct detailed investigations for biological purposes. We will, nonetheless, make use of commercial products such as the Midi Sprout or The SpikerBox to enhance and complement our diy sensors. In practical terms, it is more important to refer to the biological variations that plants may produce in response to certain stimuli than the accurate recording and analysis of those values.

Technical Approach

In order to achieve our main goal, we decided to: 1) install a cluster of sensors on plants in a fixed place (we called it The Seed) and 2) present some performances along the years 2020 and 2021. Both The Seed and the performances will be the main practical outcomes of the *Plantorumori.* The Seed has two main purposes: the first one is to "feed" the performances with real-time data (e.g. to do modulation, to generate visuals); the second one is to collect and record data (e.g. sensor`s data, photographs, thermal images) during a long period of time. This data will be analysed and will be used during the performances but, specifically, it will be used to study the variations that occurred at The Seed during that period. The performances will be music concerts which will feature plants, sensors, interfaces and acoustic objects. We will now describe The Seed and the performances in detail.

The Seed

The Seed will be a closed space, preferably outdoors (e.g. greenhouse), filled with plants and sensors. We will use sensors to retrieve the following data: indoor air quality, moisture on the soil, temperature and moisture on the atmosphere, thermal images, regular pictures, luminosity, and sound pressure (dB SPL). These sensors will be connected to a Raspberry Pi 3 and connected to the internet. A specific server will be coded to host and display the data from the sensors, and to make it possible to "play" such data in real time (e.g. trigger an audio file and change its pitch according to numerical data). Now, we are on the final stages of developing the software and the hardware.

The performances

Our performances will be focused on achieving deep complicity between humans, interfaces and plants. We want to explore the opening of "communication channels" to allow us to establish relationships with plants and to integrate that "contribution" during the musical performance. We want to think about that complicity exploring the strategies explained earlier, both the theoretical ones and the practical ones, and using all the devices developed and built within this project.

Plantorumori´s first concert

We already had the opportunity to carry out a performance, integrated in a residence of the XPERIMUS project, held in Mateus, Portugal. This concert, which has not yet had any contribution from The Seed, served mainly to get in touch with the sensors (e.g. Midi Sprout, Plant SpikerBox, Makey-Makey, contact microphones, various sensors connected to an Arduino), to experience our physical relationship with plants (e.g. touch, gesture) and the relationship of our setup in interaction with conventional instruments played by other musicians, e.g. piano, guitars (see Figure 1 and Figure 2). The experience was quite positive but two main aspects were noted: 1) the dependency on conventional music strategies (e.g. the need for a plan on musical form, the use of drones) to improvise music and 2) some difficulty on how to physically approach the plants (i.e. play music with the plants as opposed to do conventional touch gestures).

Figure 1. Plantorumori setup

Figure 2. Plantorumori performance

Conclusions

Connecting real plants to computers has become easier and more common than ever before. There is, however, an immense "territory" to be explored both from the artistic and the scientific/technological points of view, preferably from angles that can effectively articulate both, bearing in mind the ultimate goal of creating not only knowledge but also awareness, fruition, consciousness and well-being. These immaterial ideas are very close to aspects of our own artistic work which has music as a starting point but explores many transdisciplinary approaches. It allows us to explore the idea that art, music in particular, might have biological roots related to the need to communicate and be in tune with others. *Plantorumori* is in its initial phase although the authors have already established the main conceptual ideas. The first performance and our initial tests are promising, and we look forward to include The Seed and our diy sensors to take this project to the next stage. The first performance experience has given us some food for thought, thus, there is future work to be accomplished that will be focus on technological aspects but also on performative levels. Only then will we be close to creating the performative and spiritual situation we desire to achieve.

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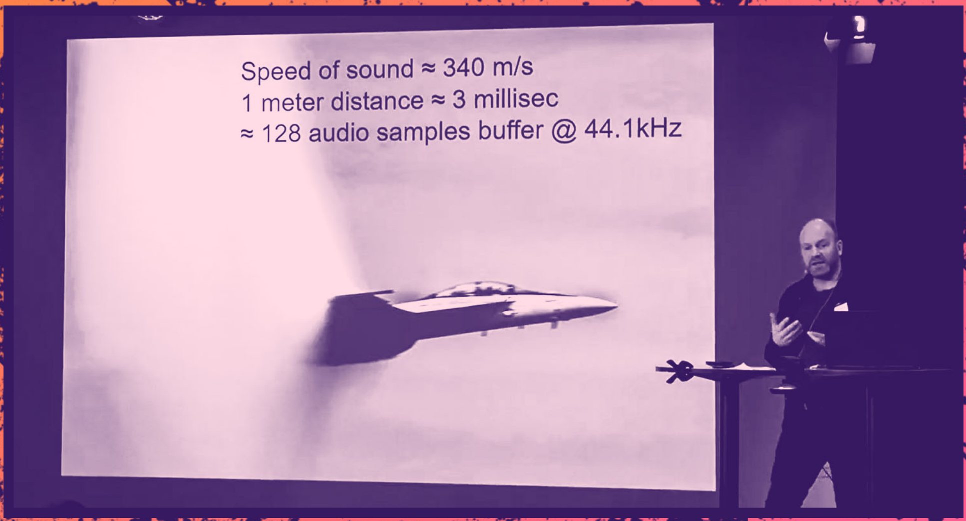
Øyvind Brandtsegg

An interface to an interface to an interface

Paper

Video of presentation can be found here



An interface to an interface to an interface

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Abstract The paper relates some experiences from a recent production of orchestrating Conlon Nancarrow Piano Studies for performance on Pipe Organ. Reflections that surfaced during this work concerned the layered nature of interfaces, automation (and thus allusions to the different conceptions of artificial intelligence), and leaky abstractons. This also touches on the authenticity and perception of compositions and performances involving machinic elements, as an extension of human aesthetic capabilities.

Keywords. Nancarrow, Automation, HID, Ontology of interfaces

Introduction

While working on a performance of Conlon Nancarrow's Piano Studies in a reorchestration for pipe organ, I stumbled on some reflections on interfaces in general and what role automation plays in our interfaces. This paper can be seen as a case study in this respect. In a very general sense, an interface is an abstraction, and ideally one that would abstract away details of the layers we want to interface with. It represents a reduction of available parameters, in order to provide a manageable means of accessing the larger world that is "on the other side" of the interface boundary. In an ideal processing system, each component is a separate entity that can be replaced without changing the overall function of the system. From the field of software development, we can borrow the Law of Leaky Abstractions, coined by Joel Spolsky (2002) stating that "All non-trivial abstractions, to some degree, are leaky." further he states that "Abstractions fail. Sometimes a little, sometimes a lot. There's leakage. Things go wrong." Looking at the relatively simple MIDI protocol for example, it acts as an interface for transmitting information about musical notes to be played on an instrument. It works reasonably well for this purpose, and this article is not a criticism of MIDI per se (although I do reiterate some points from Moore 1988). My concern is more that the abstraction is leaky, that we need to know *something more* than what the interface provides to make effective use of it. I use MIDI as an example here, but I could naturally also have used the musical score as an example of abstract representation of a piece of music. In a usual use case scenario, we also have audible feedback from the sound-producing device or instrument, and this feedback provides the user (composer, musician, ...) with the necessary detail to enable the interface to be used for nuanced aesthetic expression. This feedback is to some extent taken for granted, but is essential in the larger context of producing meaningful statements with the interface. When working with larger and larger systems of interfaces, we come to rely on these abstractions. In automated systems involving artificial intelligence (or not-so-intelligent artifices), forgetting that these abstractions are in fact leaky, can lead to some misconceptions that could put us on the wrong foot towards automation in general and artificial intelligence in particular. Criticisms of AI, from Dreyfus (1972) to more recent critique (Bickhard and Terveen, 1995) and (Pontin, 2018), often problematize representation and the abstract treatment of information. We can see a parallell to the leaky abstractions also here.

In addition to these leaky abstractions, the process of working with the Nancarrow compositions opened questions of automation in the creation, reproduction and re-interpretation of musical compositions. In this context of mechanistic reproduction and re-interpretation, also the well known issues of authenticity (Benjamin, 1936) resurface. Nancarrow's pieces, originally punched on piano roll paper and now played back from a computer, already constitute a mechanical reproduction. It is also noteworthy that the mechanical apparatuses involved all have potential errors due to physical components, something that can have a significant effect considering the mind-bending density of note events in this music. The performance of the pieces is a singular aural event, by means of the computer controlled acoustic instruments and their interaction with the space of the performance. Benjamins' considerations of the actor before the camera as pertaining to the authenticity of performance becomes slightly twisted in our context, since the music was written for machine performance with no human performer. Still we have the human action, in each layer of the process involved in punching, scanning, digitizing, orchestrating and actuating the physical playback and so on. I come back to this in the section Source materials and also under Authenticity. Regarding the modular approach to interfaces, there is also a question of the scope of the interface. Do we include in the interface the whole chain from thought to realization, or view it merely as a chain of relatively simple black boxes? One could say the main issue concerns the transmission of an idea or an emotion from human to human, via a number of intermediary steps. Each interface (step) providing an abstraction, and each interface also being leaky. I will not plunge deep into the adjoining issues in phenomenology, psychology, information theory, and so on, even if these questions open a whole panorama of further exploration in these fields. Keeping it on a more practical level, I still feel some surface reflections are worthwhile.

Nancarrow for Pipe Organ

The arrangement of the Nancarrow studies for Pipe Organ was first initiated in connection with the centennial for Nancarrow's birth. A number of concerts, events and symposiums were arranged in several locations (Willey, 2012), so also in Trondheim. NTNU had recently built a pipe organ at *Olavshallen* concert hall in Trondheim, and it was a rather opportunistic move to see if Nancarrow's music could be played on this instrument. As it was an experiment in using the MIDI capabilities of the new organ, there was a number of unknowns, and the adaption of the compositions to this instrument were done in an ad hoc manner (more on this below). A combination of Organ, Disklavier and electronic transients were used. We were also invited to do the same repertoire at the Ultima festival in Oslo (Grønland Kirke) in 2013. An excerpt from this concert is available online (Brandtsegg, 2013). Now, 6 years later, we were invited to do the same repertoire in Stavanger Konserthus. Their organ was built in 2012, but the completion of the MIDI control system was done in 2018, thus the instrument was now ready for the Nancarrow project. I also contacted the Nidaros Cathedral, asking if it would be possible to also do a similar concert there. Their *Steinmeyer organ* was refurbished in 2014, with MIDI integration, although the MIDI input had not been used to control the organ up until this point. When given the chance to do this repertoire again now, I decided I wanted to redo the arrangements from scratch, and avoid some of the ad hoc solutions from the first two concerts. Technically, this regarded both the channelization (orchestrating the single track MIDI file on to the available organ manuals while also keeping some parts on the piano) and the adaption of the material from the keyboard range of the piano (88 keys from A0 to C8) to the keyboard range of the organ (usually 61 keys from C2 to C7, but this varies from instrument to instrument). The organ I used in 2013 (Olavshallen) had slightly smaller keyboard range and also less manuals, with 4 3/4 octaves and 3 manuals, compared with 5 octaves and 4 manuals in Nidarosdomen. The number of manuals was important, as that determined how many different voices were simultaneously available for orchestration. The Nancarrow material was extended with improvisations for the 2019 concerts, where the improvisations were inspired from the musical style of the Piano Studies. Some relatively simple improvisation algorithms were used, mostly salvaged from the software ImproSculpt4 that I wrote in 2007 (Brandtsegg, 2007). A voice-to-midi converter was also written, inspired by the work of Peter Ablinger, e.g. in the piece Deus Cantando (Ablinger, 2009). The improvisations were done on a combination of Voice, Marimba Lumina, software modules, Organ and Disklavier. In Trondheim, I also collaborated with the organist in the Nidaros Cathedral, Petra Bjørkhaug. Her improvisations in dialogue with the software opened new perspectives on the meaning of using automated composition and improvisation techniques in this context. Her performance on the Organ was very different from my implementations. Where my orchestration of Nancarrow was quite "angular" in character, with terrace dynamics and timbral changes, her shaping of the organ sound was fluid, transparent and breathing. I had no deep knowledge og pipe organs before this project, and I learned a lot from listening to Bjørkhaug, and also from organist in Stavanger Konserthus, Nils Henrik Aasheim. I discussed the small nuances of different flute stops with Aasheim, as I tried to come to terms with how to differentiate between them. His advice was "you just have to sit with it, listen and try, until you know the difference". Another unknown for me in this project was the traditional musical environment of the cathedral, where there is no culture for automated music making. Against this background it can be seen as a drastic step to introduce the algorithmic and machinic music of this project.

Source materials

The midi files I have used as my basis was obtained from Robert Willey, from his work with performance an reorchestration of these pieces (Willey, 2014). He had obtained these files partly from Clarence Barlow's sequencing on a Marantz Pianocorder, partly from Trimpin's scanning of the original piano rolls, and partly from his own adaptions of these sources. Even with the formidable skill and effort of Trimpin, Barlow, Willey and others, there is some scope of deviation from the original work throughout the process these sources have been subject to. Each step in the process of scanning and representation in intermediate format could introduce artifacts. Any human intervention in correcting these artifacts in each step could also have introducted deviations from the original work. Rather than attempting an as authentic as possible interpretation, I found it a valuable asset to include these layered interpretations as the basis of the current realization. In the case where the midi files contained any orchestration or splitting of different voices, I did try these out in the first two concerts in 2013, but I decided to start over from the original single track piano representation for the 2018 production. Taking a step away from the proficient analysis of Willey, Gann (1995) and others, I wanted to explore what was there in the compound representation, close to the format that Nancarrow used for in his workflow.

Nancarrow's coding of his music on piano rolls also can be understood as an interface: The compositional interface to realizing his musical ideas. This interface also comes with its own set of affordances, but also its own set of potential for error. In the punching of the piano rolls it was inevitable that punching errors would sometimes occur. Nancarrow corrected such errors by mending the paper roll with tape, and commenced punching. Subsequent scanning of such a corrected roll might be influenced by this method of error correction. Optical scanning might disregard the tape altogether, or a piece of tape might have gone missing due to material or physical reasons. In the orchestration for Organ, I attempted to extract the various motifs and lines of the compositions. In the the original piano roll representation, whese would be superimposed onto each other in a polyphonic manner. Separation of the different musical lines was done with the intention of articulating them more clearly. The instrumentation for organ can also be said to make the overall sound of the compositions more "tonal" than the original piano versions. Of course, the tonality does not change, as the notes are the same. However, the piano is more overtone-rich and more percussive compared to the organ. This difference comes out rather clearly in these compositions.

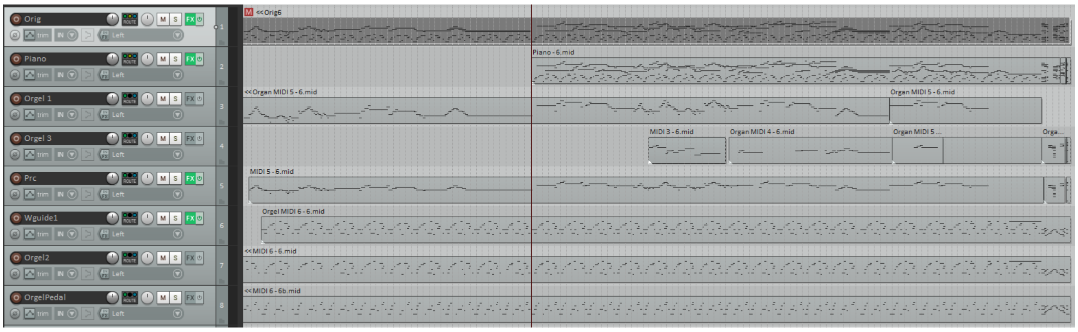

Figure 1: Excerpt from Study 6, splitting the original single track for purposes of instrumentation

The acoustic instrument behind the midi layer

When working with MIDI, we silently accept that the encoding of note information is independent from the instrument timbre used to realize the sounding result. In terms of clean abstractions (interfaces), this is a good thing. Then again, if we use a collection of drum set sounds to play back a piano score we would inadvertently change the meaning of the notes to such a degree that it could hardly be considered an equivalent musical statement. This is of course well known, as we are accustomed to changing synthesizer patches, importing new and better sample sets and so on. We could still say it is an issue containing *something more* when it comes to controlling acoustic instruments via MIDI. The instrumentality and affordances of an acoustic piano is so rich, and so laden with references, that an *abstraction* could be seen more as an *amputation*. Even if the action towards the interface, the piano keyboard, here too only consist of selecting which key to press and how hard to press it, any trained pianist would immediately know that there is so much more to it than that. How is the weight of the hand applied? How are the nuances of timbre shaped? How is this transmitted via MIDI? The example is even more rich with the Pipe Organ, since it also has the possibility to change the registration via the organ stops. Comparing this to the program changes on an electronic synthesizer would disregard the physical entity of the instrument.

Figure 2: The Steinmeyer Organ in the Nidaros Cathedral

Physical differences

The registration of the organ stops, selecting which sets of pipes to be used in the production of the acoustic timbre contributes significantly to the character of the resulting music. Not only in the most obvious sense that it controls the timbre, but also in determining what can be played (or heard) at all. The production of sound from an organ pipe is a physical process that takes some time, from the moment the airflow is allowed to enter a pipe until it starts to resonate a tone. This means that very short notes might be played but can not be heard. Similarly, there is an issue with velocity encoding of the parts played on the Disklavier. With velocities below a certain threshold (which varies for each instrument and each key, but usually lies around midi velocity 25 to 35) giving the result that the piano key in fact moves, but does not make a sound (the hammer never reach the string). The colloquial use of the term midi *velocity* (in the meaning of musical dynamics) is not entirely transparent. Velocity, meaning the speed of movement (of the piano key) corresponds to musical dynamics, but this is also a translation. There is a difference between the physical force used to press a piano key and the velocity with which it moves. Still we reckon this to be an integral part of the interface when playing a midi keyboard, most of the time without reflecting too much on the difference. The difference between the physical actions of each key on an acoustic piano can be subtle, and in many cases does not produce any significant obstacle in the reproduction of music. This is put to the test with the dense rhythmic passages resulting from some of Nancarrow's algorithmic compositional ideas, where these nuances can significantly alter the reproduction. A minor difference in temporal response could even change the order of notes in the fastest passages of Nancarrow's music. Such deviations in temporal response of a Disklavier can happen at low velocities. The individual differences between organ pipes are even greater, each pipe having an individual physical reaction time due to the physics of sound production. Larger pipes taking longer to excite, and the different types of pipes (flute, reed, trumpet) each responds differently. Adding to this, the physical position of the various pipes affects the response time. With the speed of sound being around 340 m/s, it takes around 3 milliseconds for a sound wave to traverse one meter. The distance between organ pipes can be many meters, and as we know, even small amounts of latency matters in precise articulation. A human performer on the instrument will naturally take all of this into account, when they know the instrument. Making such adjustments on a programmed sequence is a meticulous process of attending to each individual note. For a programmed sequence, we have this expectation (or at least I did) that each note is transmitted equally well through the interface, easily forgetting that the interface is leaky. We need to know the nuances of what is on the other side of the interface boundary to make expressive use of it.

One thing that I did not reflect on before this production was the nuances of articulation with different organs. Each instrument having its own set of registration possibilities, to such a degree that the music must be adapted again for each new organ and each venue. Coming from arranging with MIDI, and seeing the 4 manuals of the organ, I initially thought I could use them freely in the orchestration. Becoming more famiiliar with the different organs, I realized the each manual usual has a very distinct role in the whole orchestra of this instrument. If I needed more individual voices, I could not expect to just move something from manual 1 to manual 4, and redo the registration to produce the same sound there. Manual 1 and 4 would have their own separate set of stops, with their own very specific musical possibilities. Usually manual 4 would have the very powerful reeds and trumpets. On the Stavanger organ these are pointed directly towards the audience, with no swell doors, so the sound is very clear and direct. This means it has its specific use in orchestration, but this manual can not be used interchangeably with another one. Similar specialization of the manuals can be found on most organs. I found it interesting to experience this shift from treating different midi channels as interchangeable, to find them associated with their own characteristics and specialities. A trained organ player might find these insights mundane, but to me it was a discovery.

During playback of very fast passages, I would sometimes have hanging notes on the Stavanger organ. This might be related to mechanical issues with the closing of the air flow to the pipes. Perhaps it was related to very short notes, so that the valve would not have time to open completely before starting to close again. The behaviour was not repeateable out of context. It did not occur when slowing down the playback, and also did not occur if the density of notes was reduced. The organ did, however, close the valve properly when the same note was played again later on the same pipe. As long as these hanging notes did not occur too often, I thought it a nice effect showing how the mechanical components of the acoustic instrument could just barely keep up with Nancarrow's music.

The interface for MIDI automation of the organ stops is not standardized, and it seems the design of the midi standard does not naturally allow a perfect solution. Each organ builder has attempted to solve it in their own manner, each solution with its own pros and cons. In this project I encountered three different implementations of MIDI control of the organ stops. The organ in Olavshallen uses midi sysex messages, with the complete status of all stops contained in each sysex message. This means that changing one single stop requires re-sending the status of all stops. This implementation does not seem optimal, for the practical reason that one need to revisit all other settings just to change a single stop. Also, the use of sysex messages does not display easily in most sequencers's piano roll editors. In Stavanger, the organ stops are controlled by midi note messages on a separate channel. This means that it is relatively easy to "play" the stops, and the display of registration is easily visible in its own piano roll. It also means that the stops will only stay activated as long as the midi note is on. A standard action of a midi sequencer is to send note off messages for all active notes when stopping playback. This would then also deactivate all stops, making it somewhat cumbersome to inspect and fine tune the registration. In Nidarosdomen, yet another implementation can be found. Here, midi program change messages is used to control the stops. Program changes on an electronic synthesizer is used to activate a specific combination of synthesizer parameters, like a preset. The program change protocol does not have a message to de-activate a program, as the program would implicitly be deactivated when the next program is activated. When used to control organ stops, however, the organ builder utilized the program change messages so that each stop could be activated and deactivated independently. To enable this, the activation and deactivation messages each have their separate program numbers. For example, activating the first stop with program change 0, deactivating it with program change 1. Activating the second stop with program change 2 and deactivating it with program change 3. As can be seen, this leads to a rather unintuitive program change numbering which is workable but impractical. All of these three methods of midi implementation for organ stops does the job of automation truthfully, and all of them are quite impractical to work with during the design phase (while composing, and/or trying out various timbre nuances for instrumentation). It seems perhaps a midi NRPN (Non Registered Parameter Number) could have been a better choice, as it would allow selection of a specific stop combined with a separate value turning it on or off as desired. The different implementations of stop automation each have their affordances, and very much change the way it is possible and practical to work with registration during a composition. In Nidarosdomen one will need to play the whole composition from start to end to achieve correct registration automation, while in Stavanger one can not stop playback in the middle of the piece and then listen to individual voices. When the organ is played by a human, of course these issues do not surface, so it is a problem arising only with automated playback from a DAW.

Preparations and transients

Nancarrow was known for the rhythmic articulation of his pieces. To obtain the necessary articulation of transients, he would modify the piano hammers for a more percussive sound. Different methods of modifications were used, sometimes soaking the felt of the hammer in shellac, sometimes adding a leather strip with a nail to the hammer, and sometimes removing the felt altogether and covering the core wood with a metal strip (Willey, 2014). Regarding the reorchestration of Nancarrow's music for pipe organ one could reasonably argue that this is a step in the opposite direction for articulation. Much of the effort spent in the reorchestration has been focused on articulation within the possibilities offered by the instrument, and the timing and durations of individual notes adjusted to maximise clarity. Some realizations of Nancarrow's music have also used electronic transients to enhance the articulation, and this was also utilized here. It can be a challenge to make the electronic transients fuse with the sound of the acoustic instrument. For my realization, I have implemented some custom transient synthesizers for this purpose, based on a selection of methods (physical models of strings and percussion, physically informed resonator instruments etc.). Moreover, the playback of the synthesized tones are done via transducers rather than conventional speakers. The transducers would be mounted on parts of the acoustic instruments (the body of the piano, the cabinet of the organ pipes) to create a physical connection. This works both for spatial merging of the timbres, and also for enabling a physical resonance in the material of the acoustic instrument. Once a fused sound was achieved, I could also experiment with dynamics and balance to allow the transient instrument to constitute its own individual voice in some phrases where desired.

Authenticity

In any performance with automated playback of compositions it is reasonable to ask to what degree this is "live". Even though Auslander says "...the playback of a recorded performance should be regarded as a performance in itself" (Auslander, 2009), the perception of "liveness" (Emmerson, 2007) could be different in each case, depending on the manner in which it is performed. With automated playback on acoustic instruments, we have a physical manifestation of the instrument in the room (and in case of the Disklavier, also the moving keys). In the case of working on the limits of the physical capabilities of the instrument (like in Stavanger), there is also "liveness" in the risk for mechanical failure during performance. The performance could in some respects be perceived as more "live" when using acoustic instruments than if it was played exclusively over speakers (as with regular fixed media performances). Even though the machine reproduce the programmed sequence faithfully from performance to performance, some phenomenological aspects of performance also come into play. For me the dress rehearsal in Stavanger felt much more successful than the actual concert. So here it must (perhaps) come down to music appreciation rather than the actual content and phrasing of the performance? Some parts were improvised but 6 out of 8 pieces were playback of Nancarrow pieces in arrangements that will not change from performance to performance. This experience also sheds some light on the evaluation musicians do of their own performances. We could think it strange that some of us might judge a performance poorly, while others, in the same band, on the same stage would judge it as successful. Difference of appreciation from audience members also included, but it is just all the more surprising when two people sharing the same stage might judge their common result so differently. After having this similar experience with a machine, it is all the more easy to accept having it with another human being. After all, I could not blame the machine for being affected by the mood in the room could I?

Layered interfaces, interfaces to interfaces

An interface is often thought to be neutral and transparent. Its purpose is to provide a means of translation from one domain to another, without changing the nature of the message in a substantial manner. In practice, we see that what we think of as an interface usually consist of several layers of interfaes, and that each layer provides its own ontological characteristics. Like the lineage of Nancarrow's compositions represented as piano rolls and scores, via scans of these rolls represented as midi files, the transmission of (DAW) midi piano rolls, via the midi interface, to the keyboard of the acoustic instrument (the organ and the Disklavier), via the mechanics of the instrument, to the physical sound producing elements (valves opening for the air flow to organ pipes, hammers producing vibrations in piano strings), and further on to the acoustics of the room where the pieces are performed. Concerning this view, with layered interfaces, it can be hard to distinguish where our interface starts and where it ends. Does it start with the midi keyboard, or with the movement of our fingertips, or even earlier with the conception of a mental image of what we wish to do? What is the end point? Is it the numeric representation in the computer, the activation of the acoustic instrument, the resulting changes of air pressure, or the perception of music in the listener's ear and mind? The signal goes on, and the interfaces are layered.

Nancarrow's compositions often use algorithmic elements, like exotic tempo ratios, serial techniques of pitch and rhythm, canons, graphical shapes and more. Reinterpreting these compositions and also combining them with improvisations opened for me some perspectives on machine aesthetics, in the sense that an algorithm or program essentially provides a form of automation. It does something for us, prescribed by us, but something we would not be able to do manually (or by "hand"). We find similar uses of automation also in other algorithmic works, from Lejaren Hiller via George Lewis to David Cope, to name but a few. Compositions made by members of the Google Magenta team (Donahue et al., 2018) represent a more sophisticated technology based on A.I. and machine learning, but in essence they are still automations of layered interfaces. Similar statements could be made about modern tools for production incorporating A.I, like Wekinator (Fiebrink et al., 2009), the mastering tools of Landr, and the whole field of Intelligent Music Production (Reiss and Brandtsegg, 2018). Usually, the design of these systems are informed by practice. In early A.I, systems that would emulate the decision making of a human expert would be called "expert systems". Even though one would not use the term "expert systems" to describe these more modern tools, each such automation relies on an understanding of the job it should do in expanding human capabilities. This is not to say we should limit ourselves to recreating human performance and aesthetics, but that there is considerable scope for developing interesting works and of learning more about ourselves in the direct interaction with the algorithms. But as with any musical instrument, we need to practice, spend time with it and stay long enough to internalize its working and become intuitive performers:

> Interaction with these systems in musical performance produce a kind of virtual sociality that both draws from and challenges traditional notions of human interactivity and sociality, making common cause with a more general production of a hybrid, cyborg sociality that has forever altered both everyday sonic life and notions of subjectivity in high tecnological cultures. (Lewis 2018)

In the context of this production, we used some interactive software modules as an improvisation partner. The modules were quite simple in their musical abilities, using serial techniques for pitch and rhythm but implemented in such a way that the expressive changes (e.g. in tempo, phrasing and articulation) of the human performer would cause corresponding changes in the software output. The aim of this was not to reproduce any given style of improvisation or composition (even though in successful moments it might have similarities to the aesthetic of the Nancarrow studies). Rather than producing replication, it was intended as an incentive to the human performer to challenge habitual responses and thus attain a slightly new way of improvising. By any modern definition, these algorithms are not A.I, but the algorithms in the software have the ability to adapt to a context. Why would it even be relevant to align these tools for music performance with any definition of A.I? In my view it allows a perspective on how we use automated decision making procedures in all contexts where A.I. has been introduced. With the tremendeous opportunities this has to offer, it also shows the role of the human intervention at key points in the automated process, to keep an eye on the values we want to preserve in the dialogue with machines.

Example recordings The two performances in Stavanger konserhus and Nidaros Cathedral was recorded, with excerpts available at http://folk.ntnu.no/oyvinbra/Nancarrow/2019_recording/.

Acknowledgements Thanks to Jan Tro for initiating the Nancarrow Centennial concert in Trondheim, and for following the work as a mentor and guide through all the phases of the production. Nils Henrik Aasheim invited me to do Nancarrow in Stavanger, and with this he also initiated the process for developing both concert productions in 2019. Nils Henrik has also been generous and sharing his knowledge of the organ, enticing me to spend more time getting to know the instrument. Petra Bjørkhaug has been very important in making the Nancarrow concert happen in the Nidaros Cathedral. Her eager exploration of the musical possibilities of my improvisation software with the Steinmeyer organ has been instrumental also in getting the project accepted for performance in the Cathedral. Petra's playing is a lesson in organ registration in itself, her fluid and flowing mass of sound inspired me to take extra care with the dynamics of registration. Robert Willey generously provided the midi file of Nancarrow studies, and Willey was one of the driving forces behind the worldwide Nancarrow Centennial. Thomas Henriksen provided immense support in the multitrack audio recording of the concerts in Trondheim, while Thomas Hellem and his crew created wonderful video footage. The production was supported by Norsk Jazzforum, Norsk Kulturråd, and the Norwegian University of Science and Technology. Thanks also to Harald Rise at NTNU for eager exploration of technology in the Olavshallen organ, and special thanks to my colleagues at NTNU Music Technology.

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Information about the organ in Stavanger konserthus:
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Information about the Steinmeyer organ in Nidaros Cathedral:
https://www.orgelbau.ch/en/organ-details/801590.html

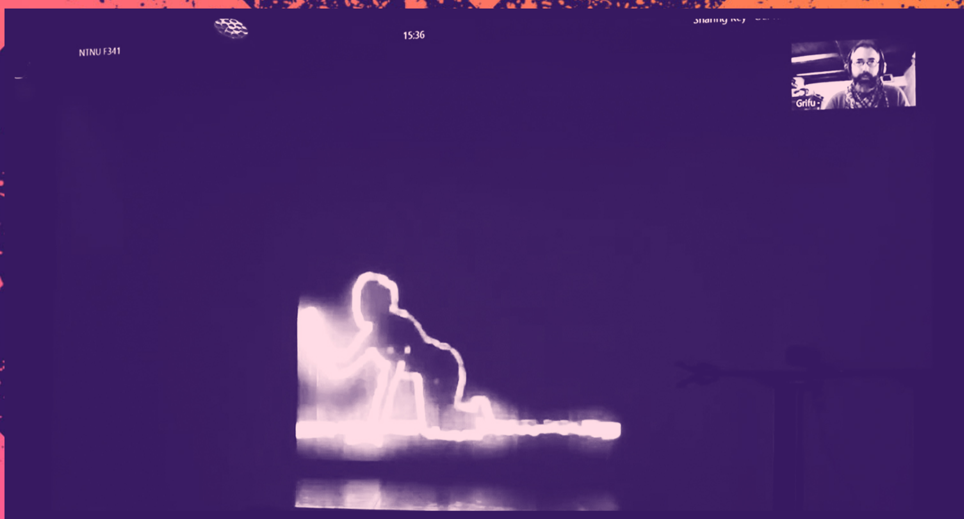
Information about the organ at NTNU, Olavshallen, Trondheim: https://www.ntnu.no/documents/10256/1267136576/Det+symfoniske+orgelet+IMU+NTNU+web.pdf/88dc4830-9f8c-4820-98d3-bbb678c46728

Luis Leite and Amândio Anastácio

Solitária - Gestural Interface for Puppetry Performance

Paper

Video of presentation can be found here



Solitária - Gestural Interface for Puppetry Performance

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Abstract. *Solitária* is a performance that employs puppetry techniques to manipulate digital media. The performance was designed upon the duality between the material and the non material existence, between the physicality and the virtuality. A gestural vocabulary was developed to manipulate both sound and visuals in realtime. We have built an interactive system to support both tangible and intangible manipulation, as well to respond and react to a specific body movement. This work explores puppetry techniques with sound and digital animation, engaging the audience with a dialog between the body language and the digital media. We found that sound and visuals can be manipulated in a similar manner through puppetry methods, as if we pull the strings from the same instrument. This framework was implemented with success responding to the requirements of the performance. *Solitária* was presented at the Festival Internacional de Marionetas do Porto (FIMP19) in October 2019. In this paper we describe the project's concept, the methodology and the outcomes.

Keywords. Digital Puppetry, Performance Animation, Digital manipulation, Digital Performing Arts

Figure 1: *Solitária* is a performance that employs puppetry techniques in the manipulation of digital media.

Introduction

This paper describes a digital framework designed to support a multi-dimensional and multi-modal puppetry performance. This framework was developed to expand the creative possibilities during the design process of a puppetry performance, by supporting and facilitating the interaction design and the integration of digital media. The interaction design was based on tangible and non-tangible manipulation challenging the puppeteer to explore methods with his body to change the media in an expressive manner. The relation between the puppeteer (controller), the media object (puppet) and the audience was a key aspect for the interaction design. In particular, methods to provide a directness feeling to the puppeteer while manipulating a non-physical media object, and to enhance the perception of the audience to this mediative choreography.

Technology and Performing Arts

Performing arts can take advantage of the interactive dimension provided by low-tech technology as a creative resource to augment the performing experience. The most common aspects addressed by performance-based digital interactions is the notion of time and space. There are multiple strategies for designing interactive performances based on body motion, and create digital contents responsive to the performer's behavior. The performer's space-time motion dimension, which refers to features such as gesture speed; gait; body posture; global/local position, provides a rich and expressive resource for manipulating digital contents. Generally, there are two common motion-based techniques employed in interaction design based on the performer's body: 1) motion tracking; 2) motion triggering. The first refers to the capability of tracking the movement of performers in space. The later refers to the digital response of a recognised motion (impulse) in a certain amount of time and space.

Among the performing arts, dance is probably the most susceptible in exploring technology as a creative tool. Embracing the fusion between art and technology, motivating the exploration of new grounds, and new artistic processes. Many choreographers have been stimulating the integration between the human performer, and the machine, between the physical, and the virtual space. This integration can be used to extend the body of the performer, as seen in the work of Troika Ranch[1], a company that combines dance, theatre, and digital media (Masura and University of Maryland, College Park. Theatre, 2007). Towards the integration of the body of the actor, and the machine on stage, their work reflects the human condition, and its extension through different media. Many dance projects use motion tracking intensively, to trigger and model the digital media (visual and sound), such as the *NUVE* (2010) produced by João Moura and Né Barros (Moura, 2012); *Seventh Sense* (2011) produced by Anarchy Dance Theatre; *Apparition* (2012) produced by Klaus Obermaier and Ars Electronica Futurelab; *Hakanaï* (2013) produced by Adrien M & Claire B; or *Presence* (2013) by the art collective Universal Everything - Nowness, to name a few.

On the other hand, gestural control of computer music has been a popular research topic, and subject of extensive work. Interactivity has been employed in both music composition, as well as in music performance to control musical interfaces and digital instruments. The close relationship between music, and mathematics was determinant to push the exploration of computational systems, within music composition. On the other hand, the gestural control of musical interfaces, is related to the traditional methods of playing instruments, in a similar manner as the manipulation techniques from puppetry. In this way, we can establish a connection between manipulating a control interface in puppetry, as in music. The notion of gesture-to-sound mapping, can be described as a way to unconstraint the performer's body, through space and time dimensions. The pioneer in exploring non-contact gestures for music production was Lev Termen who developed the Theramin in the 1920's, an electronic music instrument controlled just by gestures. This can be consider the forerunner of the gestural control of digital musical instruments. While Wanderley (Wan, 2001) introduced the term *digital instrument*, to distinguish the gestural interface from the sound generation unit, Chadabe (Chadabe, 2002) introduced the term *Interactive instrument*, to establish the dynamic relation between the performer, and the instrument. Where the interface can be consider the instrument itself, controlled by the performer's body underling the interactivity.

Animation and puppetry are two related areas that received important contributions from the artistic and the scientific communities in the fields of interaction design and live interfaces. Lee Harrison III developed the first motion capture system based on a 'data suit' for animation in the early 1960's. An armature made with Tinker Toys, and potentiometers placed at the actor's joints. A human performer wearing this armature was able to animate a character in real-time (Harison et al., 1992). On the other hand, Jim Henson, the Muppet creator, introduced digital puppetry techniques into the media production framework (Jones, 2013) exploring novel puppetry and animation methods, in particular hand devices such as the Waldo - an embodied custom interface that allowed puppeteers to achieve expressive puppet control remotely. Since then, many devices were developed for live manipulation. A wide range of comercial interfaces are available and can be adapted and employed into sound and animation control. Today, independent artists explore the potential of accessible interfaces for their creations, such as the Microsoft Kinect. This wide offer, challenge the interaction designers to choose the appropriate device. The design space of input devices is based on properties that determine its use and performance. The designer must choose the most natural, efficient and appropriate device to a given task, taking into account what is sensed by the device for an appropriated mapping between the input and the output. Some researchers propose guidelines for choosing the most appropriate device for a specific task (Sturman and Zeltzer, 1993). Other's present interaction models to manipulate digital media

[1]Troika Ranch web site: http://troikaranch.org

in realtime (Leite and Orvalho, 2017). There are approaches that focus on the design space of animation interfaces (Walther-Franks and Malaka, 2014) supporting interoperable multimodal environments (Leite, 2018) (Leite et al., 2018). An interaction approach can provide the appropriate interface design to handle the multitude of media that characterises the performing arts, supporting its expressive manipulation in real-time.

Creative tools

In the early conceptualisation phase, it is determinante for the artist to have access to a wide range of interactive media tools that facilitate the experimentation. The creative process should not be blocked or constrained by limitations of the software which prevent the artist to put in practice his ideas and explore his imagination freely. During the creation of *Solitária* we survey tools and frameworks that responded best to our needs. At the end we developed a methodology that combined several pieces together based on interoperability, allowing the tools to communicate and share their properties. We developed an orchestra of digital tools. Instead of wasting our time solving technical issues we had the opportunity to focus mainly on the creative aspects of this production. This digital orchestra was composed by a constellation of applications including: Openframeworks, Pure Data, MaxMSP, eMotion, Kinectar, Ableton, QuartzComposer, Qlab, Osculator and Synapse. Most of these applications became active during a specific moment in the play and handled by a central application - Qlab. This digital “maestro” handles the digital flow through a cue list instructing the system to open and close a specific application. The media and control flow method is based on digital media flows such as MIDI, OSC, Soundflower, and Syphon, which allows the applications to communicate and exchange data. We also explored other applications that were easy to integrate in this ecosystem such as FAAST, Kinect Spaces, or TUIOkinect. In this section the conceptual creation of *Solitária* is described as well as its technical implementation based on each challenge.

Concept

Solitária is a project that explores the human condition (loneliness) in the solitary confinement, envisioning the behavior of a prisoner through his mind and body (Figure 1). How do we move, see, listen and think in a place where there is no light? The absence of light removes any spatial–temporal references and draw us to an unbalanced world. We are trapped in a tiny place where we can barely move. Our body is the only connection to the physical world. However, our sensorial capabilities begin to misbehave and soon we became disorientated. The solitary confinement is commonly described as a prison within the prison. The prisoner is held in a cell of approximately 7 square meters for 23 hours a day with just one hour of exercise in a cage outside the solitary (Broadhead and Kerr, 2002). What are the effects of this isolation on humans? Some reports point that prisoners held in isolation become disoriented and have hallucinations, leading them to despair. Solitary can contribute to make prisoners more dangerous to themselves, engaging in self-mutilation.

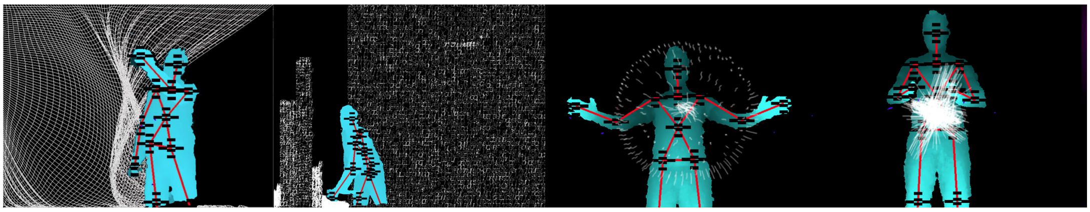


Figure 2: Envision interaction for *Solitária* performance.

This play attempts to recreate the experience of an inmate in isolation in a solitary confinement. Our focus was on the relations between the human gestures and the space that surrounds the prisoner, the progressive behaviour during isolation, from an initial disorientation behaviour to the hallucination phase. Our main reference to represent this experience was the human behaviour - body and mind. We wanted to explore a puppetry approach using the body of the puppeteer as the main controller, manipulating both sound and visuals. These elements are generated in real-time by the performer according to the character’s emotions and state of mind. The project was created in two distinct artistic residences at *Convento da Saudade* in Montemor-o-Novo. One, dedicated to the sound manipulation (sound puppetry), and the other, to the image generation (visual puppetry). In both explorations the main focus was the body manipulation of media through a space-time approach, transposing puppetry techniques to a full digital media manipulation. With this approach we wanted to answer to questions such as:

- Can we manipulate sound in a similar way as we operate a puppet?
- Does intangible manipulation provide engagement with objects creating the sense of directness?
- Does the audience understand the body manipulation in a similar way as in puppetry?

This puppetry project depends exclusively on the performer's body, and on the digital media (sound, visuals). This interplay is determinant for the success of the performance (Figure 2).

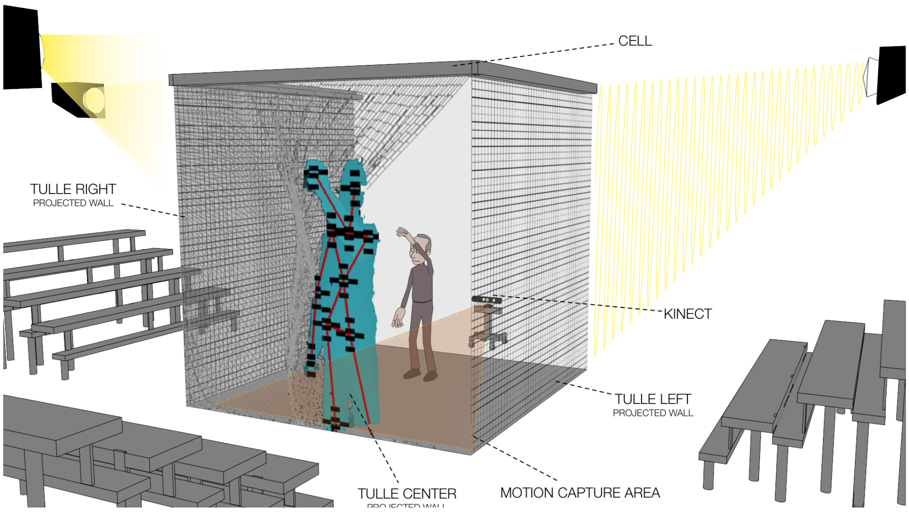


Figure 3: Simulation of the theatrical setup of *Solitária*. 3D character model by Rodri Torres.

Interaction Design

The Scenic Space

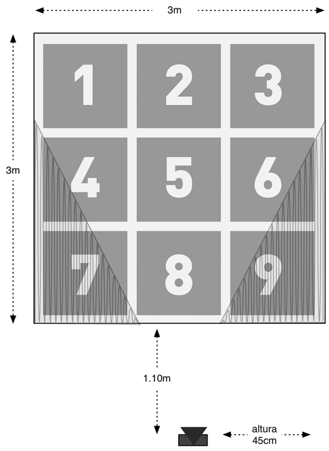
The scenic space recreates a cell with 9 square meters. The initial concept the cell was delimited with three translucent walls (Figure 3). These semi-opaque tulles could be used as screens for the visual environment. The audience could see through the tulles and see the actor and the other walls. However, to avoid too much noise and light interference we chose to have just one screen, and the other walls were represented with some tubular lights on the ground. The initial concept was composed by three front projectors, one Kinect, a web camera and several piezoelectric. The stage floor was divided into 9 squares of 1 meter that were used to segment the play (Figure 4 - Left). Each square was mapped to different functions and allowed the performer to trigger specific actions. Dividing the space for segmenting and for triggering actions based on the performer's body location is not new: Oskar Schlemmer also divided the stage (space) with visible coordinates mapping it to the performer's interaction (Masura, 2007).

The Body

We explored multiple dimensions for body interaction using: the body location in the stage; the body's posture; the body's gestures. The system was based on two distinct positioning coordinates (Figure 4 - Right):

- Position related to the camera (world space)
- Position related to the center of mass (body or local space).

The world space allows to manipulate parameters taking as reference the location of the actor in the stage, and it is useful for site-specific actions such as triggering behaviors or making objects to follow the actor. On the other hand, in the local space the position of the body parts depends on the body of the actor itself (pelvis) independently of his location in the stage, and is useful for gesture recognition.



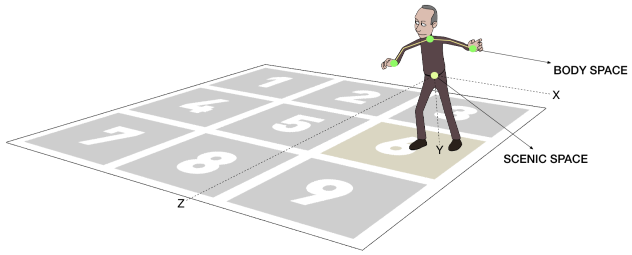


Figure 4: Left: The stage floor was divided into 9 squares for triggering actions; Right: Body space (local coordinates) vs scenic space (world coordinates) in *Solitária* setup

Gestural Vocabulary

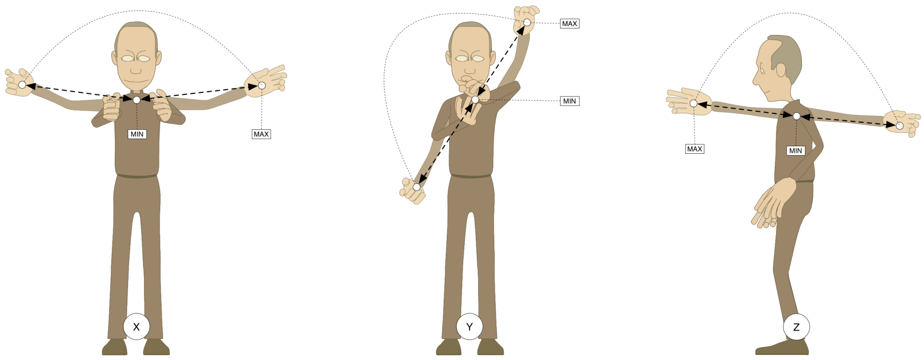


Figure 5: Hand gestures: motion ranges from different axis. 3D character model by Rodri Torres.

The body space coordinates are calculated from the center of mass (COM) of the body and are useful to retrieve the body's posture independently from its position in the set (Figure 5). In this project we use the center of hands (COH) as reference, which is based on the COM with an offset in the Y axis, aligned with the shoulder. The body's interaction is based on the position of both hands to the COH. The XYZ coordinates for each hand are mapped to a motion range between the values of -1 and 1, which represent the extremes (arms full stretched away from the center of the body). Thus, if both hands have a value of 1 in the X axis, it means that they are wide open in the horizontal plane. This is true even if the actor moves in the scenic space because the hands are calculated based on the body itself, not in the location of the body on the set. With this coordinate system and motion range, it is easy to map gestures to one or multi dimensional parameters. For instance, we can increase the volume of the sound, which is a unidimensional parameter, by raising the left arm. In situations where there were multiple unidimensional parameters, we mapped different axes, such as swiping the arm to the sides would change the panning of the sound while raising, and lowering the arm would change its volume. This flexible mapping scheme was employed in the control of sound and visual parameters, providing a great level of control. The puppeteer manipulates the digital media with his hands as if operating a marionette.

We created a vocabulary based on the body posture and gestures corresponding to certain actions or emotions such as:

- **Pain** = compressed gesture: moving the hands to the center (COH).

- **Strength** = expanded gesture: moving the hands away from each other in the X or Y axis.
- **Fear**: raising both hands in front of the face.
- **Disorientation**: sliding the arms forward and backwards.
- **Craziness**: circular gestures with the hands.

Sound-Puppetry

In *Solitária* sound is understood as an object, as a puppet that can be manipulated by the puppeteer. It was our intention from the beginning to explore sound manipulation with puppetry techniques, which we call the *sound-puppetry*. Sound is driven by the body position in space, or the movement of the body limbs. This technique can generate sounds, or drive the sound properties, such as pitch. One of the most important aspects in sound-puppetry is the mapping between the body and the sound property. We developed 4 categories for mapping sound properties to the body:

- Body instrument;
- Sound spatialisation;
- Sound triggering;
- Waveform navigation.

The sound-puppetry methodology is based on 3 steps : 1) To explore the different dimensions with the body we used the Microsoft Kinect for tracking the motion of the body with the OpenNI framework; 2) Osceleton (or Synapse) software was then employed to route the performer's skeleton coordinates, through Open Sound Control (OSC), to Kinectar. This application, used for musical performance, provides techniques for mapping the hands position to multiple actions that are sent through MIDI protocol; 3) Finally, these MIDI messages are mapped in Ableton to multiple functionalities including selection, triggering, navigation or even to play musical notes.

Body Instrument

We were able to assign the position of the hands to specific notes of an instrument through Kinectar. In this way, the actor was able to play piano with mid-air gestures. It is also possible to play a specific chord when the hand reach a certain position or even to control arpeggios. Each hand can be mapped to a different setup or action using any axes. We have explored these features searching for a correlation between puppet manipulation and music performance.

Sound Spatialisation

The space inside the cell is constrained to a few meters taking the prisoner to walk in circles. To emphasise this circular motion we mapped the center of mass (COM) of the puppeteer to the sound panoramic parameter. The sound follows the motion of the puppeteer in the X and Z axes, generating a sense of spatialisation. In certain parts we played with the sound panoramic to simulate movement while the actor stayed still. In these cases the panoramic is mapped to the right hand position X and Z, while the left hand takes control of the volume or the modulation of the sound.

Sound Triggering

Each square in the scenic space was mapped to a set of sounds associated with an action or emotion, and the actor was free to choose which sound to play according to his location. A hand gesture is required to trigger the sound, these gestures are defined accordingly to each square in the physical space. The body gestures were designed to represent specific actions. For instance, to recreate a basketball sequence with dribble actions followed by a shooting, we define in Kinectar the following mapping: the sound of a dribble will be played every time the right hand reaches the knee (-0.5 to -1) in the Y axis with a specific velocity; the shoot sound is played when the actor's right hand raises above the head (0.5 to 1) with a certain velocity. The velocity is important to avoid unintended triggers and to simulate the natural gesture. Many gestures can be mapped following this model, combining different axes such as knocking on a door, punching the face, or opening a window. With this flexible mapping the actor can improvise on stage triggering different sounds on each location.

Waveform Navigation

We introduced a waveform navigation technique based on the X axis movement, which allows the actor to use his left hand for navigating in the waveform and his right hand for defining the play range (Figure 6). To play the range, the actor needs to make a beat gesture with his hand in the Y axis by lowering the right hand quickly. In this way, the actor can trigger the sound after the range selection avoiding unintended sounds.

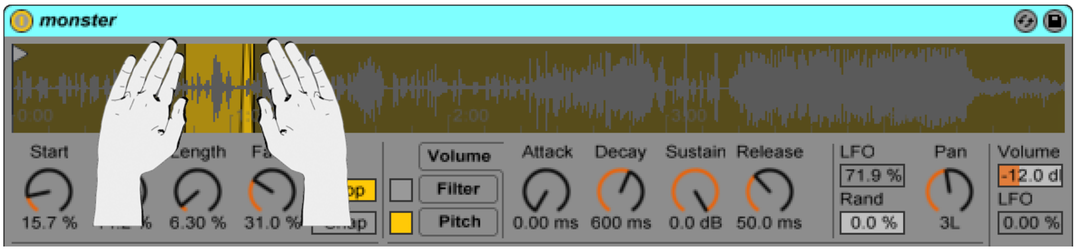


Figure 6: Sound manipulation: left hand marks the beginning of the play range and the right the determinate the end point. This range is updated in real-time.

The actor is able to jump from distinct words on the waveform deconstructing the text creating new sentences. He can also reduce the range constantly until reaching a sine wave allowing the sound to be modulated. After triggering the sound, the actor can move his left hand in the Y and Z axes to modulate the sound.

Narrative

The play was divided into 6 main moments that characterise the evolution stages of the prisoner: 1) Disorientation; 2) Hallucinations; 3) Self-control; 4) Illusion; 5) Memory; 6) The end. Each moment presents a specific interaction design which is described in this section as well as the narrative contextualisation.

Figure 7: The evolutionary stages in the cell from the play: 1) Disorientation; 2) Hallucinations; 3) Craziness.

1 - Disorientation
Narrative: When the door opens to the loneliness of the solitary confinement and the light goes out, the human being becomes a shadow of his existence and becomes disorientated (Figure 7). The character attempts to explore the tiny space that defines the cell by trying to figure out its limits, walking in circles with his hands in the walls. This space is depicted through reverse shadows, shadows in the dark, silhouettes of light that glow with life signals inside our minds in response to the character's behaviour.

Implementation: We developed a silhouette application using Openframeworks using a simple camera to draw the silhouette with glow and trails. When the actor moves he leaves trails that describe the cell space, the trails disappears when the actor stands still.

2 - Hallucinations
Narrative: Reality is portrayed as bright vultures that glow at the heart beat rate. Images from reality are brought into our minds through trails of light as if they were ghosts, fragments of their existence. Extremely

deformed images that appear and disappear as hallucinations. They become moving shadows or silhouettes that are not evident.

Implementation: Physical objects and puppets are deformed and manipulated by the actor, who uses a web-camera for capturing fragments of images as signifiers. A patch in Quartz Composer processes the video image captured from the camera, creating a raster image with bright lines and trails of light.

3 - Self-control
Narrative: Our character seeks balance and attempts to control his mind.

Implementation: To materialize this self-control we have adapted the *Chdh Egregore* patch for Pure Data. This audiovisual instrument provides physical modelling algorithms and creates expressive visual effects through particles that are translated into sound. Several parameters were mapped to the actor's body gestures allowing him to control the shape of the particles as well as the sound.

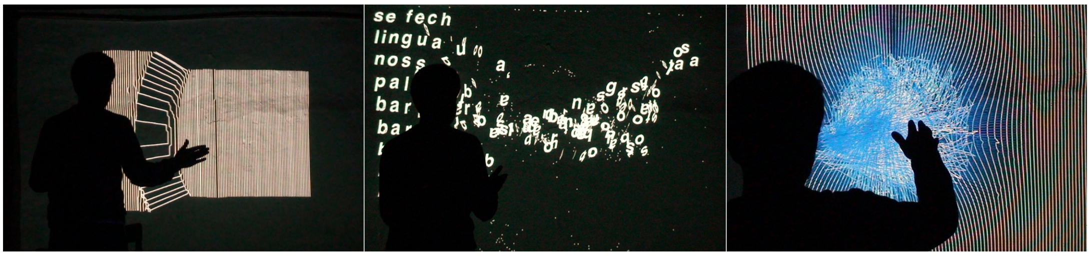


Figure 8: The evolutionary stages in the cell from the play: 4) Illusion; 5) Memories; 6) Despair. Photos by the author.

4 - Illusion
Narrative: Within the illusionary sense of control (Figure 8), our character seeks order and attempts to construct a reality made with geometric elements that are manipulable through his hands, challenging his sanity as well as his dexterity.

Implementation: We used the eMotion application to create patterns using grids made with particles that are manipulable with two touch points that follow the hands positions. These control points have physics-based effectors such as attractors or oscillators, that makes the grid to deform accordingly to the motion of the hands. In this way, the puppeteer can create shapes or interact with the grid. In specific parts, the grid presents physics properties and falls with gravity, simulating a piece of fabric. The puppeteer can manipulate this piece of fabric as a blanket, by pushing or pulling it.

5 - Memories
Narrative: In a journey through memories, the character reorganizes segments of text using his hands. He seeks meaning and attempt to create sentences that remind him of emotions from his memory.

Implementation: In eMotion we animate several pieces of text for different moments. The text made with particles is manipulable in a similar way as the grid. For instance, by attaching an attractor operator to the control points of the hands, the puppeteer is able to grab characters or words and place them in different locations. Another example is the fall operator, that makes the characters fall with gravity when touched by the actor.

6 - The end
Narrative: Memories start to pursue him and the performer tries to runaway until he gives up fighting.

Implementation: We have implemented in eMotion an operator that makes the words on screen to follow the performer. The performer attempts to escape by tricking the words with fast movements. When the words reach the performer, the cell bars start to move, as if the solitary confinement structure becomes alive, transformed into a puppet. Finally, our character becomes a physical puppet and stops moving.

Discussion

Technology brought a new paradigm to live performances challenging choreographers to rethink the body boundaries of the performer, and its relationship with the space, influencing the interplay between the performer,

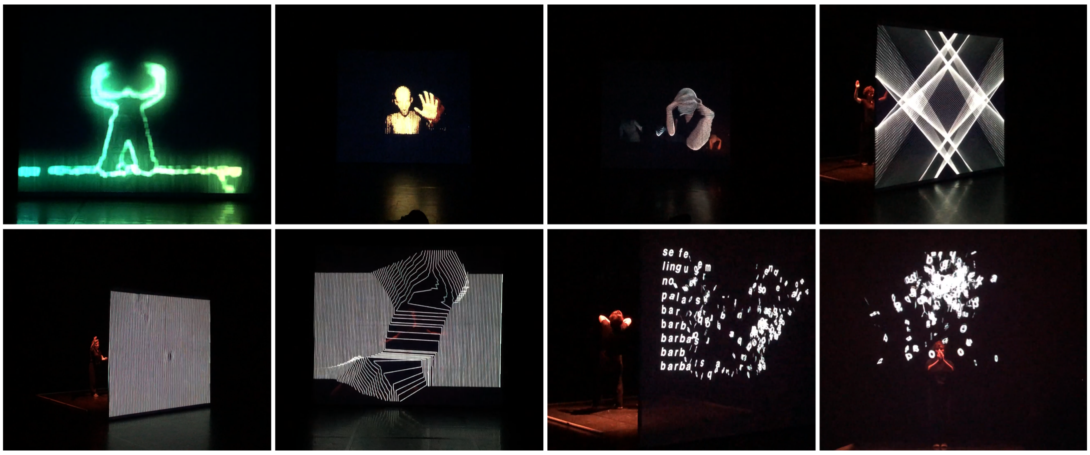


Figure 9: Fragments of the final performance. Pictures from a rehearsal at Teatro Helena Sá e Costa in Porto in October 2019

and the machine. It is important to follow a methodology when designing interactive environments based on the whole body performance (Lympouridis, 2012), and evaluate the need to use a gestural data interchange format (Jensenius, 2008), that can be used to recorded and to share the body interaction. The growing awareness of the structure of digital interfaces, allows the artist to become engaged with this augmented performance. The performance can explore new space-time dimensions through interactivity, such as the interactive performance *Messa di Voce* (2003) created by Golan Levin, and Zachary Lieberman (Levin and Lieberman, 2004). These new digital-assisted performances, should hold the principles intrinsic to the digital media paradigm, including the interactive design; the nonlinear processes; and the real-time signal transformation. The body performance can be choreographed to embrace this technological tools, allowing the body to be extended, changing the way we tell stories, the way we play music, and the way we dance. The production of a digital augmented performance, will incorporate the nonlinear multimedia composition, through interaction design, combining and transposing the body movement of the performer, into digital media processes, such as capturing or editing, augmenting the movement possibilities. This will require new interactive designers, and augmented body choreographers, to be a part of the creative process. Choreographers may choose between events that are previously rehearsed, and unpredicted events that force the performer to react, and improvise, affecting his emotional resonance. The performer becomes the sensorial machine itself.

Conclusion

Solitária challenged the performer to manipulate sound and visuals as a puppeteer (Figure 9), using physical and non-physical objects. We conclude by our experience that when the intangible manipulation presents a direct feedback, the puppeteer becomes engaged presenting a sense of directness. On the other hand, the puppeteer becomes disconnected if the feedback is indirect or subtle, in these cases the performer must focus on the process to be able to achieve expressive manipulation.The manipulation of physical objects and intangible digital media is related and both require dexterity, the great difference rely on the haptic, visual and sound feedback. We had the opportunity to work with a professional puppeteer which recognised that the manipulation experience provided a sense of directness over the digital media, even with the sound manipulation. He used his body as an expressive controller with precise manipulation over the dramatic elements. Apart from facilitating the creative process, this digital interactive framework augmented the tangible manipulation, as well the intangible manipulation of sound and visuals. Above all, this augmented manipulation can be considered the process of transformation, a process of transferring energy from the human agent to the physical/virtual object. It is through this movement that the audience has the perception of a living object.

Acknowledgements

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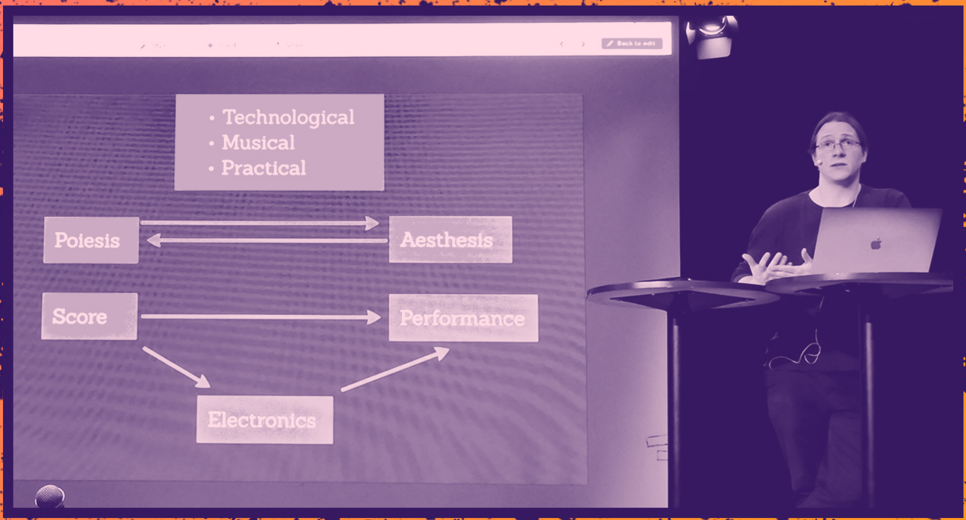
Mathieu Lacroix

The Interface as an Extension of Composition in Mixed Music

Paper

Video of presentation can be found here



The Interface as an Extension of Composition in Mixed Music

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Abstract. This article attempts to see the links between the different elements of a mixed music composition (score, electronics, performance) as different types of interfaces. The article focuses on different aspects of poiesis and aesthesis within the use of interfaces in mixed music. The final section also goes through my own compositional process and ideas as a counterweight to some of the earlier given examples.

Keywords: mixed music, composition, contemporary classical, interface, electroacoustic

Introduction

Many conferences and publications that use the term "interface" in the context of art focus on the aspect of technological poiesis, while aspects related to aesthesis have a minor role. A balance between poiesis and aesthesis is often the most conductive to research, as well as understanding a piece of music. We should think of what the word interface means. The Merriam Webster Dictionary has the following definitions. Firstly, a surface forming a common boundary of two bodies, spaces or phases. Secondly, the place at which independent and often unrelated systems meet and act on or communicate with each other. Thirdly, the means by which interaction or communication is achieved in an interface.

Although the use of technology in music is a clear interface, there are many other possibilities that are not necessarily technology dictated or so heavy on the technicalities. These definitions reinforce how we can see interface as being all the different technological, musical and practical elements that bind the different elements of a mixed music piece together. In Lacroix (2018), I had separated these elements as score, electronics and performance, which can serve as a base here as well. The interfaces in this article are the different links and glue between these aspects of composition. It is important to note that these are not only physical or digital "things" but relationships between different actors (digital, human, physical and conceptual).

In this article, I will focus on the musical, pragmatic and conceptual interfaces connected to mixed music. Firstly, we will look at a definition of mixed music to make it clear which repertoire we are talking about. Secondly, we will go through the use of interfaces when composing mixed music. Thirdly, we will look at different interface possibilities when it comes to performance practice. Finally, we will look a bit into my own compositional process to look at a few examples of interfaces within compositions.

Mixed Music

Before being able to discuss any meaningful repertoire and its musical, philosophical and technological paradigms, one must first define its limits. Generally, one refers to mixed music as a type of music in which one finds electroacoustic and acoustic sound sources. However, as Teruggi (2016) notes, this includes almost all types of modern popular musics which is not what is meant. Mixed music is a type of music in which one finds both sound sources, but also that the classical music concert is at its heart (Tiffon 2005). This definition also excludes the large repertoire of more improvised musics that use technology which often has more in common with experimental jazz and popular musics than classical music. Tiffon (2013) explains that mixed music is only truly mixed when the composer succeeds at combining both electroacoustic and acoustic writing. Mixed music is about the dialogue between both (Ibid). The strict limitation of the terminology is not meant as an aesthetical judgement on different types of music, but only to delimit a specific repertoire for this article.

Écriture's Interface

The challenges and pitfalls of mixed music have been written about for decades both from composers and performers. The whole concept of the genre is the hybridization of the note-based musics and sound-based musics (Landy 2007). How does one compose in such a hybrid sense? The difficulties of the notation of electroacoustic music have also been a challenge for many years (see Roy 2003 ; Thoresen and Hedman 2006 ; etc). Combining both worlds seems like a daunting task to say the least and it has both conceptual and notational problems which is where the concept of the interface becomes important. How does one write meaningfully between two different traditions, and nonetheless modes of working? How does this interface function? Although notation is already mentioned, I will not be discussing it at length. It's an issue all of us composers face and that has no easy solution. I will concentrate specifically on the interface between the acoustic and electroacoustic in the compositional phases.

How does one write a new piece that also uses elements of technology? Does one start with the notated score? Does one start with the electronics? The literature on the compositional process in mixed music is difficult to follow and completely trust since it is dominated by a handful of institutions. Acosta (2016) for example, raises the question of the amount of literature from places where the figure of the computer sound designer (often called RIM in the literature for *réalisateur en informatique musicale*, a decidedly French term) does not exist. It is much easier to find information on the act of *écriture* for composers with a large institutional backing such as Philippe Manoury and Kaija Saariaho than a composer like Ejnar Kandring or Natasha Barrett that have had to mainly do everything themselves.[1] The modus operandi and the creation of IRCAM are directly linked to these possibilities. Boulez' idea was to combine the work of scientists and artists to be able to create interesting art (Jameux 1991). Although Born (1995) has shown the inherent inequalities of this model, it is still essentially practiced to this day in many of these institutions.

How do composers work with the interface of composition between both sound worlds? It seems to vary especially on whether the composer exactly has institutional support. The compositional process is personal, rhizomic[2], and far from straightforward (Delalande 2007) but recently there have been more critical studies about it. Jean-Luc Hervé proposed a model for the compositional process which is mainly separated into two lines: the material and the sonic image in the composer's head (recreated in Donin 2013, 1646). These lines eventually cross into the formal plan/sketches of the composition before being synthesized into an actual realization of a single section and eventually the whole piece. However, this model is aimed at explaining the compositional process of acoustic music. When we bring into it the work with electronics, it becomes fuzzier and blurry. However, I would argue that the composition of mixed music is closer to the development of software and would look more like this:[3]

[1] It should be mentioned that having to do everything yourself is both a blessing and a curse.
[2] I would argue that the compositional process has all the rhizome characteristics that Deleuze and Guattari outline (1987).
[3] This outline is also inspired by Servière (2010)

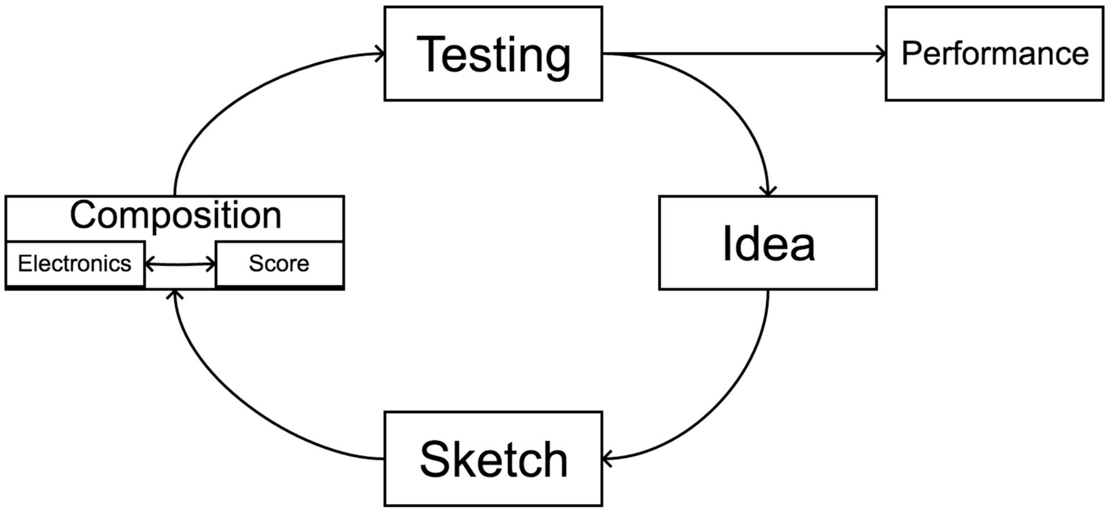

Figure 1. Compositional process

If we consider the literature on mixed music, there is a large variety of how composers interact with the compositional process and the development of the electronic ecosystems that they need. Many institutionally supported composers mention writing the electronics at the same time as the score. Saariaho mentions that this is part of musical language (Cohen-Lévinas, 1999). Manoury (2012) explains that it is a crucial aspect of his process, and that both highly influence each other. Harvey (Donin and Theureux 2008) and Murail (Cohen-Lévinas 1999) have also expressed similar attitudes. However, one does have to ask the question if this is completely correct. I am convinced that the use of electroacoustics is vital to these composers, but the practice of the RIM and other assistants, when documented, shows a slightly different story.

Faia (2014) covers in-depth his work with Harvey, which mainly shows a composer that struggles with technology. Nuno's (Nouno et al 2009) also shows this side of Harvey as a very open composer that is highly influenced by his assistants. This is not to say that Harvey's pieces are actually made by his assistants[4] but that their influence is markedly felt and heard within the produced music although filtered through Harvey's aesthetics and ideas. This also seems to be the case in Baschet's music. She had clear ideas of what she wanted but the means of doing it were quite complicated and the compositional process often had to be interrupted by more scientific endeavors of working with the sensors on the bows (Bevilacqua et al 2012).[5] Saariaho is well known for her work in the 80's and early 90's. However, for many years her MaxMSP patches do not reflect what is supposed to happen according to the score and explanations. In her piece *NoaNoa* (1992) the amplitude of the flute is supposed to modulate the amount of reverb. However, this has not been the case for many versions of the MaxMSP patches.[6] These examples paint a picture that although these

[4] And it should be mentioned that Harvey's action of giving royalties to Faia was the first time a composer had forfeited any royalties to give them to his/her assistant.
[5] It should also be mentioned that this has recently been changed as Serge Lemouton has created a new version of the piece which exclusively uses audio descriptors (Baschet et al 2019).
[6] I am indebted to Simone Conforti to have brought this to our attention in class on electrouacoustic performance at IRCAM as part of Manifeste 2019.

composers mentioned the importance of the interface between acoustic and electronic, it is not truly maintained and that the relationship is more frayed than most would think. The issue of conservation also looms strongly here, and it is luckily being brought up more and more in for example Bonardi (2013). Often a patch needs to be edited and partly re-made even if it's only from a few years ago. New updates in either MaxMSP or on the operating system can also mean severe problems that need to be addressed. Often, one can also see solutions that were done quickly within a rehearsal be saved as the main patch, with little to no documentation on why that was done. Recordings can also be edited afterwards or have completely new electronic tracks made only for said recorded offline, therefore removing a certain immediacy and liveness that is integral to mixed music. These are only some of the many issues in conservation of mixed music.

For many composers outside of institutional support, the situation is quite different. Berweck (2012) mentions how he often had to directly contact composers to get the electronics. Additionally, the composers often had to modify the electronics (or sometimes, Berweck himself had to do this) to be able to get the pieces performed once again. This also shows a much closer possible relationship between the *écriture* and the electronics, but one that is also fraught with many dangers. Acosta (2016) for example, seems to mainly have made her electronic ecosystems before the scores are written or even worked on. For other composers such as Di Scipio (2018) the creation of the electronic ecosystem is in itself the main act of composition.

It becomes clear that there is truly no cut and paste method to work between the interfaces of acoustic and electroacoustic writing. Herein lies the challenges of mixed music: one should master both types of writing and find his/her own way of combining both. This is what makes the genre exciting and interesting. Ungeheuer (2013) mentions that the duality of human and machine is gone from the genre, which I respectfully disagree. This is in many ways the essence of the genre since we have no clear-cut methodology and it is still used in many pieces exactly as an (artistic) interface between both worlds such as in Jodlowski's *60 Loops* (2006). It is where the tension lies both compositionally and when thinking in terms of the interfaces of mixed music.

Performance Interface

Another interface to address in the context of mixed music is how to connect the performer to the composition and its ecosystem. There are many aspects here that are worthy of discussion ranging from different synchronization strategies to how the musician interacts with the electronics. Performers have a tradition of writing about the challenges of mixed music such as Berweck (2012), Ding (2006), McNutt (2003), Kimura (1995, 2003) and Pestova (2008) among others. These texts give the reader a clear picture of many of the challenges that face performers of this music: electronics not working, lack of training in the use of electronics, prohibitive interpretations, lack of information and obsolescence among others. In the context of this article we will mainly be looking at prohibitive interpretations and the design of the electronics to give a clear musical meaning for the musician and audience.

A typical complaint from musicians is to be forced to use a click track. Although certain musicians have lauded the use of click tracks in its possibilities for improvisation (Ding, 2006), most seem to be against the practice such as Kimura (1995, 2003) and McNutt (2003). In my own experience, giving classical musicians a click track can cause them to stop listening to each other. For example, string players' intonation can become an issue. I would also argue that temporal flexibility is often an important element in a lot of art music ranging from classicism to contemporary music. Listening to older recordings shows us this, and it is also argued in several historical documents (Day, 2002 ; Howat, 2009).

So then, what does one do in musical passages that are highly striated or amorphous time to invoke Boulez' (1963) temporal terminology? There are many different solutions which serve different musical and performance aesthetics. In a piece like Nunes' *Einspielung I* (1979-2011), it would be unrealistic to ask the musician to trigger all the events. Therefore it was traditionally done with the RIM manually activating the different events although recently a new version using score following has had success (Daubresse 2015 ; Pages 2013). In other pieces the effort of the musician can be part of its aesthetics, which reflects ideas that Ferneyhough (2006) has written about. For example, Tzortzis' piece *Incompatible(s) IV* (2010) is physically very demanding for the bass clarinetist, and the action of having to press the pedal is part of this. However, as a compromise when I played this piece with the composer present at IRCAM in June 2019, I had to press the pedal a few times from my FOH position to help the performer.

In a more amorphous context, using score following would often also cause trouble for the musician, not being able to trust the computer as his/her trusted accompaniment.[7] In this context using different synchronization strategies such as tape or triggering through a MIDI pedal might give a more musical result that is easier for the performer. There is also, always the possibility that returning to the stage of writing the piece and working on the arrangement to make it work for all parties involved. In the same way that we expect a good classical composer to be able to properly arrange for a string section, we (as a community) should also expect composers to be able to arrange their electronics both sonically and performance-wise into something playable.

Personal Approach & Conclusion

These issues and concepts have been on my mind as I have written mixed music. Additionally, the idea of processes which are not necessarily completely determinate beforehand, or not completely calculated before performance have also become an interest. This is similar to Manoury's concept of virtual partitions (Manoury 1998). The question then arises, why would anyone want "unfinished" processes within a type of music that is mainly through-composed? How does this interface function?

Firstly, these processes can sometimes help the musicians and make them sound better. An example of this is from my solo flute piece *North Star* (2018). At several points the computer will analyze the pitch of the flutist before creating a musical process that is based on that pitch. In a tape version of the piece, if the musician played the wrong note, the section would sound wrong. In a live electronics version, if the musician would play the wrong note, the electronics would help him/her cover that up. This principle could even be used to change an electronic event in case of different tunings of instruments. While playing in different cities at different venues it can quickly happen that one piano is in A=440, while another is A=442, yet both can sound right. In this example, a pitch tracker is used and then the notes after the Bb are based on tracked pitch by semitones. This makes the music be slightly more process-based (+2, -1, etc) but it still retains a through-composed sensibility. In the score the part is written as it should be optimally played by player and computer.

[7] Slow tempi and repeated notes have been one of the problems for score following for many years.

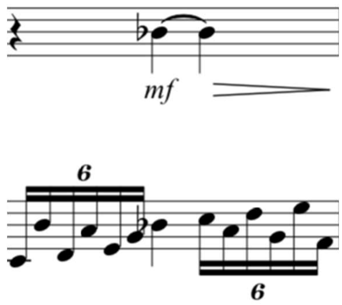

Figure 2. An interface example in the electronics of North Star (2018)

Secondly, this permits a greatly flexibility in the interfaces between the musician, the electronics and the composition which allows more interpretation as well. One of the great joys of the classical repertoire is exactly how flexible it is. A Beethoven sonata played by András Schiff is completely different from the same sonata played by Paul Lewis. Rigid interfaces and synchronization can often lead to less flexibility stylistically. In the case of contemporary mixed music, it is often difficult to say if it's the interpretation or the interfaces which are too rigid as there are rarely several recordings of a single piece, and most of them have little rehearsal times. In this sense, little has changed since the post-war avant-garde of Boulez and how his Domaines musicales to fight these problems, specifically with too few rehearsals (Jameux 1991). By having more open processes in a composed piece, it is possible for the musician(s) to play with a bit more flexibility. Loose synchronization strategies in pieces that are well written can let both the performer and electronics breathe in a way similar to the classical repertoire. These processes can also open interesting compositional doors that would not be available otherwise. Some of the processes in Hans Tutschku's music, especially *Zellen-Linien* (2007) is an example of this.

Another example from my own music is the piece *Facing Gaia* (2019). The music is written in an almost Romantic idiom that needs to contract and expand as the musician plays. Rigidity in composition and electronics would completely hamper the pianist in being able to make the music meaningful. When the piece was being written, this was a concern for the pianist Ana Claudia Assis when tape was mentioned to do a quick work in progress in August 2019, in Belgium.[8] The example shown below, shows that this rather elastic *écriture* can make it difficult to put things to a grid. The solution that was used at this work in progress concert was that I would trigger tape parts myself, slowly mixing them together. Each tape part was essentially longer than what one would calculate from the metronome, and generally had little that was in striated time.

In the finished version of the piece, the electronics are launched directly by the pianist using a MIDI pedal, but most aspects of the sound are taken from analyzing the sound the pianist is making in real-time with the use of audio descriptors and score following. These different forms of information from the real world helping to glue everything together and forming an interface between the music, the musician and the performance.

Thirdly, this extra level of interpretation and flexibility can make the piece of music easier to learn for the musician(s). Bullock (2013) as well as many of the previously mentioned articles in the last section mention how daunting a task this type of music can be. Shouldn't we be working on making it playable? I do not mean to write easy music or making artistic concession, but to make music in a meaningful way that can connect with the musician and from there, to the

[8] It should be mentioned that the piece was never intended to be for tape, only for live electronics but had to be "converted" to tape for a work in progress showcase as part of the Musiques et recherches composition workshop in August 2019.

audience. In essence, the audience could not care less if a piece is with tape, live or anything in between, it is meaningless. However, to the musician(s) that took the time to learn the piece, it can be very meaningful if whatever synchronization strategy was used was meaningful and made sense for that piece of music.

Fourthly, these changes and increased flexibility can be heard by the audience. However, this is not always possible in the case of rigid electronics. With more flexible temporality, electronics and interfaces, the musician can relax much more and play within her/his normal idiom and comfort zone as a classical musician. I am convinced that this can also be heard by the audience, not necessarily that they can hear if the electronics are live or not, but mainly that the feel and flow of the music is more relaxed and fluid. It's an important step in creation a better performance practice which can heavily influence the final result.

I feel it is relevant to mention a maxim my first music teacher often told me many years ago: "You are playing for all the audience, not the three people at the back who have a clue about how you orchestrated your paradiddle". This concept of interfaces permits us to review how we address musical issues from the score to the electronics to the performer(s) to make a good artistic statement. After all, isn't music just an interface between people?

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Thomas Moore

Hybrid Conductor: Case Study and Analysis of Alexander Schubert's Point Ones

Paper

Video of presentation can be found here

Hybrid Conductor
Case Study and Analysis of Alexander Schubert's *Point Ones*

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Abstract

At the premiere of *Point Ones for small ensemble and augmented conductor* (2012) by Alexander Schubert (1979-), I had a front row seat to Daan Janssens' impressive performance as the augmented solo-conductor. There was an observable and palpable tension between the live electronics and live musicians, created both by Janssens' performance and Schubert's programming and composition. During the compelling solo-conductor's cadenza, Janssens completely released control of the live musicians and freely explored the virtual realm afforded the conductor by the electronics.

In this paper, I will briefly explain Schubert's score and my analysis thereof. The usage of the live electronics is considered as well as the balance that the conductor must maintain between the electronics and the live musicians. Comparable pieces are then reviewed. I will conclude this paper by determining that there are five detectable artistic and socio-economic criteria for utilizing a conductor in *Point Ones.*

Keywords: New Music, Conducting, Live Electronics

The case: Alexander Schubert's *Point Ones for small ensemble and augmented conductor*

Point Ones for small ensemble and augmented conductor (Point Ones) was premiered in 2012 by Nadar Ensemble with conductor Daan Janssens in Centralstation, Darmstadt, Germany, and commissioned by the Darmstadt Summer Course for New Music. The piece is orchestrated for clarinet or saxophone, piano, electric guitar, drums, violin, cello, augmented conductor, electronics technician, and audio engineer. This case study and analysis will refer to the score that was published by the composer in 2012.[1]

The conductor is augmented with two enhanced WiiMotes attached to their wrists. The user interface (UI) tracks specific motions and gestures made by the conductor. The tracked (mapped) gestures trigger prepared and pre-sequenced live electronics. The (conductor's) score has also been augmented. On top of each stanza, Schubert has written four additional (as it relates to today's conventionally accepted orchestral/ensemble scores) horizontal lines. These lines are used to instruct and guide the conductor throughout the piece. The lines are labeled and read from top to bottom:

> <u>Right hand</u>: choreography for the right hand;
>
> <u>Left hand</u>: choreography for the left hand;
>
> <u>Electronics</u>: a description of the live electronics produced by the right and/or left hand (or manual jump);

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[1] Schubert, *Point Ones* (2012), score: https://www.dropbox.com/s/c3crop3ee9j32xf/Point%20Ones.pdf?dl=0

> Instruments: a final line intended to clarify the instrumentation of the live electronics. (For example: 'synth drums,' 'cresc..,' and/or 'held notes.')

Alexander Schubert, in his legend and performance instructions attached to the score explains this special notation as follows:

> This piece is notated in a slightly different way. The idea is that the piece is not conducted in a traditional way. The conductor is supposed to give mainly just cues - by that indicating to go to the next passage. These cues are notated by black arrows in the score / parts. Sometimes a cue goes on over a few measures - in that case the bar lines are dashed (and not solid). The solid bar lines indicate that a new cue starts after this measure. (Schubert 2012)

In the program notes on Schubert's website, the composer explains the utilization of these gestures (cues) as follows:

> In *Point Ones* the conductor is equipped with motion sensors and through this is able to conduct both the ensemble and the live-electronics. Most of the piece is not realized with traditional conducting but with cue gestures that mark [the] beginning of new passages – hence the title *Point Ones*. The aim is to be able to experience the live-electronics in an embodied way and to create a fully controllable instrument for the conductor. Because of that the piece does not use a click track or other timeline-based fixed approaches. (Schubert, Last visit 16.07.19)

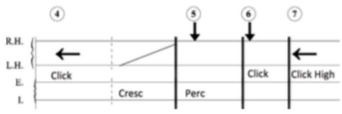

Figure 1: Example indications from the conductor's part.

When performing the material in Figure 1, the conductor would first point to the left with their left hand, then with the same hand show a crescendo. Next, the conductor will show two downbeats with their right hand. And finally, with the left hand s/he swipes left again.[2] The sounds these gestures produce are, from left to right: an electronic click, a synthesized crescendo, a woodblock, an electronic click, and lastly a higher electronic click.

Live electronics

The conductor is augmented with adapted (by the composer) WiiMotes; these are controllers for the Nintendo Wii entertainment and gaming system. The UIs' accelerometers have been fixed to two wristbands and the conductor wears one on each arm/wrist. The accelerometers track and map the conductor's movements and using the UIs' Bluetooth technology, delivers this information to a MacBook laptop running OSCulator and a Max patch. The composer has also prepared these two patches. The Max patch reads the mapped movements and, where appropriate, translates them to triggers. These triggers then initiate the pre-programmed and occasionally live recorded sounds audible to the audience. This all occurs with little or no detectable (by the audience) latency.

Schubert's use of these particular interfaces offers the conductor the opportunity to present a very realistic illusion to the audience. The conductor's arms appear to be either generating the electronic sounds themselves, or a virtual orchestra really is responding to the sometimes wild gestures choreographed by the composer. This use of the WiiMote, an augmentation and extension of human possibilities, seems to be in line with the inventor, Ako Ikeda's intention:

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[2] 'S/he' – When appropriate, the author will use the non-binary gender pronoun 'they' and its forms. However, in instances in which this presents ambiguity, 's/he' (and its forms) will be used. Please read this as intended as a continuum rather than a binary label.

> Of course, when playing a game, the nearest thing to the player is the controller. The controller should therefore be regarded as an extension of the player rather than as part of the console. I always bear in mind the importance of the fact that the player will have far more contact with the controller and UI than the console itself. (Ikeda and Iwata 2006[3])

Personnel

In addition to the staged performers (the live musicians), Schubert also insists on two extra personnel for performances and rehearsals:

> In order to run the piece a **technician** should take care of the connection with the sensors, the USB-repeater and the Bluetooth-receiver and should be familiar with setting up the connection in the computer and routing the signal from OSCulator to MAX/MSP. During the rehearsal and performance one person (can be the technician or a musician not playing in the piece) should sit at the computer and monitor if everything [is] working well. This means checking if the CUEs are triggered correctly. A **sound technician** should handle the amplification of the piece. (Schubert 2012)

Just as in pieces such as Karlheinz Stockhausen's (1928-2007) *Oktophonie* (1991) and Luigi Nono's (1924-1990) *das Atmende Klarsein* (1980-83), in *Point Ones,* the electronics technician is vital to the performance. S/he follows the score and ensures that the cueing of the electronics occurs as it should – and if it does not, corrects the situation. S/he is also present to perform four live "manual jumps." Manual jumps are moments in the score at which the electronics technician must cue the electronics by hand by pressing the space bar on the computer running the live electronics. The presence of these personnel is representative of "ubiquitous electronics" (Collins, 1998) in new music. Technicians are now considered regular members of any ensemble performing within this genre.

Analysis Method

It can be argued that in *Point Ones,* the conductor finds her/himself directing both a live and virtual ensemble. Sometimes both ensembles are conducted simultaneously and conjunctly (meaning there is some sort of suggested cooperation). When simultaneous, the balance between the two ensembles shifts between favoring either the live or virtual ensemble. There are moments in the piece in which the conductor is completely focused on the live ensemble, conducting every detail and showing every beat. There are also times when s/he is completely in the virtual world. And finally there are points at which the conductor is in the virtual world and the members of the live ensemble must conduct themselves.

To better understand and visualize the conductor's changing roles, I created a chart. Each of the six above-described situations was assigned a number. I used the number '1' to represent the conventional conductor-ensemble relationship. The number '5' represents the times at which the conductor has stepped completely into the virtual realm. The numbers between ('2, 3, and 4') represent degrees present in the piece between these two outer extremes. To indicate the moments at which the conductor is completely conducting the virtual ensemble and the live ensemble conducts itself, I have classified this situation as both a '1' and a '5.' The full chart can be found in the appendix linked in the footnotes.[4] I have consolidated the information found in the chart into a bar graph shown directly below (figure 2):

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[3] Ako Ikeda, responsible for the accelerometer hardware in the Nintendo Wii™, in an interview with Satoru Iwata, *Wiilaunch website,* Summer 2006.
[4] Appendix: https://www.dropbox.com/s/dfm27pxnegjwmxp/Appendix%20Alexander%20Schubert%20Point%20Ones.docx?dl=0

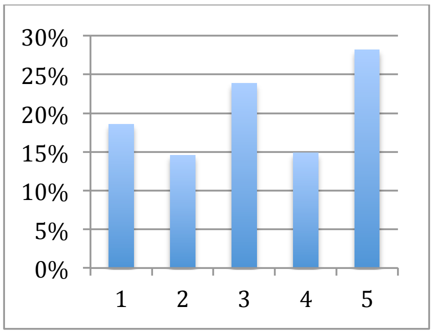

Figure 2: This chart shows what percentage of the measures falls into which category.

1 = Conventional conducting / no virtual orchestral conducting

2 = Conventional conducting / some virtual orchestral conducting

3 = Conventional conducting is the equal to virtual orchestral conducting

4 = Some conventional conducting / virtual orchestral conducting

5 = No conventional conducting / (all) virtual orchestral conducting

In analyzing this piece, it was also important that I consider Schubert's handy and pragmatic use of measure structure (bar lines and time signatures). The composer's approach is made apparent at the outset of the piece. The first four measures (measures 1-4) can be described as having an up-tempo (quarter-note = 120 bpm) 4/4 rhythmical structure. Arguably this is easily accessible for the audience. The example illustrated below begins in the fifth measure and continues through to measure 11. Schubert's measure structure for these seven bars reads: 5/4, 5/8, 7/8, 7/8, 5/8, 5/8, 5/8. The audible rhythm occurs on the first and third beat of the first measure (measure 5), and then consistently begins on the downbeat of every subsequent measure.

If we close our eyes and just listen to the piece starting from the beginning using the upbeat 4/4 structure as the frame, we could conceivably rewrite the audible rhythmical structure (bar lines and time signatures), beginning in measure 5 in the following manner:

Original: 5/4, 5/8, 7/8, 7/8, 5/8, 5/8, 5/8 = 44 eighth notes

Audible: 5x 4/4, 1x 2/4 = 44 eighth-notes

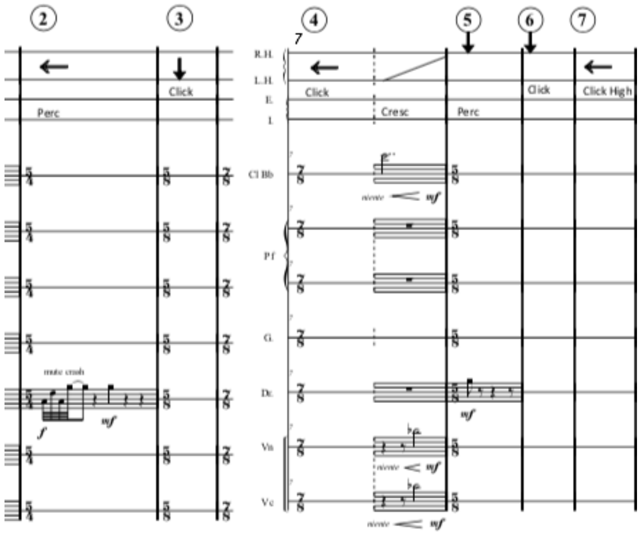

Figure 3: Measures five through eleven as written by the composer

Figure 4: Measures 5-11 rewritten; this example shows the rhythm as the audience would perceive it if they were to close their eyes.

By using Schubert's version (the actual written measure structure), the composer conceivably has delineated a clear distinction between the conductor's responsibilities to their solo instrument and those duties they have to the live performers. By being so (apparently) pragmatic, he has also decoupled the conductor's responsibilities to utilize conventional conducting gestures to represent the measure structure. This grants more freedom to the conductor to instead command the virtual instrument.

Category 1 – Completely live

Schubert opens *Point Ones* with a four-measure phrase that is conducted in a universally recognizable conventional manner. Written above the composer's part (the four lines as described above) is the phrase "*traditional conducting with right hand*." (Schubert, 2012) This is also one of the rare moments in the piece in which the conductor must also cue the electronics technician. The first cue for the virtual ensemble/live-electronics is not given/triggered by the movements of the conductor. It is instead a "manual jump" (generated by the electronics technician pressing the space bar) initiated at the very start of the piece and given/shown by the conductor. The conductor beats the first four measures, showing all, including the electronics technician, simply the effective time. The live electronics and the playing thereof are as yet, not under the conductor's direct physical control.

The universally recognizable conventional conducting gestures that are employed in the first four measures include a visible downbeat (a movement from up to down that rebounds at a visible ictus) per measure and three additional gestures per downbeat that include ictuses at regular (temporally speaking) intervals.

Category 2 – More live than virtual

Starting in measure 23 and continuing to the end of measure 31, the balance between the live ensemble and the virtual ensemble shifts to favor the former. Up until this point in the piece there was either an equal treatment of both live and virtual ensembles, or complete attention (from the conductor) for the virtual ensemble. Again, Schubert writes an indication to “traditionally conduct” in the conductor’s part. This section also represents a relatively long period of live ensemble combined with a (static) live electronic soundscape.

The live ensemble is influenced in these measures by the conductor’s gestures. S/he indicates time, gives cues, and can assist in interpreting any spontaneous expressivity (from the live musicians). The electronic soundscape is initiated by the conductor’s gesture in measure 23. However, the conductor is locked out (through the piece’s accompanying software) from adjusting the playback of the electronically produced material. While the audible balance of the entire ensemble (live and virtual) is the conductor’s responsibility, the only group that can actually be adjusted is made up of live musicians.

This balance of more live than virtual does not return in any substantial way in the piece until we approach the ending. (It returns briefly in measure 100.) In measure 237, Schubert revives the introductory material (A) with slight variations (A-Variations). These eight measures (m. 237-244) commence with a conductor-given cue (triggered via the UIs) for a static live electronics playback. During the following measures, the conductor, using conventional conducting gestures, must ensure that the live ensemble progresses smoothly in time with the pre-programmed electronic material. The conductor’s gestures (except for the initial cue in measure 237) are completely intended for the live musicians. I have classified these measures as balance cypher 2 (see chart) because while the gestures and the consequences thereof are primarily for the live performers, the conductor must still reckon with the tempo dictated by the pre-programmed (live) electronics.

The situation that commences in measure 262 (the *coda*) is similar to measure 23. The conductor’s gestures at the beginning of measures 262, 271, 288, 292, and 293 trigger a static (in regards to tempo) electronic soundscape with a pre-determined length over which the conductor has little or no influence. The soundscapes can be ended earlier than the indicated time. However, the composer has written a specific quantity of measures in a specific tempo (quarter-note = 120 bpm) and the soundscapes have been pre-programmed to match this duration. It can therefore be argued that the conductor should perform these measures as written, with one ear still in the virtual realm while s/he guides the live performers through to the ending.

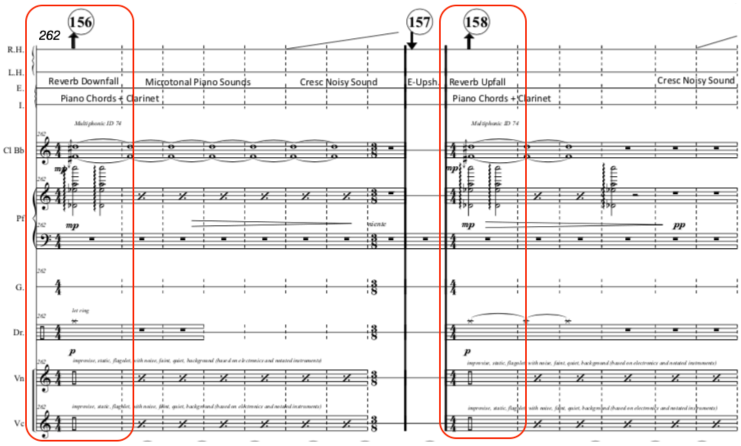

Figure 5: measures 262-276; the measures circled in red are two instances, as described above, in which the conductor triggers a static electronic soundscape that has a duration equal to that of the distance between each consecutive trigger.

Category 3 – Equally live and virtual

In much of *Point Ones* the conductor has equal command of the virtual ensemble (the “solo” instrument/live electronics) and the live ensemble. Measures 5-14 provide a representative example of such a balance. In measures 5 and 9 the conductor cues both the virtual and live percussion part. In measure 8, the clarinet and strings (both live) join the virtual synthesizer. In measure 12, the live piano, guitar, and drums are cued together with a larger virtual ensemble and in measure 14, the piano has a duet with a synthetic percussion instrument. In each of the examples cited, the conductor has full control over the timing, duration, and effects (crescendos and sonic variations) of the electronic samples. The conductor also displays the exact timing for the live musicians (deploying conventional conducting techniques) and cues their entrances. S/he is thus also in full and equal (to that of the virtual ensemble/live electronics) control of the live ensemble's performance. The exact same situation can be found in measures 32-41.

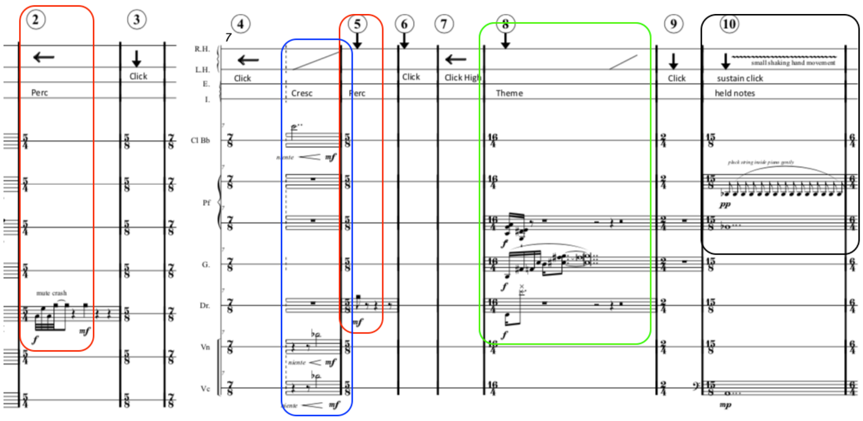

Figure 6: measures 5-14; In red, the duets between virtual and live percussion; in blue the quartet between synths, strings, and clarinet; in green, the initial motive played by the live piano, guitar, drums, and virtual band; and in black, the duet between conductor (live electronics) and piano.

Category 4 – More virtual than live

The composer's indicated conductor's choreography from measures 107-121 is quite extensive and difficult to perform for both conductor and live performers. While in most measures, the conductor in some fashion or another, is instructed to display the downbeat, there are two measures in *Point Ones* in which this is not the case: measures 116 and 122. The conductor also gives a double signal in measures 118 and 119. To play correctly, the musicians must be attentive, sure to not 'step in a hole,' playing when they should not. During these measures the conductor is especially restricted in movement. Schubert indicates every single cue's trigger-direction and he adds extra shaking gestures twice to the conductor's part (see excerpt below). The composer does not explicitly deny the conductor the freedom of movement to assist the live musicians, but it can be argued that the musicians, based on the regularly given downbeats, must organize themselves throughout this passage.[5] The composer writes in his introduction:

> The idea is that the piece is not conducted in a traditional way. The conductor is supposed to give mainly just cues - by that indicating to go to the next passage (...) Occasionally a normal conducting will be necessary - in these cases it is written in the score (...) The final decision in which parts traditional conducting will be necessary will be decided during the rehearsals. (Schubert 2012)

[5] I have performed this piece a number of times and have found ways in which to continue to conduct the live ensemble throughout this passage. My interpretation of these measures, as indicated in the linked chart, is that the conductor is mostly focused on the virtual instruments and assists the live instrumentalists in the accompaniment thereof.

Figure 12: measures 115-199; in blue, the solo-conductor's "solo" movements; the red arrow in m. 116 indicates a moment in the piece when the musicians must begin after the conductor has given the cue. In measures 118 and 119, we see in blue and red the conductor's double cue and the red arrow in measure 119 indicates the piano's entrance together with the conductor's second cue.

Category 5 – Completely virtual

Point Ones lives up to its subtitle *(for augmented conductor)* at multiple times throughout this piece, and especially in measures 179-184. During these measures the conductor launches completely into the virtual realm, improvising a cadenza. Their gestures, read by the accelerometers, are translated directly into electronic sounds. Gestures trigger along three axes and the conductor has the opportunity in these measures to demonstrate in full view of the audience their connection (binding) to the virtual world. The lack of latency between movement and audible sound blurs the line between synthetically and humanly produced sounds. In the video linked below, Enno Poppe conducts Ensemble Mozaik in *Point Ones.* This excerpt shows him performing the conductor's cadenza.

> Schubert, Alexander, *Point Ones for Augmented Conductor and Ensemble,* performed by Ensemble Mozaik and Enno Poppe (conductor): https://www.youtube.com/watch?v=3JB8qcTwDJw

Prior to the conductor's complete solo in their improvised cadenza, a section of the piece can be found in which the conductor abandons the live musicians and performs an improvised solo independent of the live musicians' written part. In measures 133-149, the violinist is instructed to cue the ensemble and the conductor is instructed to "*NOT CONDUCT THE ENSEMBLE. DO NOT follow the dynamic of the ensemble - act as a soloist and fill the gaps of the ensemble with electronics.*" (Schubert, 2012) Because the live musicians are still playing and being conducted, although this time by the violinist, I have categorized this section of *Point Ones* with the balance cypher 1 (Completely live). The conductor is completely in the virtual realm, conducting/triggering the live electronics with little or no regard for the live musicians. Therefore, these measures have also been categorized with the balance cypher 5 (Completely virtual).

Comparable pieces

In an article about the creation process of a similar piece, Jesper Nordin's (1971-) *Sculpting the Air* (2015) for enhanced/augmented conductor and ensemble, researchers and fellow musicians Bacot and Féron remark:

> There are a number of pieces in which the conductor is given an unconventional role by making the gestural component a central part of the performance (...) To that extent, Nordin's concept in *Sculpting the Air* is part of a musical trend that concentrates on the conductor's gestures, although the number of pieces (...) is quite small. (Bacot and Féron 2016)

They cite *Nostalgie (or Visible Music II*) for Solo Conductor (1962) by Dieter Schnebel (1930-), *Light Music* (2004) by Thierry de Mey (1956-), *Black Box Music* (2012) by Simon Steen-Andersen (1976-), and *Point Ones.* I would add two more works to this list: Alexander Khubeev's (1986-) *Ghost of Dystopia* (2014, rev. 2019) and Schubert's own *Serious Smile* (2018).

The Schnebel, Khubeev, and *Serious Smile* are all clearly written for solo-conductors. In the Schnebel, the conductor is the only person on stage and the choreography is an exaggerated 'mimed' *tour-de-force* of various cliché conductors' gestures. Khubeev literally binds his conductor to an instrument of the composer's own design. This piece forces the audience and musicians alike to question the role of the person standing in what they assumed to be the conductor's position. In *Serious Smile,* Schubert takes the conductor's instrument from *Point Ones* a step forward and augments all the performing musicians, giving them command of a wider pallet of virtual instruments.

The de Mey and Steen-Andersen are arguably not necessarily for a conductor, though these pieces do utilize and focus on the conventionally accepted conductor's gestures and movement repertoire. Bacon and Féron write:

> In *Light Music* (2004), for solo performer, video projection, and interactive device by Thierry de Mey, the interpreter – who can also, in a way, be considered a conductor – is equipped with sensors that enable him to trigger and process electronic musical events and display his movements' traces on the screen. This piece, focusing on the relationship between gesture, music, and their visualization, is the prolongation of the composer's reflection on gestural music. In *Black Box Music* (2012), for percussion solo, amplified box, and 15 instruments, the composer Simon Steen-Andersen also works on the audio and visual situation from the point of view of the soloist's gestures. On stage, a screen displays in real time the inside of a soundproof black box equipped with microphones and various sounding objects. The percussionist puts his hands inside the box and performs gestures, conducting groups of musicians displayed around the auditorium, and producing different sounds processed and played through loudspeakers. This work also accentuates the percussionist/conductor's gestures with regard to its visual and sonorous aspects: hands are almost considered as theatrical characters. (Bacot and Féron 2016)

Motivations for utilizing a hybrid conductor

The hybrid conductor in *Point Ones* is a crossbreed between two different cultures and realms. As has been argued above, the conductor finds her/himself in command of both live instrumentalists and an electronic ensemble, triggering both groups with (sometimes) unified gestures. Below I will determine five criteria for the motivations behind this deployment of the conductor.

Artistic and Substantive input

Schubert grants the conductor a significant amount of space for interpretation in *Point Ones*. The composer indicates in the legend (instructions on performing the piece) attached to the piece that this is in line with his intention:

> The length of the measures and the time signatures are therefore not very precise and can be interpreted longer or shorter by the conductor. The piece is not intended to be counted through - as you would do in another piece. The final decision in which parts traditional conducting will be necessary will be decided during the rehearsals. For rhythmically complex passages maintain the indicated tempo and time signatures will be helpful though.
>
> This concept also implies: If you [the musician] reached the end of your measure you will continue to play this note until the conductor gives the cue sign for the next passage. This is easy for long, held notes. If the end of the measure is a fast phrase / pattern - then you'll have to continue this one till the next cue sign. The exception is, if there's a pause at the end of the measure - that means you finish your phrase and then stop playing when you reached the last pause. (Schubert 2012)

In other words, the conductor is free to determine the length of a large majority of the measures throughout the piece, either spontaneously during a concert or predetermined together with the musicians during rehearsals. As a performer, I have found great significance in the pragmatically chosen (by the composer) measure structure and thus strictly adhere to it. However, that is my artistic choice and that freedom/burden is essential to this piece. Other conductors choose to freely interpret the length of the measures, either in tempo or rhythm. When ensembles decide to employ a conductor in order to perform *Point Ones*, they are utilizing their chosen conductor's artistic and substantive input. It is notable for such a 'young' piece that every performance varies greatly in interpretation (and duration) depending on the performing conductor and ensemble.

The artistic input from the conductor-soloist is also utilized to generate the intended (by the composer) experience:

> The aim is to be able to experience the live-electronics in an embodied way and to create a fully controllable instrument for the conductor. Because of that the piece does not use a click track or other timeline-based fixed approaches. (Schubert 2012)

Schubert expands upon this freedom at two points in the piece in which the conductor must improvise a solo. The first solo is in combination with the live performers and has a relatively fixed duration. During the second solo, however, the composer relies solely and substantively upon the artistic input of the conductor. No other live performers participate and not even the length of the solo (cadenza) has been predetermined. This is entirely the choice of the improvising solo-conductor.

When an artistic director or concert organizer programs this piece, they are also making a conscious choice to utilize a conductor for artistic and substantive reasons that are more practical in nature. The musician in question is asked to make a significant time investment above and beyond the normal requirements for conducting a piece. The utilized conductor must not only learn and interpret the score, they must also learn and master a new instrument.

Conductor as subject

The conductor is clearly the subject of *Point Ones.* The conductor's gestures trigger the live electronics, as well as conventionally cue the musicians. There are two long improvised solos, heavily focusing on the conductor and their link with the live electronics. The subtitle of the piece includes the words "augmented conductor." And, as argued below, it is the composer's obvious intent to focus on the conductor's role as interpreter between the audience, live musicians, and live electronics.

Having a performer serve as both the soloist and subject of a piece appears to be a trend in Schubert's compositions. In *Serious Smile,* the musicians' performance gestures become a focus of the piece as they separate from their physical instruments and yet continue to generate sounds. In *Star Me Kitten* (2015), for presenter and ad-hoc ensemble, the presenter plays the main role in a parody of a lecture on "the relationship between sound and content." (Schubert, 2015)

Economy

When looked at in a broad sense, "the economy is defined as a social domain that emphasizes the practices, discourses, and material expressions associated with the production, use, and management of resources." (James, 2015) There is a tradition of conducted (new) music ensembles. The "practices, discourses, and material expressions" of such an ensemble would include the relationship between the musicians and a conductor – two of its resources. This relationship is defined by certain keywords and key-gestures. For example, as Paul Verhaege explains it in his book "Identity," within a group of musicians, when one suggests that the music should be more *agitato* or when a conductor prepares and then gives a downbeat gesture, all present would comprehend. (Verhaege, 2012)

Without this tradition and the group's (conductor and musicians) universally recognizable keywords and gestures, *Point Ones,* would be meaningless. It relies on the audience's understanding that there is a traditional relationship between the cue-giver (the conductor) and the cue-followers (the musicians). In this sense, the economic utilization of a conductor by the composer is present and detectable in *Point Ones.*

Audience/musician perception

It has been argued above that the conductor is leading (at least) two ensembles. One of them is live and is made up of a clarinet, piano, drums, electric guitar, violin, and cello. The other is virtual and is made up of synthetic, digital, and pre- and live-recorded instruments. During a performance the audience can perceive a clear link between gesture (cues) and sound (both produced by the live performers and the triggered live electronics). A visually attentive audience will associate the movements of the conductor with the movements (and sounds) of the live musicians. They will also begin to associate the movements of the conductor with the sounds made by the live electronics (triggered sounds), especially when the live musicians are not playing.

This appears to be an intended utilization of the conductor by the composer based on both the text in the legend and on the analysis above. Here is the specific text from the legend:

> The movements of the conductor trigger and change the live-electronics of the piece. (...) The [indication] arrows give a general idea for the movement - the detailed movement can be chosen by the conductor - and also depends on the electronics triggered by it. (...) The movement of the conductor has not only a technical but also a theatrical side. Think of the conducting for this piece as a choreography! (Schubert 2012)

Measures 1-12 offer a clear introduction to the roles of the conductor throughout this piece. In the first four measures, the conductor is fulfilling their conventional role and using key-gestures to show a 4/4 measure in the indicated time and musical intensity. In measures 4-12, the conductor switches rapidly, but perceivably, between serving as the trigger for the live electronics and her/his functional role conducting the live musicians while simultaneously triggering the virtual ensemble.

For these reasons, it is demonstrable that the composer has utilized a conductor to enhance the audience's perception of the live electronics. By having the conductor trigger/cue both "ensembles," it can also be argued that the composer has intentionally drawn even more attention (from the audience) than usual to the conductor's gestures.

The first twenty-six seconds of the video linked below contain the first twelve measures of *Point Ones,* performed by Nadar Ensemble with Daan Janssens as the solo-conductor. This video serves to demonstrate the arguments made in the preceding two paragraphs.

> Schubert, Alexander, *Point Ones for Augmented Conductor and Ensemble,* performed by Nadar Ensemble and Daan Janssens (conductor): https://youtu.be/CN-rIIuyNbY

Visual component – movement repertoire

The presence of the conductor in *Point Ones* is no secondary phenomenon of the music. Recognizable and conventional conductor's movement repertoire is a central theme of the piece and it is ubiquitous throughout the whole. A trained conductor is utilized for the visually apparent conventional key-gestures associated with the role. This also appears to be the intention of the composer. Schubert writes in the legend:

> At the end of the piece most of the cues should be - even more extreme than in the beginning of the piece - interpreted as "traditional conducting cue gestures". This can include for example: Giving an instrument or a group of instruments a cue, a stop gesture, a fade-out gesture or anything you can think of. This is partly true for other cues as well (do as it works for you) but asked for in the cues with the "☛"icons." (Schubert 2012)

Schubert ensures that the universally recognizable conductor's movement repertoire and key-gestures become central to his piece by the attaching UIs (two WiiMotes) to the conductor's wrists. The movement repertoire is literally mapped live and gestures themselves have become artistic stimuli. This differs from previous works because there is no fixed-media (requiring a click-track) and seldom does a secondary person (a technician) trigger the electronics. It is the conductor's gestures themselves that cue both live musicians and the live-electronics. It is therefore evident that a conductor and conductor's movement repertoire is deployed in *Point Ones* by the composer.

Conclusions

The role of the conductor in *Point Ones* has inherent responsibilities that differ and go beyond that of the conventional conductor. In the first section, it was demonstrated that the conductor spends the largest quantity of measures in this piece conducting the virtual instrument. The word conducting is used instead of playing because universally recognizable key-gestures present in the conductor's movement repertoire are artistically utilized by the composer to trigger the live electronics. By employing exactly these conductorial key-gestures, the conductor's conventional responsibility to direct and cue the live musicians is not limited, but rather augmented and enhanced. Their gestures cue both live performers and trigger virtual musicians, sometimes at the same time.

This paper has also argued that *Point Ones* is a part of trend in new music in which the conductor's role, and the enhancing thereof, plays a central part.

And finally, five criteria for utilizing a conductor in new music are present in this piece. When programmed, the presence of the conductor is not a secondary phenomenon of the music, but an essential aspect of the piece and a clear artistic choice made by the composer and programmer/concert organizer. The conductor is deployed for their artistic and substantive input. S/he is the subject of the piece. And, the tradition of the conducted ensemble and its universally recognizable key-gestures and movement repertoire (a visual component) lend meaning to the piece both economically and in assisting the audience's perceived perception of the live electronics.

Notes

1. When the term "new music" is used in this paper, it refers to music that has been written since 1950 and in the Western art music tradition.

2. This research is part of a larger PhD-research trajectory. The central hypothesis of that trajectory states that artistic directors', musicians' and composers' decision(s) today to utilize a conductor in new music ensembles are for reasons that can be divided into one or more of the following five non-exclusive criteria:

- the **artistic and substantive input** of the intended conductor;
- the presence of the **conductor as subject** being central to the piece;
- **economy** (as in required or available rehearsal time, difficulty of the music, and tradition);
- the **perception** of the audience of a piece, program, and/or conductor;
- **recognizable conductors' movement repertoire** is integral to the piece – both musically and visually, his/her presence is not a secondary phenomenon of the music.

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Stian Westerhus

Transcending the interface

Paper

Video of presentation can be found here

Transcending the interface

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Abstract. A musician- and composer's perspective on how working with interfaces, performative formats and exploratory instrumental practices has fuelled a deeper understanding of the process behind musical improvisation, human choice and abstract contextual musical value, this seen in the light of the present-day digital analytical tools offering new ways of definition and musical governance as the instrumental idiomatics are redefined.

Keywords: improvisation, composition, instrumental practices, idiomatics, musical governance, machine learning, AI, singularity, aesthetics.

In 2016 I started my artistic research project at NTNU called "The shape of Concerts to come". Within the project I wanted to explore the musical meaning of the instrument in my improvisational and compositional practice. Throughout my musical career as a guitarist and composer I have done hundreds of solo- and ensemble concerts and consider the concert setting, in a club, on stage, with a full-scale PA system to be an integral part of the instrument. The actual act of playing the concert has become so tightly connected to the improvisational practice I found it hard to play otherwise and I wondered if it was at all possible to detach it, change it, and to see what any practical changes done to the instrument as a whole might give musically.

The research question and strategy, I must say, was a typical one with a focus on the tangible elements of the music. Take what you know and try to change it to see what difference it makes. At this point I should note that I by no means felt that my instrument was of any hinderance to me in the act of playing these said concerts, and in fact I have felt incredibly empowered by the sheer force, and the dynamic- and expressive capability of my extended instrument, so why did I feel the urge to change it? About a year in, and I realised I didn't. In fact, it was a contradiction.

Throughout my entire career I have drawn a hard line for myself when it comes to electronics and extensions to my instrument. Yes, I have utilized electronics to extend the range and dynamic flexibility, and I have certainly used electronics to magnify extended techniques which would otherwise be impossible to use in a musical setting, but I have continually asked myself whether the electronics I used were a necessity for the way I wish to play, or if the effects, in themselves, were generatives, as in some might spell out a musical landscape I can only take part in, or even create their own music and expression where my role would be more of that to control it. If the latter was the case I would remove them in order to take back control of the instrument. I tend to think of my instrument and the act of playing it like this:

In the core, the mind - the ability to play without playing. To hear and improvise music in much the same way as I do with the instrument in a performance setting, but without the instrument. To fully engage in the music, without an output at all. Already here we might start to see where the contradictions loom.

Secondly; "acoustic instrumental proficiency". This refers to the technical ability to be so well connected to the instruments sound generators, in my case mainly strings in one way or another, or it's touch interface as we might call it in this setting, that the interface in itself is of no hinderance to the player for producing the sounds that are possible and are at the best of times directly connected to the emotional expressivity of the mind. The sound of a single pluck of a string draws from thousands of factors which is built up though thousands of hours of practice, and the proficiency not only to be able to play, but to acknowledge the capabilities of the instrument's inherent expressiveness, and to be at one with this expressive capability is all within this onions layer.

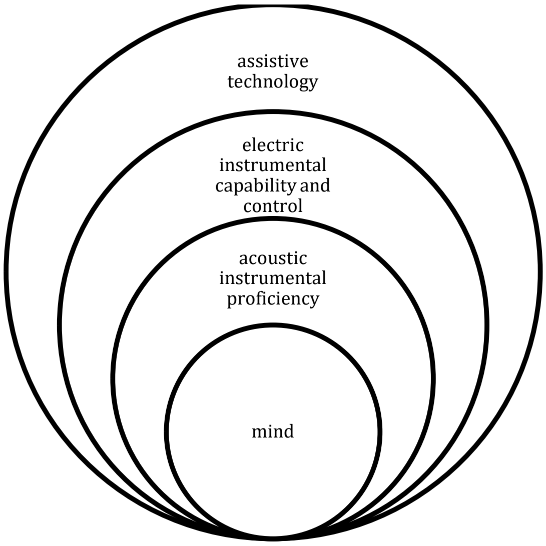

Figure 1. Instrumental layers (Stian Westerhus)

Next to the outer ring it reads "electric instrumental capability and control". This is where a physical acoustic instrument meets the electronics. In my case this as a guitar connected to the amplification without any other electronics. The sound is amplified to such a volume that the acoustic possibilities within the instrument changes. Resonances, sustain, frequencies and the interplay of feedback, not only as loud howls of uncontrolled noise, but the subtle resonating feedback in the strings, the bodily resonance of the wood, the proximity effect of certain ways of playing the strings are just some of the many aspects amplification adds to the previous layer of acoustic instrumental proficiency, and then we haven't even touched upon the technical aspects, such as gain staging, frequency linearity or volume, that play in to the abilities of maximizing the instrumental expressive potential and controllability. As with the second layer, the acknowledgement of this layer's factors should be emphasized.

The outer ring reads "assistive technology". From the subtle analogue overdrive that slightly compresses certain frequencies when pushed hard to the digital effects that can interconnect in complex ways in software. These are additional tools to the instrument and used correctly they become integral parts of the instrument in the same way as amplification amplifies the acoustic potential. The assistive technology amplifies, or make possible if you wish, the next step of the capability. It is the electric motor in the bicycle. On its own it is useless, though interconnected to the already fully ended potential of the bicycle it not only becomes valuable in its own right, but the potential in itself is of much greater value as a whole. The bicycle is an instrument for getting you from A to B faster than walking based on your leg's muscular capability - the bicycle lets you insert your muscular potential, multiplies it by using gears and wheels, and in short gets you home in time for dinner. The electric motor takes that same potential, and extends it by helping you turn the pedals when your own potential isn't really cutting it and the going gets tough, but extending the potential also makes new things possible - like cycling up a steep hill you wouldn't even bare walking the cycle up, with your kids on the back, a rucksack full of food, whilst talking on the phone to your wife and not breaking a sweat. Great potential - great assistive technology takes that potential and multiplies it.

Now, since we are at this image of the sleep deprived father who after extending his own genetic potential in the past few years has just picked up his kids from school and kindergarten, let's back up to this idea of generatives in this outer ring of figure 1. When I say I've tried to steer away from assistive technology that dictates the music to an extent I find obtrusive, this would be calling this fathers transportation vehicle a bicycle when he was clearly driving a car. Not that I don't respect fathers who pick up their loved ones with cars, or motorcycles for that matter, but I would find it strange to see that same man in cycling wear pretending to be riding a bicycle whilst getting in to his BMW. It could be the same thing of course. He would get from A to B, but the potential that started out with his muscular strength isn't utilized in his car.

Every single slice of the onion has an interface, of course. The assistive technology needs an interface to be controlled and/or modified, the amplification - the same, the guitar is in its own right an acoustic interface for sound creation, but what about the mind - because where does this music come from? From the instrument? Is it a creation of the mind, or is it even the same as the mind? Can the mind be seen as an interface for the instrument?

I recently released a new solo album and was asked in an interview with No-Wave magazine: *"what is channelled when you improvise and from where?".* It was a puzzling coincidence that I found myself the night before in Vega Cinema in Oslo to see the first screening of a film where I, 5 years younger, in 2015 was struggling to find answers to similar questions. In the film "Randsonen", which translates to "on the borderline" the director of the film, Tom Hovinboele, interviewed and followed six different improvisors and composers in a quest to understand what experimentation and improvisation means and the processes behind the creative output. At that time, I was starting to see the classic idea of myself as "an artist who could push hard enough to squeeze music out of the instrument with my sheer force and skill" was cracking.

The research, the instrument and most importantly the contradiction is where I would look for answers. The research reflects where I thought I could alter my music which in 2015 was starting to feel somewhat cemented and repetitive - the practical elements - the focus on altering various interfaces and acknowledging even more outer factors and interfaces like the club setting, surround sound and more - was, and still is contradictory to everything my entire musical philosophy and work method has dictated, but I hadn't seen it clearly until now.

That doesn't make it wrong necessarily but seen in that perspective there is a light that can be directed in the opposite direction. Remember, I had tried to extend my instrument in all directions to maximise the flexibility of its potentials without losing control. My view on the instrument was and still is strictly technical. It is only there as an extension and an interface to my music - and there it was! My music. My music is not the instrument. In the original research I set out to explore what would change if I changed my instrument. Of course, the instrument can be further developed to facilitate a different palate of musical expression, but it will still be my music, and if I change it so that I play my music differently - is the music, in itself, really different?

I will be the first to acknowledge the fact that yes, I do believe that my music is what it is both from playing a specific instrument and listening to related music, but that still doesn't spell out in clear text that all my music, lives within the instrument and changes from mere technical alterations to its interface and inherent powers. My musical intentions do not, but I might make changes to the instrument/interface to cater for changing musical intentions demanding greater flexibility.

If this contradiction wasn't embarrassing and challenging enough it sparked the existential question: what is my music? Not how it sounds, but more like a "what" which also needs a location - a "where is my music?". (at this point I started to wonder if this was the 40-year mid-life crisis everybody keeps talking about - I had hoped for something like a Norton Commander 750 motorcycle, or at least a fascination with BMWs.)

If I try to see beyond the creative processes, beyond the instruments inherent idiomatic, beyond the creative use of limitations, concepts, extensions and what not, beyond social or even biological factors, where does it start? How does one person end up with a completely unique musical reference?

In my mind I give meaning to musical entities and out of them music is like abstract contextual structures, and those structures - they can be interpreted as music with an inherent musical meaning. Combine this with instrumental-, theoretic- and technical ability, active referencing and an instrumental output - for me that is a general overview of my personal expression, but more importantly it describes the interface of the inner circle: the mind is an interface to the abstract measures that are uniquely us as interpreters of music and connected to the extension of the instrument - the extension being the body.

There's a saying that almost all jazz students at Trondheim Jazz Conservatoire can relate to - it's: *"you have to become your instrument."* This is said in the context that you have to know it so well that it disappears, that it is of no hinderance to you. I can truly say that this technical ability is something I myself strive for, but this new perspective of what my music is enlarges the meaning of it. Seen as layers of interfaces the mind in its own right becomes an interface connecting the body and thus becomes part of the instrument. You have to become your mind.

If I change my mind - does it make my music different? (don't worry, it's a joke) Let us read again the description of the inner ring: In the core, the mind - the ability to play without playing. To hear and improvise music in much the same way as I do with the instrument in a performance setting, but without the instrument.

Then what is the mind playing? When I look at my six-year-old at home dancing and singing songs she can hear in her head - she's responding to the feeling of the music in much the same way as I am when I try to practically answer the question in the interview, but when playing a concert. The only difference might be that I have 35 years more listening under my belt and have learned develop analytical hearing and to mirror what I have heard on my instrument - recreating the ipso facto sounds of others. What I have not learned is how that feeling of music - that preference - that goose bump-moment - that, god forbid, "magic" has shaped my musical output. What happens to music in the deep states of our subconsciousness when you go through years of intensive listening to music that floods your brain with both pleasures, wonder and a feeling of belonging? You practice musical theory, instrumental technical ability, and go through the musically driven social networks, listen to music whilst going through life changing experiences. You grow up, with, together and in your music.

Remember that single note with all its thousands of factors, abstract networks of decisions formed in a single sound of an individual human's expression. People who think you can express everything through analysis and recreation have not experienced true musical meaning. Or the acknowledgement of its existence.

If seen in the context of layering interfaces - the acknowledgement of the proficiency the human mind has in acting as a managing interface of its own abstract network of musical entities is of the greatest importance, and now maybe more important than ever.

In my own practice the acknowledgement has been a pulveriser of the ego. Before I would brace myself before entering the stage to play a solo concert. It felt like a combination of preaching a strange holy gospel as much as going in to a boxing ring, ready to find this mythological focus, fight the instrument and in many ways fight myself. I had to convince myself that I, myself, had the answer. That I could dictate my music and persuade every one of its value.

With an understanding of what my music is I now have no choice but to trust it and let it be. I'm 40 years of age. I have, like most people, a ridiculous amount of musical meaning internalized, I just need to concentrate on managing it - both by acknowledging its existence and also through attaching the interface of the mind, linking the mind to the body to the instrument - in the most direct and unfiltered way - without trying to shape it or change it. There is no NO, there is no WANT. You are what you are, the rest is technical machinery, your physical body is just an extension of it as much as the assistive technology is - and your ability to make your music transcend the interface lies with the technical control of both the mind, the body and the instrument. You can't escape yourself.

Also, by doing so there is almost no need for "me" - as in the me earlier described - on stage - the ego. The decisions are in many ways already taken in that they are decisions regarding the previous musical input rather than the current output. The building of musical entities and its inherent structural potential is already there. "I" am on stage now. It's too late to be somebody else. By managing these musical entities and their inherent possible meaning through contextual relationship with other musical entities endless musical meaning is made.

So apart from being a fundamental in my own creative process, a tool to lift the focus away from the instrument and the performer as an instrumentalist - why is this more important than ever? Well, the keyword is definition - and the price of it.

With what you are about to read I should make it clear that I am in no way objecting to research on machines that take so called creative choices, but in this perspective of myself as a performer of my own musical entities - I am questioning if I can bring myself to give music that comes from generative machinery any value. I previously described the processes of removing generative parts of the instrument in order to keep a streamlined control, but as generative machinery's complexity through revolutionary processing powers is surging it is interesting to investigate what this does to the hierarchy of interfaces earlier discussed.

In a machine's abstract neural network - with an aim to take musical decisions; can the analytical powers compensate for not having a sense of itself as a being whilst learning? If we abstain from acknowledging the subjectiveness of expressivity in music - then yes, the complexity can surely act on many of the same levels but take a musical project where you have what is often described as interaction between a human and a machine. Let's say that the machine mirrors the human and both listens to the human and reacts with own sound through its generative output. What is it listening to? Does it acknowledge the expressions and emotional content, the context, its own role in the interplay? On the surface - this seems possible. If you would program it to find references in its own networks to portray a sense of emotional content to the listener, build contextuality within the music and reference human-like expressive structures, then yes, possibly you could create a sense of human-like interaction, but it would not be able to experience these feelings in itself. It has no emotions, it has no real fear, it has no empathy. What it has learned is a way of defining human output. There is of course an enormous complexity to be had within analysis and definition, but as an interface - as it might well be seen in the interplay within the fictional example, If I can play the role of the human; I would need to acknowledge the fact that I was playing with a dead being. If I played with another human I would on many levels experience empathy for their ideas and output and have respect for the fragile situation of creating music together, as I would expect the same attitude to a certain extent from my fellow musician, but with the said machine - what we would share would be the lack of empathy for each other's output.

Maybe more importantly it would bring to mind the question of what my musical meaning was worth when it would be analysed and used to create music with caricatured meaning - to put it bluntly. What would the human complexity be reduced to? The emotional content of my life flowing through the streams of music - only to be used as variables to create complexity in an output. Zoom out wide enough and it looks like there is a coherent image, zoom in and the picture is just a thousand of pieces of puzzle, all from different puzzles, in an unintelligible and thus uninteresting context.

The way I define the governance of my improvisatory musical practice, the act of creating music, define the instrument and outline a clearer map of the process - the clearer I can see which interface, tool or layer does- and affect what. The change of thought and the clearer definition of subjective musical ethics, has opened up a space that for me seems to lie between what we know, such as musical theory, technique, technicalities etc. and aesthetics. It is shining a light on how subjective musical meaning is built within a performer and the acknowledgement of its existence. As a performer the acknowledgment of musical meaning will change the Shape of Concerts to come, and hopefully keep changing my music, forever.

Stian Westerhus (Photo by Voldseth)

Bruno Pereira and Pedro Santos

MIRROR Espelho meu - Performance/installation for voice, body and image

Paper

Video of presentation can be found here

MIRROR:
Performance/installation for voice, body and image

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Abstract. This paper explores the creative process related to the performance Espelho meu (Mirror), premiered in 2017, in Porto. This performance is the materialization of a creative process into the artistic gesture of the performer. We believe that the creation of new performances is the most effective way to develop the contemporary performative scene promoting new visions of the world. We will briefly discuss the process of creating a vocal gesture that externalizes an inner thought, the role of the body, the cross paths between artistic practice and technology as a mediation that doesn't limit the performative interaction of the performer with the space and the audience. We will also consider ways of exploration of the performance after its physical existence in time through the concept of performative resonance. This resonance would work as a creative tool, again mediated by technology, to reconfigure time, provoking the ephemerality of performance.

Keywords: live performance, vocal improvisation, body, performative resonance, multimedia, programming.

Introduction

In this paper, we want to present the process of conceptual creation, performance and reflection related with the work *Mirror*. This performance/installation for voice, body and image encloses in its description some of the key issues to be developed in the next pages. The performance itself relates directly with the core of the physical manifestation of a concept, of a thought. It comes with the strong belief, expressed during this text, that the creation of new performances is the most effective way to develop the contemporary performative scene. The second layer is present in the installation. It points out to an important issue in this work, an interesting concept that we have been developing in this and other performances/works: the performative resonance. This concept works around the concepts of time and the related ephemerality of performance. For this purpose, it's also described the relevant role of technology, as an interface that grants us the possibility of materializing our conceptual ideas in the performance and installation.

Following the path showed in the performance's title description we arrive to the voice and body. The voice, inseparable of the body in our assumptions, works here as an interface too, that connects the inner thoughts with the exterior world of sounds. In this context, and with a strong improvisation drive, we reflect on its expressive role, always linked with the body, and, in this case, linked with a text.

At last it's also referred the visual layer of this work, through the video projection. This reveals the multidisciplinary characteristic of *Mirror*, important for the increment of layers for those who receive the final object. This performance works referentially to some of the work of artists such as David Moss, Jaap Blonk, Meredith Monk, Merce Cunningham and Laurie Anderson.

Mirror is structured on a constant overlapping of different layers of contents and time. This creates, in each moment, a renewed space-time relationship, promoting a permanent internal movement, a metamorphosis that, conceptually, never ends.

MIRROR: performance/installation

Mirror[1], premiered by the authors on March 10, 2017 at the Faculty of Fine Arts of the University of Porto (FBAUP), is a series of 3 small performances of 9 minutes each that continue in performative resonance (see the performative resonance section of this paper). The 3 performances of 9 minutes are divided in 3 episodes of 3 minutes each.

The first performance triggers the beginning of the installation. It then persists in a slow and progressive metamorphosis through the use of software-controlled processes that record, manipulate and reuse the performance. Each subsequent live performance interacts with these manipulated excerpts of previous ones. Additionally, it is also added to the system as new source material. The installation culminates with the third and final live performance, on March 13.

During the 9 minutes of the performances the audio is played through a set of 4 speakers distributed around the performance area. Using two projectors, video is displayed on the gallery wall behind the performer. The installation part, as referred, happens in between the live performances, without the physical presence of the performer. Visitors of the installation can watch the video projection in the wall and listen to the audio using two pairs of headphones clearly visible in the wall. The same visitor may experience it differently in each moment as the audio and video are algorithmically programmed for a permanent transformation of the pre-recorded material from previous live performances.

Mirror is a performance/installation in a metamorphic cycle by its internal evolutionary process.

Figure 1 - Performance of *Mirror*, 10.3.2017, FBAUP

Assumptions and contextualization

What does it mean to express one's idea of some inward or "subjective" process? It means to make an outward image of this inward process, for oneself and others to see; that is, to give the subjective events an objective symbol. (Langer 1976, 80)

Mirror has a focus on the exploration of the improvisation as a tool of greater creative freedom, referring us to what seems to be one of the possible and most interesting ways to contribute for the continuous development of a performative language. It intends to be a small contribution in the construction of a new contemporary performative

[1] In this link the reader may find the video of the first performance of 9 minutes: https://www.youtube.com/watch?time_continue=4&v=zMDUOFfncM8

gesture. A gesture that appears and then fades away as an object in permanent becoming, in a metamorphosis movement, in a specific time, space and context.

Mirror is a suspension tattooed in the time that receives it. This written output is the answer to the challenge of putting into words what is born of a gesture, a non-linear thought that acquires visibility through devices such as a body and a voice (Pereira 2016).

These words are like another embodiment of the intangible. Parts of the creative process have reached their visible side by way of *an appearance*, as Susanne Langer (1976) would say. This appearance, this dynamic image - to use another concept coined by Langer (1976) that, read by Deleuze and Gil (2001) is embodied in the "plane of immanence" -, is not only a set of physicalities that unfold before us. There are virtual entities that, although they do not have a physical nature like ordinary objects, are real and perceptible. Virtual, precisely because they exist only for perception. Real, when perceived.

Mirror was willing to work around the "plurality of ways and means of being-in-the-world, of reflecting and producing versions of the world" (Hannula 2009, 31). It was searching a way of inscribing in our body, in our voice, in our ears, in our eyes, in our thought, singular versions of the world.

In *Mirror* it was decided to develop work in the experimental field of performance, breaking conventions, not by its denial, but by the need to confront the acquired models, as frames of artistic reference that nevertheless serve as a basis for their own unfolding. The acquired technical and aesthetic models unfold themselves in order to confront each other. The voice and the body unfold and gain a character of otherness. The voice *other* (Pereira 2016), which serves as mediator, in permanent interaction with the body, of the intangible of thought. A voice that is close to the primordial root of expiration, close to an unfiltered authenticity, close to the authentic self.

In a foundational multidisciplinary perspective, we take as an example, among others, the dancer and choreographer Merce Cunningham whose new choreographic language was born simultaneously from the "critique of previous [conventional] languages and a virgin soil." (Gil 2001, 39)

There is the will to build, in this performance, an "unusual spectacle, a mystery whose meaning he [the public] must seek out." (Rancière 2009, 4) It is expected that this type of new performances may compel the spectator to "exchange the position of passive spectator for that of scientific investigator or experimenter, who observes phenomena and searches for their causes."

The mirror as element

Using the mirror as a central element helps us distorting a linear time and space. Foucault (1984) says, in Dits et écrits, on the relations between utopia and heterotopia, that:

> [The] mirror is, above all, a utopia, since it is a place with no place. In the mirror I see myself, where I am not, in an unreal space [...]. [...] a heterotopia, since the mirror really exists, and where it has, on the space I occupy a kind of opposite effect; it is from the mirror that I am absent from the place where I am [...]. (Foucault 1984, 47)

The mirror is a fascinating element starting from either the mirror as physical object or as a virtual mirror that exists only in a layer of reading a space and a time.

Mirror departs from a site-specific approach and interacts, from its conception, with space and time (9 minutes of performative act/9 columns at the top of the FBAUP entrance foyer, 4 slices of video projection/4 columns at the bottom of the same foyer, a statue/a performer) from there to the deconstruction of a possible pre-signification.

This appropriation of space in the decision of the work macro-structure, as well as of its presentation, is another way explored to remove obstacles between public and performer, between space and event, allowing the non-imposed interaction, creating the ground for a meeting between performative exteriorization (an output of the performer) and emancipated reading (an output of the viewer).

The concept of mirroring goes through the entire process of creating the work including its text, in Portuguese, written for this performance. The questioning of the mirror and an elaboration on the authenticity of its reflex took part in the construction of the text that accompanied the musical and sonorous development of the piece.

> Espelho meu, espelho meu, quem espelhas tu que não eu? Quando olhamos para um espelho... é como se nos desdobrássemos noutro ser que estranhamente se parece com a imagem que temos de nós próprios... Não fossem os espelhos e nunca nos teríamos em todo... em espelho... ali... (*smile that becomes a laughter*)... ali… Será aquele espelho verdadeiro? Porque será outro espelho mais verdadeiro do que este? Ali... é incrível como sai de dentro, de dentro de nós, e se põe ali, em frente, escancarado.[2]

Performative Resonance

In the performative resonance, performance is used as a raw material for its own transformation, functioning as the thematic material that will be shaped in a new temporal linearity, a new sequence of *nows* (as Heidegger would call it). In the performative resonance a new spatial-temporal relationship appears with the overlapping of past fragments of time, recombined, transformed, filtered, creating a *zone* (Gil 2004) of the result of the set of micro-perceptions that frame the macro perception of the experience.

This experience, controlled by the interaction of the micro-perceptions, allows the existence of new layers of the macro perception of each instant and, as such, allows the construction of a new and unique present. This interesting feature challenges the works to an exercise of reinvention of a stretched time. This reinvention leads to the metamorphosis of the performance into an installation, or in any other format, identified here by the concept of performative resonance. It is, basically, to explore the potential of a non-linear time that is fittest to translate a thought that is also non-linear.

Byung-Chul Han (2016) considers that thought "has a particular temporality and spatiality" (129). The thought runs non-linearly and reaches this freedom precisely because it is not possible to calculate the time and the space where it develops itself. If this is the case, time, the environment in which the same thought is effective, where it acquires body, must also be free and tendentially discontinuous, not because it must be, but only because it is naturally like that when it accepts its mission of welcoming the substantiation of thought.

In *Mirror* we consider an elastic time, conceptually non-linear, which leads us to a place where the body of the performer becomes time. A space-time that feels no need to be measured or to be aligned. A space-time other that is expected to be able, given its elasticity and complicity, to transform the expected context into another context that is reflected in the space-temporality of the immanence of the work.

This concept of performative resonance can earn even more interest if we consider the difficulty of preserving the performances through documents that capture the ephemeral nature of the performative works. However, this documentation is naturally incomplete, since core issues are lost at the level of spatio-temporal experience and the original context. The performative resonance allows the creator himself to manage the work and its presentation / representation in a coherent way. Is it possible to propose a work that already considers its metamorphosis in time?

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[2] Text's excerpt in Portuguese translated into English here, in foot note.
Mirror, mirror, who do you mirror that not me?
When we look at a mirror ... it is as if we unfold ourselves in another being that strangely resembles the image we have of ourselves ...
If it were not the mirrors, we would never have ourselves in total ... mirrored... there ... there…
Is that mirror real? Is another mirror truer than this one? There… It's amazing how it comes from inside, from within us, and it stands there, straight ahead, wide open.

That considers, from the scratch, a form of self-preservation? That considers its own re-enactment? Is it possible to act on the tension of the ephemeral temporality of a performance by stretching it out in a perspective of extending the ephemeral moment of the physical performance and where the performer's presence may not be materially constructed? We believe it is possible with the use of the performative resonance and *Mirror* is an additional contribution to experiment these possibilities and to go deeper in discovering the added value of this concept. One may argue that it's just an effect or a theoretical jargon, but we believe that, if deeply instated in the conceptualization of a work, it will impact subtly but determinately in the visible output of the performance. Although apparently subsidiary to performance, yet the resonance keeps the tension and the performative drive.

Returning to the fruition perspective of the performative resonance, we prefer to consider that the public's experience in relation to it is managed by the auditor himself who makes decisions about the time of contact with the resonance of the work, thus presenting a greater degree of openness within the concept of open work, consolidated by Umberto Eco (1991).

In *Mirror*, the work is structured in 3 performances that resonate, which means that the second live performance already interacts with the resonance of the first live performance and consequently the third live performance will happen with a cumulative result of the performative resonance of the first and second performances. Thus, the performance generates its own resonance and receives it later as a performance itself. A spiral is created that reuses, at a higher level, the same thematic material that, due to the temporal mismatch, acquires a new meaning and impacts differently the development of improvisation and performance. This becomes possible using a technological interface that is fed by the performer itself that provides content to be reused by the machine. We may then consider, and assume conceptually, a content driven control. The control of this part of the technology is done in a deferred way thus freeing the performer from the role of a user of the technology, making the whole process more organic. The focus is on the performance and the technology becomes transparent. The system voice/body is the first layer of mediation followed by the technology as a second layer in the same process.

We consider having found a relevant tool to be explored creatively, within the framework of performative creation. This can also allow the creator to extend the ephemerality of the performance or even consider this extension as a constitution of its own archive. The performative resonance, when one opts for its use, directly impacts the design of the work, since it transforms the temporal relation of what is performatively drawn.

Technological Implementation

In a traditional context of musical performance practice, most musicians perform works by composers using a pre-conceived instrument; the distinction between composer, performer and luthier is most of the time very clear. In fact, we could argue that it takes a necessarily different set of skills to effectively accomplish each of these functions. However, in the current landscape of audio-visual improvisation/performance practice, to which this work belongs, these roles are most of the times interwoven or even superimposed. In a sense, artists also need to be the inventors and engineers of their own instruments in order to perform. Currently, propelled by advancements in technology, the lowering of its cost and its increasing ease of use, using programming environments such as Max or Pure Data artists are able to materialize their concepts, realizing their full creative potential by building custom solutions for each artistic project, if needed, and tailor them to very specific tasks. This section aims to describe the technical specifications, procedures and related custom programming of the audio- visual installation. Additionally, we will also focus on the decisions and the development of the real-time control of the programmed system by the performer.

The proposed system had the function to record, process and manage the playback of video and audio content, in a feedback chain with the performer. Figure 2 illustrates the spatial arrangement intended for the elements, with the performer in front, complemented by 2 projectors beneath him (each divided in two separate spaces) and 4 speakers (2 at the front and 2 at the sides). A microphone and a video camera are also present, to capture each performance for further processing and playback.

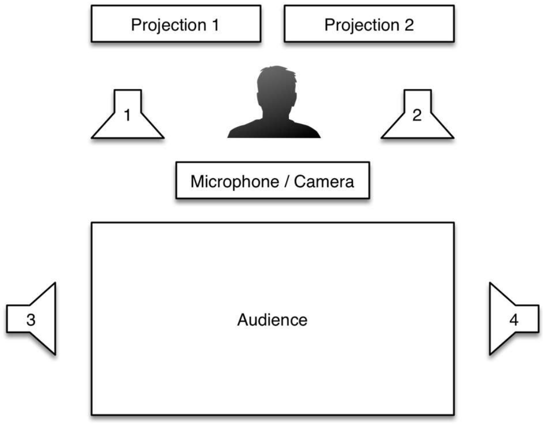

Figure 2 - Schematic of the installation

The main hardware setup of this performance/installation consisted of a computer equipped with a multi-channel audio interface and a graphic card with 3 separate outputs. The audio interface was used to receive the sound captured from the performer's microphone and to output the resulting audio through separate channels to the 4 speakers and to a headphone distributor. The nearest pair of speakers to the performer were responsible for playing a previously structured sequence that served as the base content. This linear media was produced using a DAW[3], deconstructing parts of the text with a differentiated articulation of the phrase and its syllables.[4] In contrast, the lateral pair of speakers were filled up with recorded excerpts of the performance, played in a semi-random manner, with a temporal discontinuity and overlapping sound elements throughout the installation period. For the installation to not disturb the regular activity of the facilities, a separate audio mix containing the contents of all speakers was purposely built and sent to the headphone distributor, allowing for the audience to experience the installation at any time using two pairs of headphones.

Concerning the video, the graphic card's outputs were connected to two video projectors and to an additional computer display. This display was used to monitor and, if required, to operate the software without interrupting or disturbing the performance/installation, since it is one of its requirements to be continuously running for several days. Content-wise, we worked on several pre-recorded videos shot with the concept of a transforming mirror. In that regard, we captured images that usually do not hold our attention on our daily life with a particular attention to the lights as they have a fundamental role in the way we see what surround us. The performance's rehearsals were also recorded, with the intent of including the experimentation process, as it already encapsulates the potential of the final performance. Lastly, the video camera connected to the computer permitted us to also capture snippets of the live performances for later processing and reuse. The same principles of content manipulation were applied to the visual part of the system, resulting in a progressive growth in rate and density of the elements.

The programming of this audio-visual system was accomplished with the Max visual programming language. A small set of audio and video assets was previously prepared to serve as the basis for the performance. The application we developed received the captured audio and video contents of each performance and saved the resulting files to a folder that was being periodically scanned for new content. This way, the files of each recorded performance became available

[3] In this case we used the software *Reaper* to build the fixed media. The multitrack editing enabled us to create the different layers of deconstruction of the text. All the audio content is created using the performer's voice.
[4] Some of the possibilities that were used in the process of deconstructing the text: Espelhastuque, Espelhastuquenão, tuquenão, espequenão, espequeu, espelheu, tuqueu, quetuque, quetuquenão, quespetuque, lhasquenão, lhaseu, queu, queque, quequenão, tueu, lhastu, [...]

as material that could be used at a later time, in a processed and non-linear manner. Figure 3 illustrates some of the options taken to build the partially random nature of the audio and video playback system and its progression throughout the installation period.

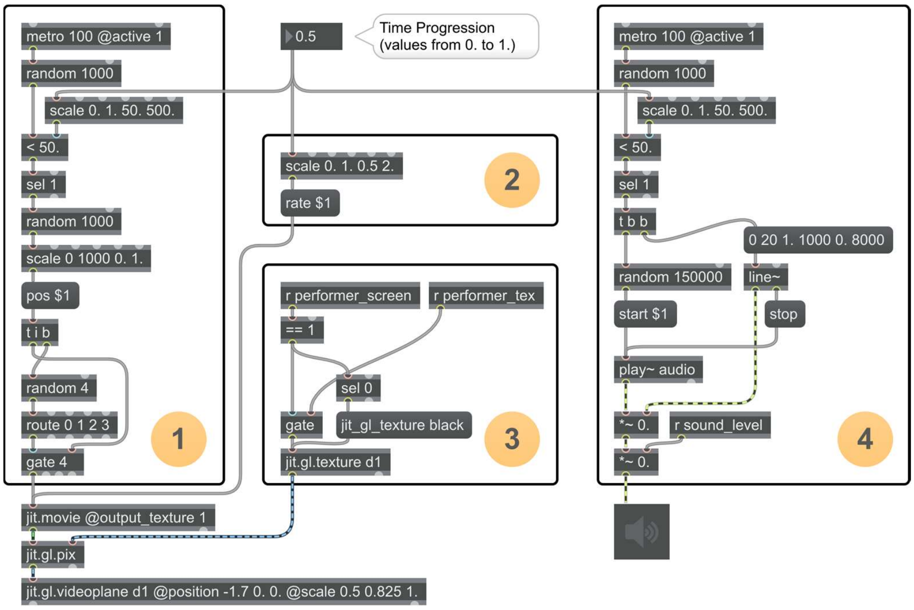

Figure 3 - Excerpts of the audio and video playback implementation in Max

1- In section 1, the probability of triggering a temporal discontinuity for the playback of the pre-built video sequence is calculated, progressively increasing from 5% to 50%. After this, the time position is randomly chosen and sent to 1 of the 4 available spaces.
2- In this section, the rate of playback of the mentioned video is also increased, from half the normal speed to double speed.
3- Section 3 receives videos recorded in previous performances. These performance images follow a similar pattern to the one described before and are combined with the existing material in a randomly chosen space.
4- In this section, we demonstrate the methodology behind a random audio excerpt, with the particularity of modulating the audio with an amplitude envelope (fade in/fade out) in order to seamlessly integrate them in the end result.

The video programming took advantage of the OpenGL graphics API whenever possible, using the GPU to accelerate most procedures, instead of relying on the main CPU. This approach gives us good graphics performance (multiple screens, high resolutions and high frame rates) as well as the added advantage of freeing up the CPU for the processing of audio tasks, thus increasing the overall stability. This is undoubtedly a key requirement for a system such as this, since it's intended for it to be continuously active for days on end.

In this performance/installation, as we intended for the live performer to focus on freely exploring its voice and physicality, we tried to minimize the level of explicit control he would have over the programmed system, as feeding it content-wise already plays a fundamental role on both the conceptualization and the materialization of this artistic work. Nevertheless, there are a few ways in which the performer can directly interact with it, described below. Given the conceptual importance of the body, and the fact that we were already capturing the performer as source material for further processing, we thought that a computer vision approach capable of detecting the performer's presence, its position and amount of movement would be appropriate. The performer's black outfit further aids in this process by making it easier to the system to distinguish between him and the background wall were video content is being projected. We didn't have the intent of making the audience conscientiously aware of the mappings between this detection and the audio-visual response of the system, preferring instead to consider it as an opportunity for a deeper consonant discourse between the performer and the system.

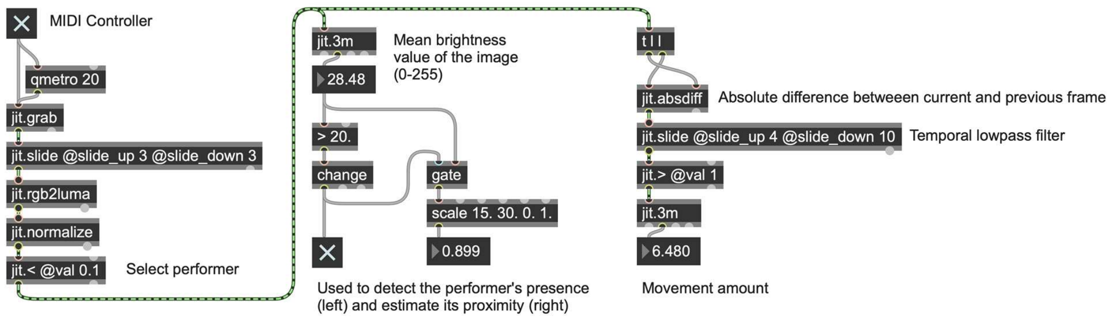

Figure 4 – Max/Jitter image processing algorithms to detect the performer's presence, movement and proximity

After the initial setup and configuration of the system, on day one of the performance/installation, a MIDI controller switch is used to start the installation. An additional MIDI controller can switch between performance and installation mode, which have different requirements as described before. In performance mode, the video detection algorithms are turned on and, shortly after the presence of the performer is detected, the system turns on the microphone input, switches audio from the headphones to the 4 speakers, starts playback of the pre-recorded content, and starts recording the current performance, given a minimum amplitude threshold.

Another parameter being continuously measured is the amount of movement of the performer. This directly correlates to a modulation in the rate and density of the algorithmic audio-visual content playback. Lastly, we used an estimation of the performer's proximity to the camera (and therefore audience) and reflected that on the level of intimacy of the sounds. As the performer gets closer to the audience, its live voice becomes progressively highlighted from the pre-recorded content and the reverberation effect becomes less pronounced.

Conclusions

Mirror is a collaborative work, part of an artistic research, and is intended to be a small contribution in the exploration of creative tools within contemporary performing practices. We consider that the contributions of a group of artists, performers, researchers or hybrid figures of such a qualitative or praxis research are of central importance in maintaining open the possibilities of the *new*, in the relationship with the *world.* The contributions of the performers are fundamental in an approach in which the real experience comes from an experimentation that implies a doing.

It sought to make the body and voice, the first layer of the performance's mediation, a vehicle of an energy that goes beyond the muscles and physical limits of the body. From this encounter, between physical movement and the perception of the immanence, grows the performance that impacts the audience, the receiver. The technology allows us the development of the concept of performative resonance that plays with the linear time, granting technology another layer of mediation after a deferred feed of content (sounds and images). This detail assumes a relevant role in this work as it frees the performer from the burden of the constrain of controlling the technology in a real time situation. This brings organicity to the performance and also builds the possibility of a metamorphic installation that runs without the direct interaction of the performer, during the moments of performative resonance.

Mirror is a site-specific approach that works with time while problematizing its linearity and exploring other temporalities, detached from the *chronos*. Using technology, we approach a greater number of possibilities of exploration of this and other parameters such as the spatial projection of sound and the immersion of the public in a more active and present sound space.

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Performance Papers

13

Andreas Bergsland

Feedback systems with FM receivers
and transmitters as musical instruments

Performance Paper

Video of presentation can be found here

Feedback systems with FM receivers and transmitters as musical instruments

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Abstract. This paper investigates how FM receivers connected to FM transmitter in a feedback loop can be applied as musical instruments, but with an inherent instability that at the same time breaks with traditional instrumentality. The paper begins with delineating the specific historical situation in Norway with the closing of FM band for national broadcasters, and how this could be seen as a call for action. The paper proceeds with a short review of the application of radios in music and sound art and practitioners working with feedback techniques, before presenting relevant theories of nonlinear dynamic processes and feedback systems. The paper then briefly delineates a simple setup of equipment, and goes on to address issues related to playability and sonic output. The paper shows how certain sonic categories are recurrent, but how different models have different sonic signatures, how some features are unstable and difficult to consistently reproduce. The paper concludes by discussing the findings in the light of the research literature in the field, and potential musical applications of the radio as instrument in different setups and contexts.

Keywords. FM radio, feedback, unstable interfaces

Introduction

This project was spurred by the shutting-down of FM-broadcasting for the national radio stations in Norway in 2017. Digital broadcasting (DAB+), its technological successor, required other receivers, an this resulted in that between 15 and 20 million FM-radios were suddenly useless, according to Dagbladet (Grønneberg 2016). In many regions in Norway at the time of writing the FM-band is almost completely empty of radio stations. E.g. in the Trondheim region (Norway's third largest city), one can normally receive broadcasts only on two frequencies, one around 87 MHz and the other around 104Mhz. The frequency band in between is therefore like a blank canvas, filled only with static. This project emerged as 1) a reaction to a political decision which effectively created tons of E-waste, 2) an attempt of countering this decision by finding some use for technology, which after many years had developed a certain level of sophistication, 3) the emerging availability of the FM-band as an open space, awaiting transmissions, and 4) an interest in exploring the artistic and sonic potential of FM-technology, inspired by the numerous instances of repurposing and hacking in music technology history (Holmes 2016; Collins 2009; Katz 2010).

The research question so far in this project has been: how can a simple setup with one FM radio coupled with one transmitter in a feedback loop be used as a musical interface? I have explored this research question from the perspective of sonic output, playing actions (input), and how the two are related. One additional aspect of this has been to explore different equipment and setups in search for the most interesting configurations regarding both sonic output and playing actions.

After presenting a historical reference and related work, I will briefly present some relevant theoretical concepts from the literature. I will then briefly present the equipment and the applied setup. Subsequently, I will present the main categories of sonic output before turning to how the setup can be played. The following discussion will draw on concepts from the literature and lead to the conclusion of the paper, with an outlook to future developments.

Background and related work

The artistic explorations of radios and radio technology go back over a century. Only a decade after the vacuum tube was invented by Lee De Forest, the inventor himself saw the potential to use radio technology to make a musical instrument (Holmes 2016, 18). *The Audion Piano* (1915) was based on *the heterodyning principle* using vacuum tubes, the same technology that was to be the core component in broadcasting radio. A few years later, Leon Theremin launched his now famous *Theremin*, based on the same technology, but with a radical way of playing it: without touching the instrument and only using the proximity of the hands (and body) to control pitch and amplitude (Holmes 2016, 18-25). A number of other instruments using the same technology followed.

After radio was developed as a mass medium, its artistic potential was noticed from early on. The two Italian futurists, Pino Masnata and Filippo Marinetti, wrote the artistic manifest *La Radia* in 1933, where they called for the "utilization of interference between stations and of the birth and evanescence of the sounds" as well as the "utilization of noises sounds chords harmonies musical or noise simultaneities of silence all with their graduations of appaggiatura crescendo and decrescendo" (Marinetti & Masnata, 1992). As far as I know, there are no records of Masnata or Marinetti realizing their ideas into an artistic practice.

It was first and foremost with John Cage, with pieces like *Imaginary Landscapes No.4* (1951) and *Radio Music* (1956), that radio definitely found its way into Avant-Garde music. For Cage, using radios as a musical instrument was one way of opening music to all kinds of sound, but it also fit well with his aesthetic of intdeterminacy, since the sonic content only to a limited degree would be determined by the performer and composer (Kostelanetz, 1986; Gurevich 2015). Later, also Karlheinz Stockhausen took up the use of radios in his music, especially with *Kurzwellen* (1968), *Spiral* (1968), *Pole* (1970) and *Expo (1969-70)*. In these pieces, the performers used short wave radio receivers with sonic materials consisting of a combination of noises and whatever is broadcast at the time of performance. More recently, other performers and sound artists have used FM-radios together with transmitters, sometimes connected into feedback loops and sometimes not, among them Tetsuo Kogawa, Gert-Jan Prins, Anna Friz, Knut Aufermann and Matthew Burtner (Friz 2009; Corax et. al 2019; Collins 2009, 15; Burtner 2003). Kogawa's political take on radio-art certainly resonates with the backdrop of the current project, although the context for his practices has been different (Kogawa 2008).

Unstable and nonlinear interfaces

In the history of electronic and experimental music, people like Robert Ashley, Steve Reich, Alvin Lucier and Gordan Mumma are presented pioneers of using audio feedback as an intended part of their performance practice (Holmes 2016; Chadabe 1997). The pieces and practices these and later artists working with feedback created, were often playing with the feedback in amplified sound systems and its interaction with the acoustics of the room they are localized in. Even simple microphone-loudspeaker feedback, also sometimes referred to as Larsen effect, can demonstrate many interesting nonlinear and chaotic effects and behaviors (Mudd et al. 2014). Several such effects or features are discussed in the research literature on feedback systems and nonlinear dynamic processes in music. Here, I will briefly introduce some effects and properties that can be relevant for the current setup.

- **Critical thresholds**. In a paper focusing on nonlinear dynamical processes in digital musical instruments, Mudd and colleagues are particularly interested in what they call "edge-like interactions", which happen around critical thresholds where there is a jump or abrupt transition from one state to another (Mudd et al. 2019).
- **Nonlinearity**. Although this term in itself is not very precise, it is often being used to describe situations where the relationship between input and output is discontinuous, warped or disproportionate in any way. Thus, it will in principle also include abrupt transitions as mentioned above. In addition, it can embrace situations like e.g a) the input is fixed while the output is changing (Mudd et al. 2014), b) the input changes, but there are no observable changes in output, c) there are small changes in input that create big changes in sonic output (see example in Sanfilippo and Valle 2012).
- **Hysteresis**. The state of the system depends on its history, so that e.g. a certain setting of input parameters might not give the same results when the history is different (Mudd et al. 2014).
- **Unpredictability**. Many nonlinear and chaotic systems will despite their deterministic nature in practice appear unpredictable, especially around critical thresholds, as mention above (Mudd et al. 2019).

Method and Equipment

In the project reported in this paper I have chosen a highly exploratory and practice-based method. I have started out with an initial exploration to get a sense of the possibilities of different equipment and setups. Subsequently, I have had a number of sessions playing with the most interesting configurations of equipment and settings (see the subsection below), and these have been recorded on video. I have also made notes after sessions about experiences and lessons learned. The video recordings and the notes have then been reviewed with the intention of answering the research question.

Equipment and Setup

Although I have experimented with more complex setups, the focus of this paper is on very simple setups with feedback loops between one single radio and one transmitter, as in the setup Burtner (2003) reported (see Figure 1). Using this setup, I have experimented with a number of different radios and three different transmitters, and my conclusion from this experimentation thus far is that the choice of both radio and transmitter will affect the sonic outcome.[1] The setup is dependent on some form of audio output connection, usually in the form of a mini-jack output, which is then connected to the line input of the FM-transmitter. By tuning in to the same frequency of the transmitter one effectively will create a feedback loop. However, since the mini-jack output is usually intended for headphones, the radios will most of the time go silent when a plug is connected. In those cases, an additional radio for monitoring is needed. For some radios, one can also insert the mini-jack only half way, so that the radio will transmit the signal without silencing the audio output. This solution is somewhat unstable, since the connection might easily be broken, or alternatively, be fully connected, so that the radio will be silenced.

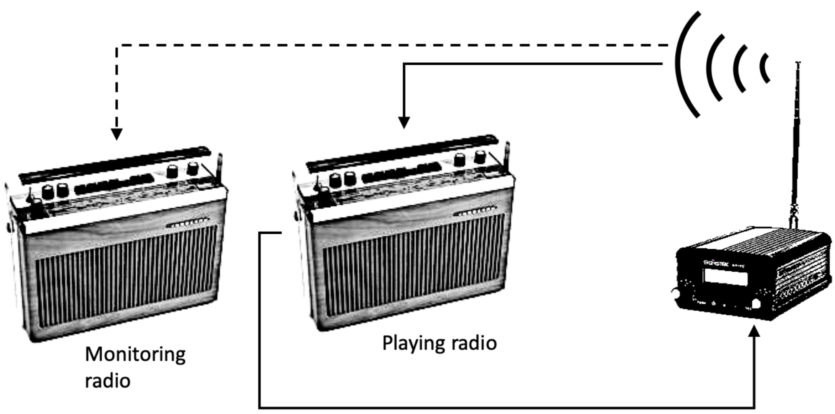

Figure 1: Equipment setup

[1]Although I have been experimenting with more complex setups, e.g. using 4-5 transmitters and just as many radios connected in multiple feedback loops, this will not be discussed in this paper.

Transmitters

So far, I have tested three different transmitters with this project, all belonging to the consumer segment of electronic products: 1) Belkin Tune Cast II[2], 2)CZE-T200[3], and 3)CZE-05B.[4] Of these transmitters, I have definitely found the T200 most useful, since it has a good range, is not subjected to grounds hum and can work without external power supply. Unless otherwise noted, I will refer to playing situations and sonic output using the T200.

Receivers

I have tested around 10 receivers in this project ranging from the 1960s to the 2000s, and from the cheapest consumer radios, to high-end models. Although one can achieve a certain variety of sounds with most of these, some of the radios have a larger palette interesting sonic properties than the others.[5] Among the most interesting, and the ones I will focus on in this paper, are *Radionette Kurér 1001* shown in Figure 2a), *Philips* (no type mark on the radio), shown in Figure 2b, *Tandberg TP41*, shown in Figure 2c, and *Blaupunkt derby de luxe*, shown in Figure 2d.

These radios have in common that they are high-quality table radios from the late 1960s or early 1970s. As mentioned, a mini-jack headphone or record out connection is an essential to achieve the described setup, and all of the radios possess this feature. All of them also have the following knobs and buttons, which are the primary control knobs of the radios when playing them: 1) tuning (receiving frequency), 2) volume, and 3) tone controls. I will expand on how turning these controls are used in playing below in addition to other modes of playing. In addition, all radios except the Kurér have a button for automatic frequency control (AFC). Although it will in some conditions change the sonic output, I have not focused a lot on using this.

Sonic output

Through my practical explorations I have found that the different combinations of equipment and configurations can produce a wide range of sounds. With a background in electroacoustic music studies I have found it useful to apply terminology from that domain to describe the sonic output. Especially, I will lean on post-schaefferian terminology from Lasse Thoresen (2007) and Denis Smalley (1997).

Sound spectrum

Regarding the sound spectrum part of Thoresen's typology[6], I have noticed considerable variation in the sounds I have been able to produce, but most sounds can be classified as either pitched or complex.[7]

Overall, and perhaps not very surprising, the most frequently found sounds fall into the complex category, close to what one could characterize as highly saturated or white noise. For example, whenever one deviates enough from the TF, one will eventually hear typical "radio static", i.e. a sustained complex sound with saturated spectrum, in Thoresen's terminology, close to what one would hear as white noise. This is a kind of "default" sound of the radio, perhaps comparable to e.g. playing open strings on a guitar (Sound example 1a, complex sound). However, by using both tuner and tone control, one can produce a variety of complex sounds (Sound example 1b, variations of complex sounds). Occasionally, I have also sometimes found sounds close

[2]The *Belkin Tune Cast II* is definitely the least flexible, since the only adjustment one can do is to change the tuning frequency (digitally). Moreover, it doesn't allow for an external connection other than its 15 cm long included mini-jack cable. In other words, the transmitter has to stay very close to the radio. The low effect of the device (the documentation says nothing about the exact effect in Watts) requires that the receiver is placed on a distance up to 2-3 meters, at least for a clean signal (the documentation claims 30 feet). This feature can although be interesting in a performance perspective, since it enables you to use the distance to the receiver as a parameter to affect the degree of noise in the signal.

[3]The *CZE-T200* is the most flexible and versatile of the transmitters, since it is battery operated, has a mini-jack line and microphone inputs, and can modify both the input volume, transmission frequency (TF) (digitally) and RF power setting (0.01mW, 10mW, 100mW, 200mW) steps.

[4]The *CZE-05B* is the strongest one of the three transmitters, but less flexible than the T200 since it needs a power adapter. As the T200 it has analogue input volume controls, but only two power settings (100 mW and 500mW), and these can only be set when turning the device on. It also has a telescope antenna which secures a strong transmission. If localized close to the receiver, it may produce some grounds hum, which can be interesting in some contexts, but undesired in others.

[5]It would require profound research into the electronics of the radios to explain these differences. Although this is interesting, it is not a priority for the project at the moment.

[6]As all of Thoresen's framework, this is strictly an experiential category

[7]Without any perceivable fundamental, often towards what one would refer to as noise.

(a) Radionette Kurér 1001

(b) Philips (no type)

(c) Tandberg TP41

(d) Blaupunkt derby de luxe

Figure 2: The four radios discussed in this paper

to a subcategory of complex sounds in Thoresen's system called *nodal* sounds, i.e. complex sounds with a spectral emphasis that produces a pitch-like experience, like bandpass filtered noise with a narrow band width.

All of the radios I have tested can produce sounds in the *pitched* category. These sounds can vary a lot in pitch and timbre, from relatively pure to heavily saturated with noise and overtones in the harmonic series, and from the very low, sometimes crossing into the realm of rhythmic pulses, to the very high. Perhaps the most typical pitched sound, that all of the radios can produce, is a sustained sound with a single relatively stable pitch in the low-mid range (Sound example 2a, pitched sound). Most of the time, the pitch has some irregularities, but not rarely these sounds can also have a more or less static pitch.

The *Blaupunkt* has proven to reliably produce sustained sounds with what perhaps could be characterized as having dual pitch, although the frequencies are so high that they are at the edge of perceivable pitch. Interestingly, the two pitched components do not respond similarly to playing parameters, so that the pitch distance also will vary when playing (Sound example 2b, dual pitch).

Energy articulation

As a general observation, the *energy articulation* of the sonic output, i.e. how the energy or intensity of the sound is shaped in time, most often falls in the *sustained* or *iterative*[8] categories of Thoresen's main typology (Thoresen 2007, 133). Only rarely or with specific intentions and rehearsal, one can achieve sounds belonging to the *impulse*[9] category. This corresponds to an emphasis towards the texture part of Smalley's (1997) concept pair gesture-texture.[10] I will get back to how playing technique, certain states of the system and specific faults of one of the receivers, all can produce sonic output more towards Smalley's gesture category.

Many of the complex sounds mentioned above belong to the sustained category of energy articulation, and usually have a predictable envelope. While iterative sounds can also be highly predictable, I have found that they often have irregularities in timing and spectral content, which often make them highly interesting in my perspective. In the following sound examples, (Sound example 3a-e, iterative sounds with irregularities), one can hear a) an iterative sound, mainly with irregularities in onset timings (Blaupunkt), b) an iterative sound with irregularities in onset and duration timings (Blaupunkt), c) and d) iterative sounds with timing and spectral irregularities, modest (c) and d) large respectively (both TP41), and e) an iterative sound with relatively regular timing, but with spectral irregularities (Kurér).

Even if the categories I have presented thus far comprise most of the sonic output produced with the system, there are also moments which transcend these, with rarely occurring "gems" of sound, often close to critcal thresholds, where there are a number of irregular variations and sound categories involved. For example, during an improvisation with the Kurér, I hit a state of the system with an irregular vacillation between bursts of sounds with different typologies and values, as well as irregular onset timing an duration: a) saturated complex sound (noise), b) a pitched sound in the mid-range, varies slowly, c) a pitched sound in the low range, about an octave below b, and d) a complex impulse with an attack with relatively low spectral brightness (Sound example 4, composite). In Thoresen's system this may be characterized as a sustained composite sound with complex and pitched components with irregular timing.

Playing Radio Receivers

Adjustments on the transmitters can indeed have an effect on the sonic output, for example input gain setting (it is only the CZE-05B that has a button which allow for analogue changing of the value), placement relative to the receiver, and degree of extension of the antenna (for the CZE-05B). However, the receivers as objects have a broad cultural, historical and technological signification that the transmitters lack, and conceptually it is the receivers which constitute the links to the ideas of the project. Moreover, being around half a century old technological artifacts, they also have flaws and idiosyncrasies due to wear and tear that often make them more interesting. The *Kurér*, for example, reacts with a burst of noise that gradually fades out when one touches the volume button, probably a result of a worn potentiometer. All in all, I have therefore chosen to focus on using only to play the receivers in this project.

Playing with Knobs

The knobs on the receivers typically function as in normal radio listening when the system is set to operate below the critical threshold. At the critical threshold the signal level, usually controlled by the volume knob, but also affected by the tone buttons and tuning, has to reach a certain point at the same time as the receiver is tuned to, or close to, the TF. At this point the knobs functionality change almost completely. Here are some observations I have made during several sessions playing with the knobs close to or above the critical threshold of feedback:

- The function of each knob is much less predictable than below the critical threshold.
- The volume and tuning knobs generally make more drastic changes, whereas the tone controls will generally will make smaller changes in the sound.
- The pitched sounds often appear close to the critical threshold, whereas the iterative sounds with irregular properties often appear far from it

[8] Overall sustained, but with sub-elements which has quick repetitions

[9] With a short thrust of energy

[10] Smalley (1997) suggests that gesture and texture are two central forming principles in electroacoustic music, where gestures are related to human physicality, have shorter time span, and are forward driven while textures stretches out on a more environmental time scale, don't have much forward impetus and tends to create a focus towards inner detail.

- Close to the critical threshold turning the knobs slightly usually makes a large sonic change, often changing the overall sonic category (cf. Sonic Output section).
- Further away from the critical threshold turning the knobs will generally produce less sonic changes.
- All knobs might in some cases affect the same sonic parameter, like for example pitch or spectral brightness.
- The physical shape and resistance of the knobs as well as the "resolution" with which they can affect their parameter will affect the interaction a lot. The Blaupunkt has e.g. a very fine resolution and high resistance allowing for minute changes in tuning frequency and thereby very subtle control, whereas the Kurér is has a resistance and resolution that often will produce a change in the values with small jumps.
- The receivers are different when it comes to the critical threshold. While for the TP41 it might be highly variable how high the volume needs to be turned up to achieve feedback or how low it needs to be turned down to stop the feedback, the Kurér seems to have a quite consistent critical threshold.
- If the radio is in a certain state that allows for some adjustment of knobs without changing the sonic category, but instead modifying a sonic quality or parameter, it is possible to approximate a form of stepwise playing. Thus, it is possible to play simple quasi-melodic sequences, or sequences with distinct timbres.

Lastly, I want to make a comment about playing to achieve sounds with a more gestural quality (cf. Sonic Output section), through having an energy articulation that is relatable to a human gesture. This means normally that it has a relatively clear beginning and ending, and that it does not last more than a few seconds. Through experimentation I have found that the receivers afford different possibilities for creating a more gestural sonic output. On the Kurér, with its highly consistent critical threshold, it is possible to move between silence and sound by a very slight turn on the volume button. To transcend a simple on-off gesture, changing the sound quality, e.g with the bass knob to change the pitch and noisiness of the sound, can give additional shape to the gesture (Sound example 5a, sequence of gestures). With the Blaupunkt, however, this is easiest to achieve when there are areas of the band close to TF that are either close to silent or much lower in intensity than an area of the band close to it. Then, one can by a relatively small movement of the tuner control the onset and ending of the sound. The size of the movement of the tuner can then be used to shape the gesture additionally, e.g. changing the pitch and noisiness (Sound example 5b, sequence of gestures with quasi-melody).

Playing with Proximity and Touch

When the setup is in a certain state, one can change a property of the sound by touching or changing the proximity of hands and/or the body to different parts of the radio: this can be the antenna, but touching the volume and/or tuning knobs will sometimes also have an effect. Here are some observations about playing with proximity and touch:

- The proximity of hands or the whole body might act as a continuous control
- Curving the hands around the antenna can affect the sound. In some cases, changing the height of the curved hands can continuously change the sound.
- Touching the antenna, or letting go of it, often creates an abrupt sonic change. The same can apply for touching knobs.
- It is difficult to reproduce states in which proximity and touch might effect the sonic output.

Discussion

It is quite clear that the setup described in this paper demonstrate many properties described by the literature on nonlinear dynamic processes and feedback systems as presented in the Background section above. The term critical threshold, as introduced by Mudd and colleagues (2019), seems highly adequate for the point when feedback becomes audible in the setup. This is also a really important point of reference when playing. The radios seemed to differ, however, in the degree to which this point could be reliably retrieved, with the TP41 demonstrating a clear hysteresis effect with its changing location of the critical threshold. That the relationship between playing input (turning knobs, touching, or changing proximity) and sonic output is highly variable also attests to the nonlinearity of the system, even if certain states could demonstrate close to linearity for certain parameters. The nonlinearity is also evident from the fact that very often all knobs will affect the sonic output in the same way, at least within a certain range.

The nonlinearity of the setup can have a positive effect if one appreciates a way of playing and interacting with the system driven by exploration (cf. Mudd et al. 2019). The complexity and variability of the sonic output also supports an exploratory approach. While I have demonstrated that it is possible to play the system in with a more instrumental approach, where the control of single parameters is desirable, this is very limited and needs a lot of practice. Thus, the setup described in the paper seems more fitting for a free-improvisation setting, where exploration, surprises and sonic variability can be valued. The fact that in certain states, the system can render highly interesting sounds with both temporal and spectral variability also invites adding more layers, either in the form of other instruments or other similar systems. This is something I will proceed with in the future.

The radio receiver as an interface has one feature that would be well-known for an electronic musician: knobs. Playing by proximity and touch is less common, but e.g. in the ICLI and NIME communities, this would probably also relatively well-known.

Conclusion

I have argued in this paper how radio receivers connected to transmitters in a feedback loop can be used as a musical instrument. This setup might very weakly comply with a traditional sense of instrumentality, but in certain contexts which favor nonlinear mapping between playing gesture and sonic output, sonic richness and variation, free improvisation and exploration, it might be highly adequate. Although the sounds produced by a single system might not always be very interesting, combining several systems might create additional musical interest. This is something I would like to pursue in the time to come. Testing different setups with a group of users to validate the findings in this paper is also planned for the future.

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Øystein Fjeldbo and Diana Lindbjerg

GJØRME

Performance Paper

Video of presentation can be found [here]()

Gjørme 0.1

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Abstract

"all our individual efforts to stand out are futile, we all just decay into the same smiling pile of shit!" User_5884499 (insert: emoji of smiling pile of shit)

This paper is a description for the initial stages of the collaborative project Gjørme. GJØRME is a web crawler / multimedia installation / performative piece aiming to render its creators obsolete in its creative process. The project is an exploration of boundaries between automated and manual labour using Instagram as a datasource for colour profiling, analysis and interpretations in RGB, CMYK and audio outputs. The aim of the project is to make an installation with a freestanding automated apparatus that, if prompted by a user, can analyse and output without human intervention.

The title 'Gjørme' is a norwegian word for 'mud' or 'muddy' and was chosen as a worktitle as it describes what happens with subtractive colours (CMYK), when you physically mix them and end up with a dark brownish colour as opposed to additive colours (RGB) in light that mix into white. Destincting between these two systems is a key component in both the method and the motivation for the project.

Keywords: automation, colour profiling, social media, digital, analogue, performance, CMYK, RGB

Introduction

Summer 2019: The User - Diana Lindbjerg, approached the Future Daughter - Øystein Fjeldbo, and wanted to discuss matters of colour and online presence.

> *Dear Future Daughter*
>
> - Have you ever mixed beautiful colours in paint and ended up with an unsatisfying brownish colour on the paper? I was looking at Instagram the other day, thinking about how most profiles have a very strict colour profile. If you look at a random profile and squint your eyes, you realize that it is quite easy to pick out three to five colours that dominate the images. Maybe that in all our attempts of creating profiles on social media designed to 'stand out' and promote our individuality and creative efforts we all just end up producing different samples of similarly unsatisfying brownish output. On our last project together in 2016 we worked on social media feedback loops and I was thinking that we could work together again with these thoughts in mind. We could explore what happens if we extract colour profiles from Instagram profiles, creating different outputs and see where we can take it. My theory is that all our individual efforts to stand out are futile, and I predict that we all just decay into a colour scheme and noise. Basically resembling the same smiling pile of shit!
>
> *Dear User_5884499*
>
> - I have blended sounds until I've reached a thick dense mass of sound, where nothing stands out except the sensation of some sort of massive multitude. I guess that would be analogous to the myriad of voices enabled by the democratization of the internet. Your theory is intriguing. There is absolutely a perceived homogeneity in these efforts you talk about. Do you think your theory would also apply the other way around - to taste? That there is some kind of aesthetic ideal that under the right circumstances all humans can enjoy? We could automate this as an experiment. Set up a kitch-machine to plunder material en masse and use this sampled material to create new material. Its creations can be broadcasted back online, testing its appeal to the people.

What is GJØRME?

The title 'Gjørme' is a norwegian word for 'mud' or 'muddy' and was chosen as a worktitle as it describes what happens with subtractive colours (CMYK), when you physically mix them and end up with a dark brownish colour as opposed to additive colours (RGB) in light that mix into white. Differentiating between these two systems is a key component in both the method and the motivation for the project.

GJØRME is a web crawler and could be described as a multimedia installation and performative piece. The goal is to render its creators obsolete in the creative process. An autonomous web crawler is collecting material, using this sampled material to create new audiovisual content both digitally and translated into physical space. Its creations will be broadcasted back online. In this version of the piece, the bot will be working on the social network Instagram. Instagram is an ideal platform for automated collecting and publishing. The idea is to insert the bot in a network of users, where the bot might inspire its peers and at the same the bot is fed by its peers. In a long-form feedback loop the bot will go through the content of its list of followers (the audience may follow the bot and thus feed it with input). The bot will here extract content from these profiles, determining a mean color profile of each one. Firstly the color profile will form the basis of an automated digital processing, projected in the room. Secondly the analysis will be translated to colour pigments through a motorized squirting of paint into a glass container. By allowing the colour profiles to mix, each of these processes will present a changing colour over time. The digital, additive system will most likely create a light tone almost white light and the physical subtractive colours will most likely mix to a brownish colour. Similar to the visual part, any audio from videos the bot might encounter will be sampled. The bot will use an automated cut-up technique to create a continuous audio collage from the sampled material, which in turn will be time stretched and averaged in frequency and amplitude, thus building an ambient composition in realtime based on the profile's sonic content. The output of the bot will be recorded both in image and audio, and snippets will be uploaded to its Instagram profile, hopefully making contact with others out there. This automated process is inspired by the ideas and creative output from plunderphonics (Oswald 1985)

Example of process development: The development of the project is a constant dialogue between the digital extractions and analogue samples. By testing the crawler and then translating this digital outputs into additive and subtractive colour systems.

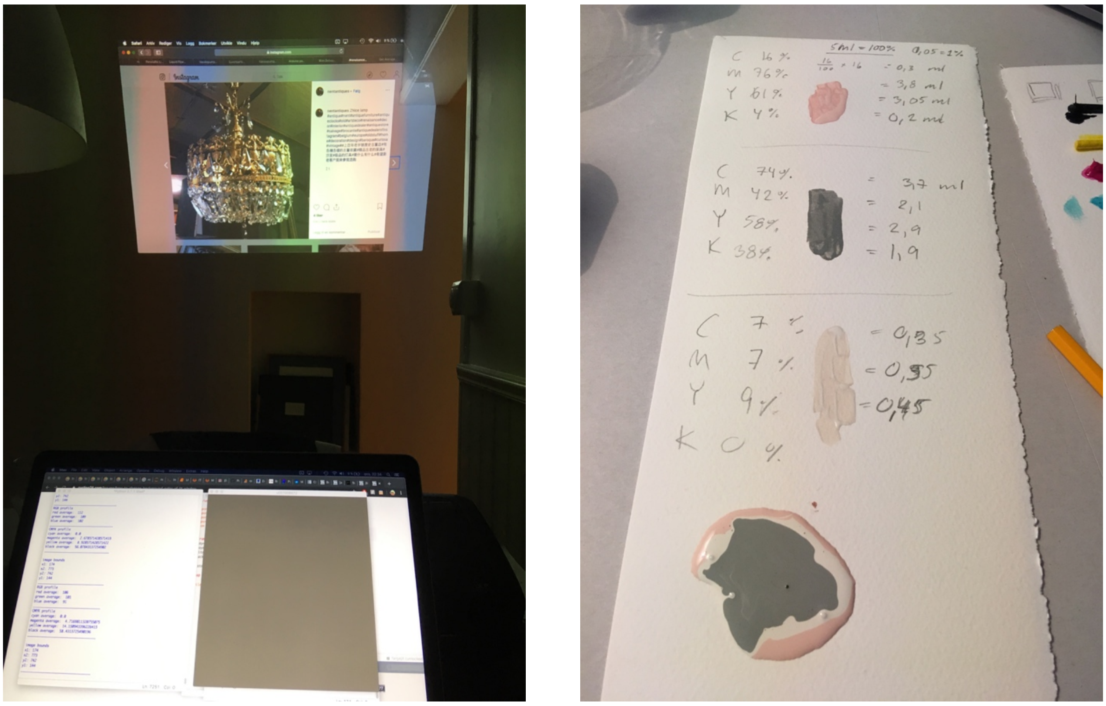

Figure 1. Extraction test and analogue subtractive colour test.

Technical aspects

The web crawler is written in Python, and utilizes a combination of keyboard emulation through pyautogui library (Sweigart 2019) and computer vision through the OpenCV Python library (Heinisuo, 2020). Thus the process is transparent, as one can observe Python interacting with the browser, stopping for each new element it discovers while it analyses and records the content. When encountering a video, the video will play through and the audio is patched into Csound for sampling and processing. Python does the color extraction through averaging the RGB values for each pixel in a frame. For the ICLI presentation this information was then sent to Max and Jitter for a simple visual overview design. In the future, this information will also be converted into CMYK and output as physical paint through digitally controlled fluid pumps, setting the mix of Cyan, Magenta, Yellow and Key for each analyzed image, before it is squirted into the muddy overall mixture. At the core of the auditory content presented at ICLI was averaging the amplitude and frequency spectrum of the sampled audio material through *pvsmooth* (Lazzarini 2006), and partial tracking through the *partials* opcode (Lazzarini 2005) , creating an automated ambient composer.

Aesthetic philosophy

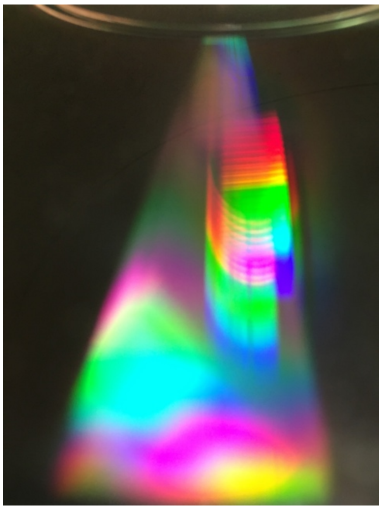

Figure 2. Spectrum of sunlight. Homemade spectrometer. Diana Lindbjerg (2020)

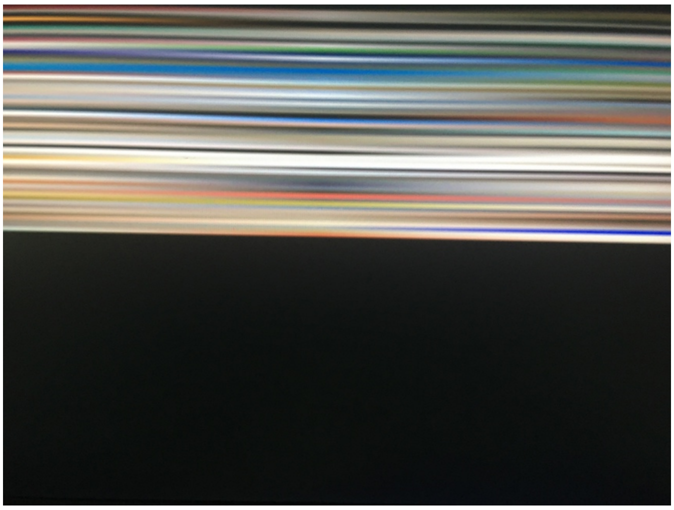

Figure 3. Gjørme extract of profile of User_5884499. Diana Lindbjerg/Øystein Fjeldbo. (2020)

We use the spectrometer as an analogy to understand what 'Gjørme' does. Not splitting the white light into rainbows but extracting reference points in photographic images normally perceived as figurative signs and signifiers. The project is informed by ongoing research into the ontology of the photographic image and colour theory. Our source material for 'Gjørme' - Instagram - consists of digital images that we popularly recognize as photographs, however the way they are organized in a fixed size, format scroll or grid formation highly informs our reading of them and both maker and viewer. "The apparatus does as the photographer desires, but the photographer can only desire what the apparatus can do." (Flusser, Roth and Poster, 2011) By breaking down the information we are presented with in a fixed interface or 'apparatus' and presenting this information through a 'new lens' we can maybe understand different aspects of what we output in social media as well as creating a completely new output.

Ambition

At the moment we are really just at the starting point of the project, using very crude techniques for extracting a relatively low amount of data. For the final part of GJØRME, and as the goal of the project as a whole, it would be optimal to utilize a machine learning component for analyzing encountered content in a lot higher detail than what is achieved by us today. Implementing an understanding or at least an estimate perception of what is present in a picture, a video or an audio stream would open up a new world of possibilities where the bot can build up an archive of what sort of information is posted to the web and also connecting this information to what content has gotten the most interaction in the form of likes. Thus the computer is building statistics on what kind of content is most heavily consumed and enjoyed by the end user, and it's possible to imagine the bot to be able to react to end user interaction (likes), and tweak its output to try to please the end user base. The next step would then be to experiment with different ways of building content containing new iterations of this information. It is easy to imagine image and audio synthesis to be the first base here, but also robotized drawing or playing should be tested for its possible X factor of purely existing in the «raw» outside world before it is documented and again uploaded to the web. The complexity of the analysis and creation is of course infinite, and thus the project may grow for the entire foreseeable future. The same idea of finding an average still applies to this infinite complexity level, where the bot is averaging content. GJØRME is of course an experiment. It is meant as an examination of human taste as it applies to web content. And if it really is so that our preferences are homogenous, then we might just as well automate the creation.

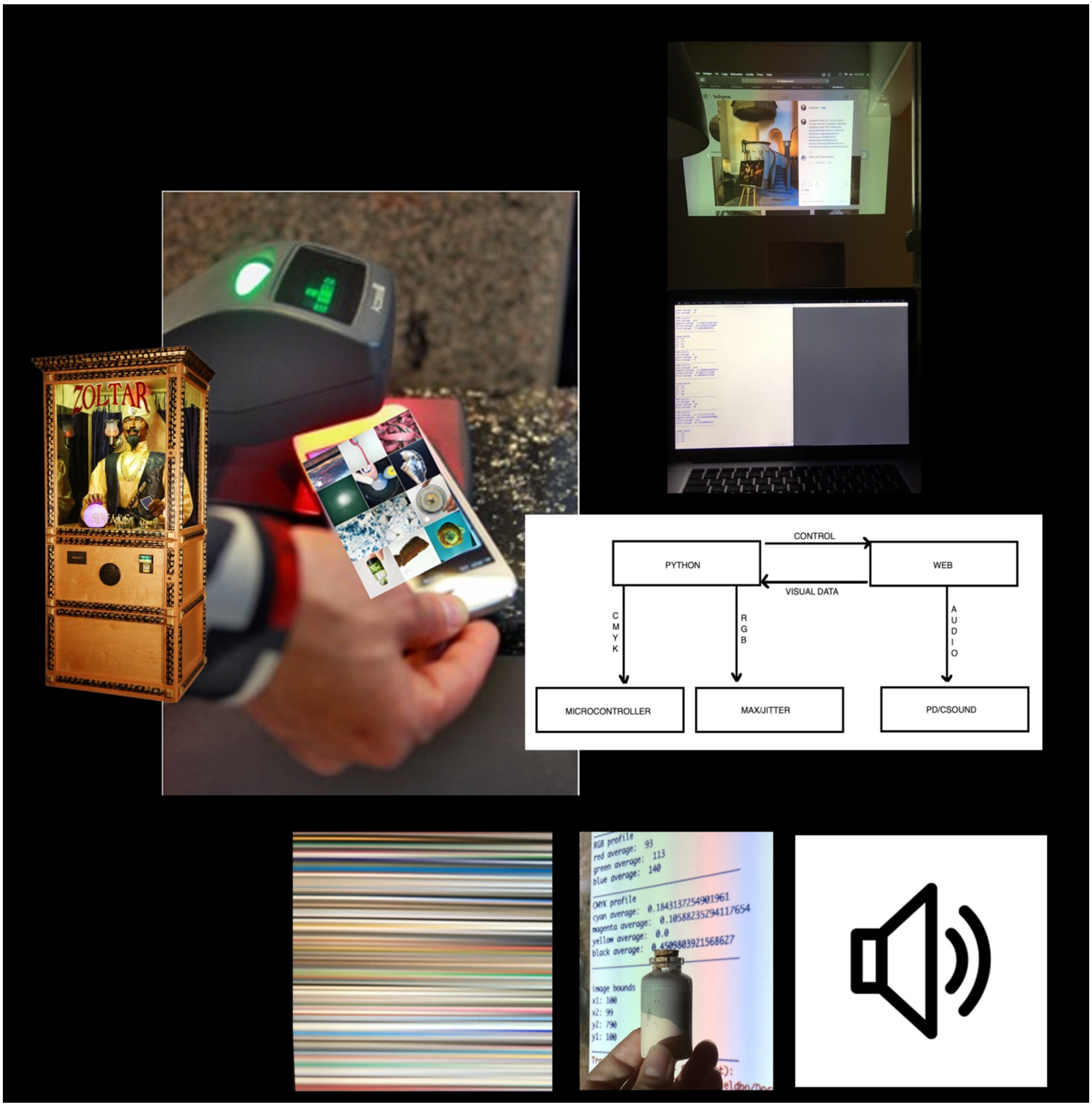

Figure 4. flowchart sketch of a potential interface. We have used The image of a Zoltar fortune telling machine as an idea of how you could interact with a potential new interface. By scanning an Instagram profile and then receiving different types of output. For example a spectrum (additive colours), a physical sample of 'gjørme' (subtractive colours) and an abstracted audio output. D.Lindbjerg/Ø.Fjeldbo (2020)

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Luis Arandas, Rui Penha and José Gomes

Directing Selfness - A Step Back from Digital Collaboration on Stage

Performance Paper

Video of presentation can be found [here]

Directing Selfness – A Step Back from Digital Collaboration on Stage

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Abstract. Collaborative networked performance has been at the forefront of recent proposals in computer music and digital performance research. A feature of its stage effectiveness derives from the composition being often drawn from the instrument or the system. Also, these digital environments are programmed with both the inherent characteristics of human interaction and the properties of networks in mind. The performance *Directing Selfness* takes a step back from networked interaction using an interface made specifically for performative collaboration through an audio-visual solo. It is made in order to promote a stage-based exploration of a tool not only designed for other performative purposes, but also to promote a unique adaptation of the artist using it.

Keywords: Artistic Performance; Collaborative Computer Music; Interface-based Interaction; Network Music Performance; Audio-Visual Interaction.

Introduction

Performative collaboration using post-internet technologies allows artists to become deeply involved in various ways. This involvement, which is also fostered by the speed that optical fibre and wi-fi allow, is dependent on distinct factors. Such as the concept of networked agency, the way interaction takes place and especially the mediation characteristics of the environment. With respect to Shannon's well-known message communication diagram (1984) and the way in which intermedial and interactive network spaces can modify meanings in the artistic gesture (Tanzi 2005) designers and users sometimes tend to break and write software to match their needs. Something that is very common in the development of new live-coding languages and network structures.

When on stage, and in order to get to know the tool you're using better, artists are sometimes forced not only to know the high-level structure of the software but also how the back-end operates. Occasionally understand how communication happens or what kind of architecture facilitates the connection between instances. This is intrinsically linked to the artist's control and position of what is done in the performative space. It helps to define both the greater notion of causality and the very trajectory and physiology of the artistic gesture. That gesture, is here defined adapting Iazzetta's definition (2000) as a movement or change in some original state that is marked with meaning by an agent. Described in a broad way and with regard to the whole intermodal problem of the gesture in electronics, this is something that can be found in various fields of artistic performance. There are many different performative explorations that can serve as an example for this topic which is the case in Santana's work (2014) on networked dance performance, distributed live-coding by Kirkbride et al. (2018) and both machine learning and signal processing (Bernardo et al. 2019).

All these topics and their traits, especially from a phenomenological point of view, have been present almost always across the artistic practice. And a fair number of them aren't formalized here for the first time. The inherent characteristics of networked musical performance often mirror aspects that have always happened in chamber music. And these analogies, accompanied by aesthetic nuances, help to relate practices and even model new ones. We would like to mention the long distance concerts by telephone (Hopkins 1891) as a clear reference to musical practice in digital networks. Although they were experiences that do not exploit collaboration as delicately as some more recent examples, they are an excellent early exploration of the use of networks as an extension of the mentioned gesture. These provide experiences that are able to show the musician a mirror of himself (as well as in audio recording) and help shape the position of each member of the acting group. Also from a learning point of view, many personal artistic conclusions and experiences might be born from group interaction during performance.

Interface-based Mediation

Networked collaborative performance needs some underlying structure in order to happen. The digital environment where this happens, inherits a performative space that offers something different than the conventional use of acoustic/analog instruments in a *network* of artists with corporeal communication. It offers a new space, codified in a specific way[1] that can provide attributes such as actions, acoustic properties and modes of existence. The way to interact with that space is through an interface[2], a system or a device through which non-related entities can interact (Sá 2017). This can be done by writing code, in a graphical environment (being the most common) or through pieces of hardware that is not the focus of this article but can be mentioned through the work of Nicholas Collins (e.g. *The Royal Touch*).

Several times, the network mediates the artistic gesture. Not only for its practical limits conditioning the freedom of the user, but also by the fact that it is a vehicle for the flow of information. A vehicle that can be optimized, hacked and specifically programmed for any purpose. When it comes to networked musical performance, actions are very flexible. Whether from various artists in different places, from an artist with various devices, or even with the public as participant or lead. However, even though there is a vast set of virtual performative possibilities, the embodied communication on stage is almost null. Also, when there is no projection of each performer's code, instrument or even distributed video streaming it is difficult to have a full causal notion of the events. This is something that is present all over across laptop performance and should be understood and embraced as a transformational attribute (Fernandes 2015) capable of providing experiences other than pre-digital performance. The characteristics of the material change the performance as well as its external perception. This is important to take into account when thinking about perception and interaction through digital interfaces.

Of course the limits of a network or interface for networked performance are not very different from the limits of a classical musical instrument. It has pre-defined boundaries that are adapted for a subjective purpose. This is a characteristic that leads not only to their remodelling, but also to the development of new methodological structures in their construction. Movements like telematic hacking (Landy 2017) can be related to this shift, a kind of *digital circuit bending*, and the most varied types of appropriations of both musical and visual tools are often presented as live-interfaces[3]. Software allows this, with all its representative features, something that is not possible in analog media with such freedom.

When collaboration comes in, the context becomes more complex. As mentioned in the previous section, and largely due to the drastic change that exists when an artwork is done in group (compared to the absence of), all the paradigms raised here are transposed into a different field. It is necessary to study the mediation offered by the interfaces that are purpose-built for collaboration in a completely different way from singular ones. Both in terms of development, experimentation, performance and composition. My gesture may not work or even be possible to make

[1] Sometimes simulating the world as much as possible, as well as creating new virtual paradigms.
[2] For a deeper exploration of the term embraced in this text is recommended the work of Cristina Sá (2017) considering the interface and time, space, plasticity, speed and intelligibility. The word *entities* with an abstract connotation.
[3] For an example of mixing analog media with web technologies (which are used in the performance presented in this paper) see the recently presented *gravity|density* performance by Marasco and Allison (2019).

when I am alone in a collaborative environment. As well as issues of autonomy, choice and convenience have to be carefully designed so that the interface used is robust enough to provide an acceptable level of decision.

Directing Selfness

Building in all the text provided, the whole point of interpersonal collaboration is to produce some kind of content in a plural and shared way. All members present become responsible parties to the whole, and this is often more than the sum of the parts[4]. The presented performance is called *Directing Selfness* and its fundamental difference from an usual audio-visual solo has to do with the objective and inherent characteristics of the medium used. It is done using a web environment whose architecture was proposed in Arandas et al. (2019) in order to conglomerate various devices by allocating them in different interaction modes. Properties that (considered by the performer) are aesthetically relevant are explored on stage, and the software is remodelled to better match procedural needs. This remodelling is completely coherent with Magnusson's definition (2018) on musical technologies as "cybernetic devices that exist in the interstice between our inner self and outer motor movements, constantly attuned and calibrated in real-time practice" mentioned as a deep and emerging phenomenological relationship.

The technical changes start by eliminating everything that makes the software a networked environment. All the contents of the server as an event manager are deleted, also removing it from the cloud serving it locally. No one else is able to connect to the performance, even from the audience's mobile phones. The graphical interface is also deleted (sliders, knobs and buttons) reappropriating the canvas they're built on. The mapping done previously on the laptop keyboard through event handlers is adapted, and the (web)midi will be hardcoded to an Evolution controller (UC-33 model). The presented content is made from the mentioned environment, without mixing it with other musical or visual instruments. The performance takes around 05:00 to 10:00 minutes and is in itself an exploration, made in one of the best places for that to happen, on stage. The act of removing all interaction between other instances helps to increase awareness of the environment used. It is designed to allow the user to do something they can't do on their own so it promotes a personalized optimization. Also, automating processes (e.g. dynamic behaviour of oscillators and filters) is somewhat analogous to what Galanter calls "rules as recipes for autonomous processes" (Carvalhais 2016). It also takes advantage of a scheduling system that is present in the software, allowing the orchestration of gestures in time, and the printing of text of the various processes that are happening. Several elements present in the system are used as material, which in their initial form are not present or visible.

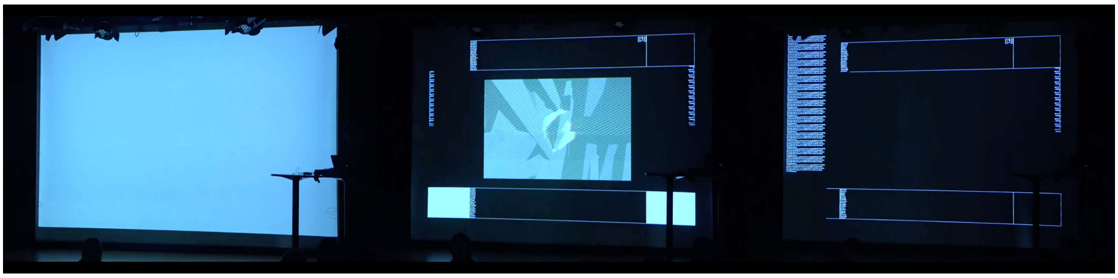

Figure 1. Photographs of *Directing Selfness* performance in Dokkhuset Scene

[4] Linked to the emergence phenomenon in physics, for future reading Sawyer's (2000) work in collaborative emergence and improvisation is recommended.

Conclusion

Shifting the purpose of the tool used, and as referenced by Tomás (2016) “something that is scripted with ideologies” (Chicau and Bell 2018), the main objective of this piece is to explore singularly an interface designed for a plural and distributed use of agents. *Directing Selfness* is presented as a conventional solo laptop performative expedition on stage, using the mentioned networked environment. There will be no external connection either from the cloud or from those present in the concert. Promotes an adaptation of the artist to a tool that was developed for a different purpose through a user-centered design process. It is used without having the necessary characteristics for its complete operation, and maintains the fundamental role of the computer as a musical instrument.

Acknowledgments

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Helena Marinho, Rui Penha

Embodied alien. Nobody - no body

Performance Paper

Video of presentation can be found here

Embodied alien. Nobody – no body

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Abstract. This paper presents a work in progress focusing on machinic feedback as a means of cyclic co-creation, in order to understand procedures of interaction, adaptation and expressivity in the context of technologically mediated performance. This is a part of a larger ongoing project focused on cross-adaptive modulations, AI, and their contribution towards the expansion of human actions on stage. AI methods, as automation and modulation in software, represent a disembodiment, acting both as an intimate and an alien partner in contexts where humans perform the physical action. Embodiment of the alien partner has its physical manifestation in an acoustic instrument (piano) equipped with transducers, and the resonances of the piano body thus become the common playground for the machine - human encounter.

Keywords: feedback, live interfaces, actuated instruments, machine learning, improvisation

Introduction

The use of microphones and loudspeakers as musical instruments has a rich history (Eck 2017), one that includes the use of electronic technology to control the feedback on acoustic musical instruments (Berdahl, Niemeyer, and Smith 2008), namely to pursue the idea of actuated musical instruments (Ângelo et al 2018). Within the project "Fostering innovation in musical performance research through the study and development of technologic interfaces", we decided to base a number of experimental music approaches on the setup of an actuated grand piano. The basic setup was common to all approaches and was based on the digital control of the audio feedback happening between two transducers attached to the piano soundboard: a piezo transducer, acting as a contact microphone, and a contact loudspeaker (Figure 1).

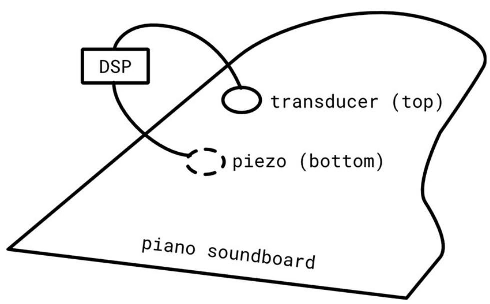

Figure 1. Setup description

Together with the other members of the project — Øyvind Brandtsegg and Trond Engum (NTNU), Alfonso Benetti (INET-md, UA) and Bruno Pereira (i2ADS, ESMAE) —, we developed and explored a few case studies around this setup, focusing on the use of feedback control techniques to allow for the introduction of digital signal processing of the acoustic sound of the piano via the amplification attached to the soundboard. Thus, this paper focuses on machinic feedback as a means of cyclic co-creation that can underlie specific procedures of interaction, adaptation and expressivity in the context of technologically mediated performance.

Approach and implementation

The basic idea for this case study was to develop an algorithm capable of expressive control of the feedback loop, providing the means for a cyclic co-creation with the piano player. In order to achieve that, we devised a simple interface for the control of the feedback and trained a machine-learning model on data recorded during several performances played by a human player using the same interface.

The algorithm is based on the recording of the sound captured by the piezo transducer on a buffer, which is then made available for playback with spectral manipulation using five parameters:

1) Playback position, which defines a point in time for granular playback of the contents of the buffer.
2) Frequency of low-pass FFT crossover, which defines the highest FFT bin which is allowed to passthrough to the inverse FFT for playback.
3) Frequency of high-pass FFT crossover, which defines the lowest FFT bin which is allowed to passthrough to the inverse FFT for playback. If this is lower than the former, no audio will passthrough.
4) Minimum amplitude for FFT bin playback, which defines the minimum amplitude a given FFT bin must have to be allowed to passthrough to the inverse FFT for playback.
5) Time of automatic cross-fade between FFT frames, which defines how much time (and, consequently, how smooth) it takes for the change of parameters to be reflected of the playback of the subsequent FFT frames.

The implementation of this algorithm was made in Max/MSP, based on the techniques for spectral manipulation proposed by Jean-François Charles (2008). Albeit simple, this algorithm enables an easy and very expressive control of feedback by a human performer, which was what we aimed for in several rehearsals and public presentations. The adopted strategy for the musical gestures of this controlled feedback was always based on a simple set of principles:

1) Identify a suitable point (parameter 1) to start a new feedback gesture, based on a combination of both listening to the piano performance and looking at the sonogram of the recorded audio.
2) Select a value for parameters (5) based on the visual analysis of the complexity of the spectral content of the chosen playback point.
3) Manipulate parameters (1) to (4) based on reactions to the complete sonic performance.
4) Continue until the parameters reach a combination that generates no sonic output, point in which a new recording of the buffer starts, thus recording solely the acoustic output of the piano, until a new musical gesture starts.

All the data of these performances was recorded and used to train a combination of three machine-learning algorithms (MLAs), all having spectral frames as inputs:

1) MLA1 has as input the spectral content of the frames currently being recorded and is responsible for identifying suitable frames to start feedback gestures. It thus provides a Boolean decision based on the analysis of the spectral input. Since the recording is only active when no audio is being output by the system, MLA1 is only active during acoustic piano solos.
2) MLA2 has as input the single spectral frame selected by MLA1 and as output a single value for parameter 5.
3) MLA3 has the most complex task, which is to output values for parameters (1) to (4) based on the spectral content of each frame of the audio input. MLA3 is only active when there is audio playback by the system, hence it always "listens" to the combination of the acoustic piano as played by the player and the system output as amplified by the contact loudspeaker, both captured by the piezo transducer. Even though the decisions of MLA3 are made for each spectral frame, a smoothness of the audio output depends mostly on the value of parameter (5) as selected by MLA2.

A simple envelope follower tracks the system output, looking for silent moments in which to retrigger the audio recording of the acoustic piano to restart a new musical gesture. A second envelope follower tracks the audio input, disabling the output of MLA1 when the audio input is silent. This way, the computer will never start a new gesture when the pianist is silent, which is then used to control both the beginning and the end of the performance.

Performance implications

For a performer of an acoustical instrument such as the piano, relating to electronic contents – be it in live electronic or pre-recorded contexts – involves specific challenges: the corporality of the electronic sounds function as an alien sound when compared with the acoustic properties and affordances of musical instruments, and their historic / symbolic background bears on performance both in technical and gestural terms. Moreover, as Simon Waters states, when proposing an ethics of listening in the context of improvisation, “the objects with which we surround ourselves (such as musical instruments) act as prosthetic sensors, amplifiers, and transducers of our interactions with our environment and with others, […] a capacity for empathy can be imaginatively designed into the non-human agents with which we interact” (Waters 2018, 1). He also adds that, “in a network of human and non-human actors, empathy might be ‘designed for’— by looking at attributions of indigenous agency to circuits, computers, and software; to knobs and physical interfaces; and to sound itself” (Waters 2018, 3). Visually (especially for an audience) and aurally (in particular for the performer), the use of interfaces require a particular mode of listening, which informs and shapes the manners in which acoustically-produced materials are intertwined with electronic contents.

In 2000, Simon Emmerson, when evaluating extant tendencies in music produced by and through technology, identified two main streams: one that persists on “representing humanity” (Emmerson 2000, 212), another that conveys a “clear imprint of the human *will* rather than the human *presence*” (idem, 213). In a more recent publication, however, Emmerson (2018) acknowledges a broader and polystylistic taxonomy of forms at the core of live interfaces, demonstrating the wide range afforded by current developments. This wide range implies adaptive modes of listening and playing, reflected in the current project.

Some specific issues were identified during studio work, undertaken in Norway and Portugal from October to January 2020:

- contrarily to the voice, for instance, which displays a wide inherent adaptability in timbre, acoustical instruments, especially the piano, are often bound to fixed height and timbre features. The piano, with its wide range of frequencies and volume, can become overbearing, and this fact imposes several constraints when working with feedback, requiring constant adaptation, and the choice of specific and effective strategies;

- feedback mimics and extends piano sounds but, from the pianist’s point of view, the connection can range from a recognizable identification of standard piano features to a totally alien content. At this far end of the scope, the issue of selecting improvised contents becomes more critical (i.e., assuming a non-tonal, non-jazz approach);

- extended techniques can successfully bridge that divide. Their “improper” (Vaes 2009) sound quality, and the implicit deterritorialization of the piano sound, can act as “proper” affordances when combined with digitally generated sounds. Thus, extended techniques can function as a mediator, levelling the transition from electronic to acoustical, and vice-versa;

- we can therefore label the performative results as a controlled improvisation, focusing on creating a sound scape, and engaging with the effects created and generated rather than adopting a virtuosistic discourse and techniques.

In conclusion, AI methods, as automation and modulation in software, represent a disembodiment, acting both as an intimate and an alien partner in contexts where humans perform the physical action. The embodiment of the alien partner displays its physical manifestation in the acoustic instrument equipped with transducers, and the resonances of the piano body thus become the common playground for the machine - human encounter.

Acknowledgements

This research was funded by the project "Fostering innovation in musical performance research through the study and development of technologic interfaces", financed by the Fund for Bilateral Relations of the EEA Grants Portugal, and by the project "Experimentation in music in Portuguese culture: History, contexts and practices in the 20th and 21st centuries", co-financed by the European Union, through the Operational Program Competitiveness and Internationalization, in its ERDF component, and by national funds, through the Portuguese Foundation for Science and Technology.

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17

Tijs Ham

Multiple Minds

Performance Paper

Video of presentation can be found *here*

Multiple Minds

An audio/visual performance with actant technology

Context

My Artistic Research project 'Tipping Points' is situated in the field of **live electronics** and focuses on the exploration of **tipping points** in **chaotic processes**, related to sonic expression. These topics are investigated through the development of an iterative series of new chaotic **electronic instruments, compositions and performances**. My practice is thoroughly interdisciplinary and includes the design and building of the instruments, the development of compositional strategies and taking the role of the performer in the eventual piece. The activities related to these elements continually inform each other.

Abstract

'Multiple Minds' is an audio-visual performance that poses questions about the origins of the creative mind behind the sonic behaviors and images that are produced. The instrument that lies at the heart of the performance is based on three sawtooth oscillators that are cross modulating each other. The recursive nature of this process is expressed through developing patterns, shapeshifting timbres and fragile frequencies all generated from deterministic yet unpredictable origins. Recursivity amplifies the slightest performative input to echo through the instrument, affecting the sound in unforeseen ways. Minor changes of a single parameter could start a chain reaction that completely readjusts sonic behaviors. The combination of a broad sonic lexicon combined with unpredictability suggests that the instrument can be interpreted as having its own form of agency, acting independently from the intentions of the performer.

The unforeseen

As in much of my artistic work, 'Multiple Minds' is concerned with the *experience of sonic discovery*, shared directly with audiences. In other words, both the performer and audience will be exposed to an **encounter with the unknown** during a performance. These encounters are vulnerable situations, best to be approached with curious, open mindsets and a readiness to experience unexpected twists, turns and surprises.

> *"[...] the audible result is, to a certain extent at least, unrelated to the corporeal actions of the performers. Hence, they are challenged to react to sonic developments taking place outside of their direct control. Rather than considering this as a negative or impractical side effect, 'Tubes' thereby creates a situation of experimentation and creativity. Performers and audience share a space of surprises, discoveries, and unexpected sonic results; they encounter the un-fore-seen" - Paul Craenen (Cobussen 2017, 115) [1]*

While it seems counterintuitive, this type of performance accumulates into a form of **designed surprise**. Although there may be only one human performer present, the situation feels much more like playing a duet. The instrument poses sonic suggestions, reacts to each touch according to its own determination. With each iteration the instrument functions more and more as an **actant technology**, capable of responding to performative gestures in perhaps *disobedient*, but nonetheless *intricate* ways. One of the pioneers of recursive electronics David Tudor has described his relationship with his instruments as follows.

> *"I try to find out what's there—not to make it do what I want, but to release what's there. The object should teach you what it wants to hear" - David Tudor [2]*

Play

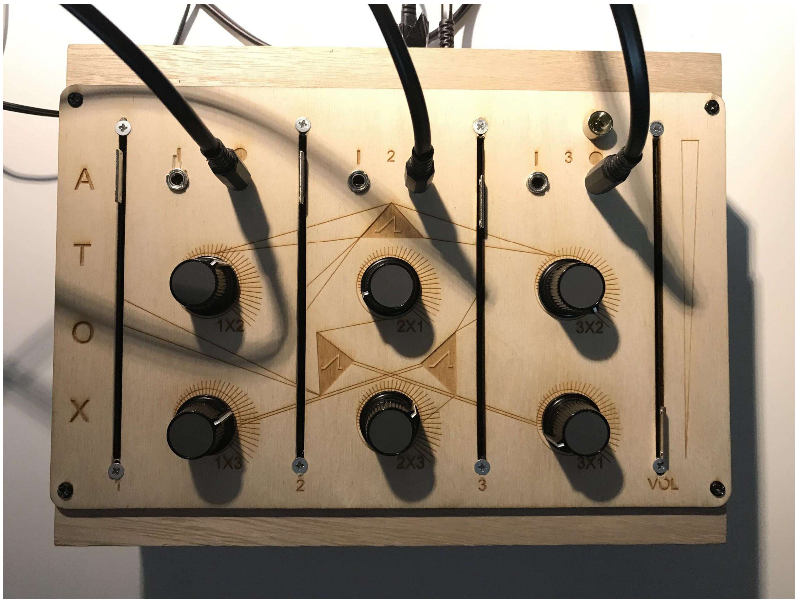
Another way to approach the relationship between the performer and the instrument is to take cues from the writing of Karen Barad and interpret the music and visuals as resulting from the playful **intra-actions** between the performer and the instrument, each embodying their own form of artistic agency [3]. The use of the word *intra-action* instead of interaction, stresses the fact that the sound is the result from the ***exchange*** *between* the performer and instrument, neither of which are able to impose prior intentions on eachother. The actual sonic output can only be uncovered through the act of play. This requires that the prior intentions of both the performer and the instrument have to be unfinished and open to the suggestions that are offered through the performance.

> *"The notion of intra-action (in contrast to the usual "interaction," which presumes the prior existence of independent entities / relata) represents a profound conceptual shift. It is through specific agential intra-actions that the boundaries and properties of the "components" of phenomena become determinate and that particular embodied concepts become meaningful. " - Karen Barad (Barad 2003, 815) [3]*

An intricate dance of actions and reactions ensues, in acknowledgement that each step is fragile and irreversible, as the dance itself reshapes the dancefloor.

Multiple minds

Practically, the setup for 'Multiple Minds' consists of three connected parts. An analog chaotic synthesizer developed specifically for the performance is plugged into a laptop via a soundcard. Inside the laptop, the sounds are digitally processed through software written in SuperCollider and visualized through software written in Vuo. These digital processes listen to the audio and CV outputs of the synthesizer and react according to its own logic which again complicated the question of the origins of the artistic agencies. The output consists of stereo sound from the soundcard and visuals via an hdmi port on the laptop. During the piece, the performer only engages with the analog synth, the laptop screen mirrors the visuals and is pointed towards the audience. The length of the performance is flexible and can be made to fit circumstances.



The analog chaotic synthesizer ATOX is part of the Multiple Minds Setup. The synth contains three sawtooth oscillators. Each oscillator has a master pitch slider and two knobs determining the amount of modulation of the other oscillators. Although this setup seems rather simple, it is capable of producing an extremely wide spectrum of sonic behaviors.

The **unpredictable** and non-linear nature of chaotic instruments forces us to reevaluate the traditional roles of the performer and the instrument. Where classical instruments allow for the development of mastery through rehearsal and repetition, chaotic instruments *refuse* to repeat the same thing twice, turning rehearsals into sonic explorations driven by *curiosity* *rather than virtuosity*. The instrument is responding to the performer as much as the performer responds to the instrument. The act of playing the instrument *changes* the instrument. Musicianship shifts towards a dialogical model, accepting the quirks and sonic gestures emanating from the instrument as being equally integral to the overall outcome as the intent of the performer.

> *"The unpredictability of the instrument requires an attitude of obedience and resignation to the system and the sounds it produces" -Toshimaru Nakamura [4]*

Conclusion

'Multiple Minds' examines concentrated curiosity and adaptive methods of exploration as key factors in establishing new roles between the creative minds of the human- and the instrumental performer. During performances there are moments when the instrument is left untouched and given space to display its own sonic expressions. These moments evoke a powerful sense that the instrument is allowed to express its own voice. At other moments, when the instrument is actively played, its sonic behaviors and responses contain surprises and non-linearities. The instrument doesn't merely execute instructions, instead, it processes performative input through its own chaotic logic. 'Multiple Minds' requires a deep and unaverted attention by the performer, who can not fully rely on the knowledge gained through prior experiences. The instrument has to be explored and discovered anew each time it is performed. The music of the piece itself begs to be uncovered, examined, inspected, extended, diminished and concluded. Performances take the shape of sonic expeditions where instrument, performer and audience explore the ever shifting sonic landscapes together, seduced by the tensions and expressions that are encountered along the way.

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[3] Barad, K. 2003. Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. Journal of Women in Culture and Society, vol. 28, no. 3, 801-831

[4] Toshimaru Nakamura webpage: http://www.toshimarunakamura.com/bio

Annina Ruest

Bad Mother / Good Mother: an audiovisual performance

Performance Paper

Video of presentation can be found here

Bad Mother / Good Mother

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Abstract. *Bad Mother / Good Mother* is an audiovisual performance involving a projection, a modified electronic breast pump as a sound generator, and a sound-reactive LED pumping costume. The project has four songs that critically explore technologies directed specifically at women like breast pumps and fertility extending treatments such as egg-freezing (social freezing). Depending on the song, the breast pump is either a solo instrument or part of an arrangement. The idea is to use workplace lactation as a departure point to uncover a web of societal politics and pre-conceived perceptions (pun intended) of ideal and non-ideal motherhood.

Keywords: Technofeminism, audiovisual performance, breast pump, motherhood, politics, physical computing.

Introduction

Bad Mother / Good Mother (Ruest, 2018) is an audiovisual performance involving a projection, a modified electronic breast pump as a sound generator, and a sound-reactive LED pumping costume. The project has four songs that critically explore technologies directed specifically at women like breast pumps and fertility extending treatments such as egg-freezing (social freezing). Depending on the song, the breast pump is either a solo instrument or part of an arrangement. The idea is to use workplace lactation as a departure point to uncover a web of societal politics and pre-conceived perceptions (pun intended) of ideal and non-ideal motherhood.

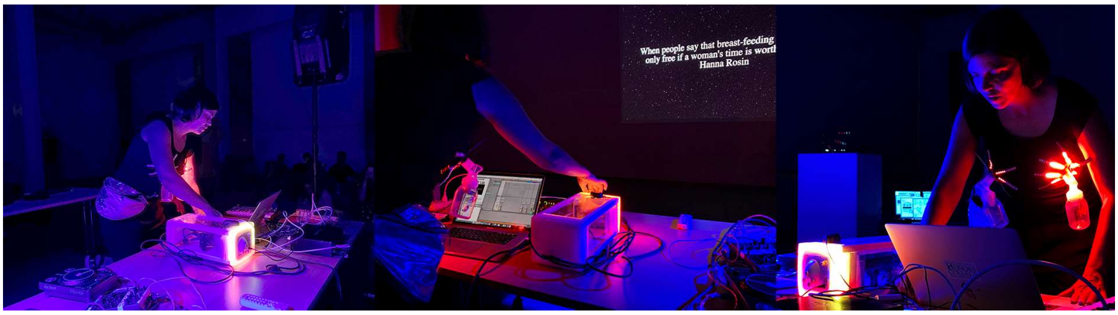

Figure 1. Three Stills from a performance of Good Mother / Bad Mother at xCoAx 2019 in Milano, Italy.

The Songs

The first song uses the breast pump sound as a solo instrument. Thematically, the song is about different aspects of pumping breastmilk at work. It has two basic sounds: The sound of the milk letdown which is slower and the sound of the pumping which is faster. In the performance, I am switching between the

two modes, playing them at different intensities. The visuals are still images of different breast pumping situations and the stresses related to extracting milk in a work environment.
The second song is about maternity leave. In the US, parental leave is not mandated by law (Department of Labor). The visuals show (US) politicians displaying fake reverence towards women. The breast pump is playing in the background, defamiliarized by vocoding.
The third song is about freezing eggs to delay motherhood. Egg freezing is an elective medical technology that is sold to women as empowering because it allows women to delay motherhood by freezing their eggs (Rosenblum, 2014). Because the motivations are social and not primarily medical, the procedure is also called "social freezing". It is big business especially since large tech companies like Facebook have announced that they will pay for employees' eggs to be frozen. Facebook was criticized for using this "benefit" to pressure women to delay motherhood (Alter, 2015). This song uses the breast pump as the heavily vocoded lead vocals in a cover of Daft Punk's "Get Lucky". I call this song "Daft Pump".
The fourth song is improvisation, using filters to distort different aspects of the sound signal. The visuals are of a woman pumping. Individual movements are repeated rhythmically along with the sound. It signifies the repetitiveness of the pumping routine

The Costume

The costume is an exaggerated pumping top. Around the cut outs where the breast pump shields attach to the breast, it has seven rows of LEDs pointing outward like a star. The LEDs are attached to a microcontroller board. Each arm represents a frequency band. The LEDs therefore pulse along with the sound. However, the bands are lit individually depending on the energy content in this frequency band. It is designed similar to a rock star's costume. It ironically glamorizes the profoundly unglamorous act of pumping breastmilk.

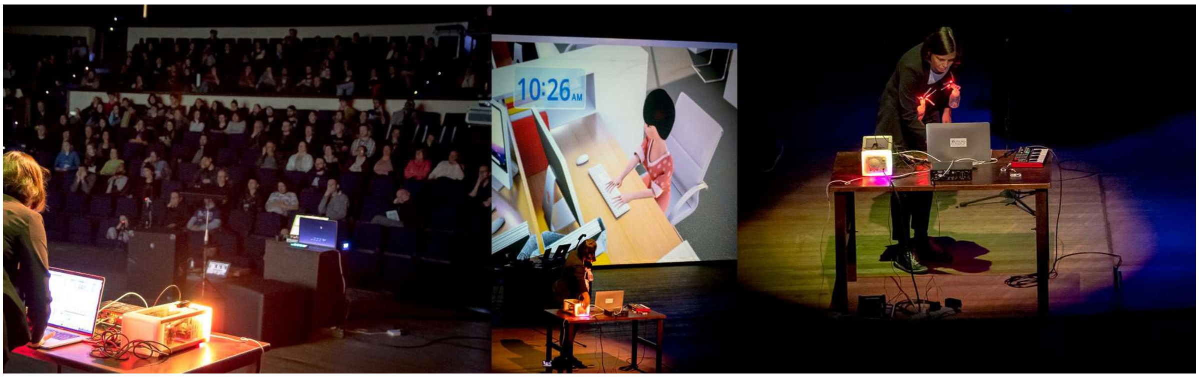

Figure 2 Three Stills from a performance of Good Mother / Bad Mother at NIME 2019 at Salão de Atos in Porto Alegre, Brazil

Reactions

I have performed *Good Mother / Bad Mother* in the United States, in Italy (twice), as well as in Brazil. Overall, reactions to the performance vary between women and men. Women in the audience have a clear idea what the performance is about while men on average have not been confronted with the topics

discussed in the performance. Men's reactions vary depending on their sensitivity to the theme. Some ask questions along the lines of "what is the problem?". Others want to learn more or tell me that someone in their life is going through something similar.
Women's reactions are divided between those who are experiencing the stressors described in the performance and those who have experienced them in the past. For women who are struggling with fertility combined with career pressures the performance is (understandably) difficult to watch. Positive reactions typically come from women who have experienced stressors related to motherhood and gender inequities but have in the process found some distance to the specific issues described in the performance.

Technical Discussion

The project is a patchwork of different software and platforms: Most of the software runs on a Macbook. A fairly simple *Max* (Cycling74) patch controls the visuals. The sound of the breast pump is recorded through two microphones and amplified in real-time via a thunderbolt audio interface. The sound is then processed via the MacBook. The audio part of the performance is mostly improvised. It consists of several *Ableton Live* (Ableton) projects that have different levels of pre-determined arrangements. The second song and the last song (of four songs) make use of the knobs on a midi keyboard to control filter parameters. I am also using the breast pump itself as an interface, playing it at different speeds to create different sounds to accompany the visuals.

The LED costume runs on a regular *Arduino* microcontroller board (Arduino) with a Sparkfun *Spectrum Shield* (Sparkfun). The LEDs are Adafruit *NeoPixels* that may draw 60 milliamps per individual *NeoPixel* at maximum brightness (Burgess). There are 140 *Neopixels* on the costume, however, not all of them are turned on at the same time, so a battery that can source two Ampere-hours is sufficient. Inside the breast pump enclosure there is another *Arduino*. It has a small microphone and activates a strand of *NeoPixels* that surrounds the breast pump enclosure and is sound reactive via a small electret microphone.

The visuals are mostly found (YouTube) footage and images that are remixed to form a narrative. They are images from advertising, from magazine articles, news coverage of press conferences. Some of the footage also comes from breast pump demonstration videos.

Conclusion

I created this performance because I found audiovisual performance programs at festivals and conferences to be dominated by male performers and technologists. These are the people in the field who decide what is interesting and what is not. It was (and still is) my impression that this kind of event is generally in need of feminist intervention. My project contributes insofar as it demonstrates a use of the breast pump as an interface for musical expression and performance. It also contributes to the diversity of possible (political) topics and interfaces to be explored through audiovisual performance. It has been my impression that *Bad Mother / Good Mother* is not a performance that seamlessly blends into a performance program. And while that may be uncomfortable to many in the audience, it does expand the idea of what performances with electric and electronic interfaces can and will do.

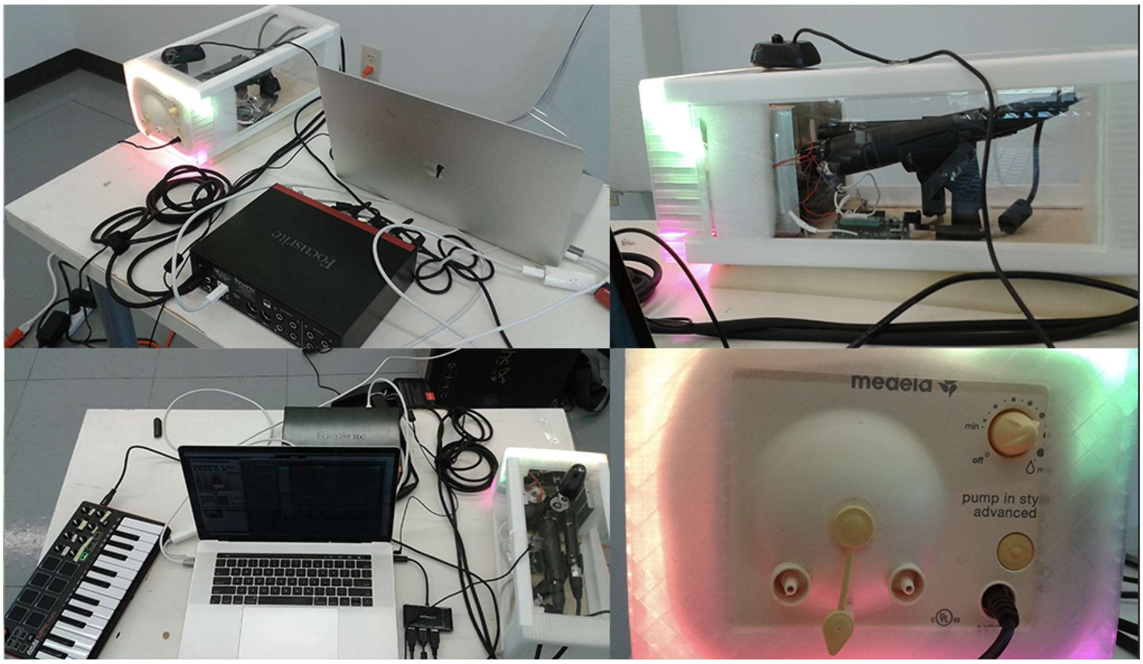

Figure 3. Table layout for performance.

Link to Work

Website with videos, etc.: http://anninaruest.com/badmother.html

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Jordan Sand

A Three-Dimensional Geography of the Double Bass

Performance Paper

Video of presentation can be found here

Instrumental Geography: Illuminating Relationships through a 3-Dimensional Interface

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Abstract. This paper presents a new three-dimensional way to map pitch on the double bass. The project is designed to illuminate spatial and intervallic relationships between two pitch systems, or "layers" of the instrument – stopped notes and harmonics – in order to facilitate a more polyphonic, harmonically-varied approach to composition and improvisation within a composite pitch system. After contextualizing the work within the instrumental field, overarching goals and early versions of the mapping will be presented, followed by the processes taken to develop it to this point, and some of the coding structures used to render digital visualizations. Due to the in-progress nature of this project, this paper will also envision future versions of and uses for the mapping.

Keywords: double bass, visualization, harmonics, geography, choreography, instrumental research, performance

The MAP is the interface

The fingerboard of the bass spans over 600 square centimetres of blank playing surface – for reference, that's almost twice the area of the cello's fingerboard, four times that of a violin, and just 10 cm shy of the length of a piano keyboard. We find no frets or inlays, few tactile anchor points for the hand, and forget about standardized spacings from bass to bass! On this unwieldy instrument, pitch is a wilderness. Even the most fundamental musical functions rely upon a precise, comprehensive internal map: the bassist's indispensible interface.

First formed in the mind's eye, this map structures the fingerboard's blank space into collections of points and relationships – a *geography* – which then guides the design of intricate *choreography*, sequencing the reflexive recall of exact physical spaces. What we practice "seeing" on this instrument eventually sinks into the body, transforming from visual to kinaesthetic. We *perform* the interface internalized.

The map is assembled from one basic unit: a set of coordinates, or a *node*. Defined as "a point in a network or diagram at which lines or pathways intersect or branch", in bass lingo a node marks a point on the string where one presses or touches to sound a musical note. On the fingerboard, I see constellations of these nodes crystalizing in space, guiding the shape and movement of my left hand. But unlike the flat diagrams of astronomy books, my constellation springs from the page. I envision the nodes of the bass as if you could step inside them, witness to their prismatic depth.

How does a third nodal dimension occur on the theoretically two-dimensional playing surface of a fingerboard? In addition to length (of string) and width (repetition of strings side-by-side), there is an undeniable dimension of height, or elevation, resulting from two "planes" or "levels" of playing. We may fully depress the string against the fingerboard, shortening it to change the pitch – this lower level produces fundamental, or "stopped" notes. Or we can lightly touch the string at its natural elevation, causing it to vibrate in equal divisions – an upper level, producing natural harmonics.

In practice, the distinction is subtle – only about 8mm change in elevation between a stopped note and its cohabiting harmonic. From the outside, the dimensions of length and width pack more of an empirical punch. Perhaps the player, too, may overlook elevation. We mostly experience the distinction between levels as a nuanced tactile shift. After all, both emanate from the same string, which is, for all intents and purposes, one-dimensional. [1]

But another factor, more conceptual than mechanical, may confine the map to two dimensions. Most bassists habitually view harmonics as sort of an isolated phenomenon, an unorthodox "extended technique", rather than a ubiquitous, fundamental characteristic of the instrument. Even with deeper understanding, the widespread tendency is to use harmonics and stopped notes independently, as if shifting gears on a car, releasing one to engage the other.

In truth, the two pitch planes work as one integrated machine: a phenomenon unique to the bass. Its long fingerboard, low register, and resonant build render its natural harmonics playable throughout the entire string length, pitched roughly in the advantageous range of the human voice, and acoustically supported.[2] Thus, unlike smaller stringed instruments, the bass's harmonic series is an anomalously robust and omnipresent pitch system, ready to rub elbows with stopped-notes in every single hand-position known to mankind.

Bertram Turetzky, writing in 1989, observed that:

> "One seldom-used technique with extensive potential is the double-stop combination of natural harmonics and stopped notes. The sound is unique, often not having primarily the character of two notes, but rather something fused, almost "electronic"…… the technique releases the contrabass from being merely a "one line" instrument. There are somewhere between one and three hundred such possible combinations, depending on the size of the performer's left hand and the extent of his or her proficiency with higher partials." (Turetzky, 137-138.)

When I first stumbled upon this quote, I laughed aloud in my empty new studio at NTNU. My teacher's teacher summarized my obsession with this instrument a year before I existed. Such combinations are more widely explored now, perhaps,[3] but still used sporadically, unsystematically – for, in spite of the ample scholarship on bass harmonics, we seem to lack a thorough geography, nay, *topography*, of this unique composite pitch system, and the utter bird's nest of intervallic relationships forming therein.

There might be a method to the madness in there, but we can't get at it with two dimensions. A flat map is built to track one line or layer at a time; indeed I've yet to come across a position chart, map, or tablature of the bass that *wasn't* two-dimensional, as the vast majority of bass playing is currently linear.[4] But what of an approach to the bass that is primarily chordal, using both pitch layers simultaneously at every moment? In order to systematically explore the hundreds of intervals occurring across strings *and* levels – the raw materials of my music – I actually need a *model*, not a map.

By illuminating the full scope of this insane interval machine, I'm hunting for new pitch combinations within my primarily dyadic, polyphonic approach to the bass. I am compositionally motivated. I want to unleash its idiosyncratic counterpoint and complete harmonic palate, in the hunt for more color, movement and complexity within my writing. It's essential to do so through the lens of practice – what is physically playable on the bass?

To that end, my secondary motivations are pedagogical. A model helps to bypass rote familiarity and objectively discover new combinations; but then how do I learn to play them? A thorough geography will help me approach this task methodically, to more successfully develop and internalize custom choreographies. Then, turning outward, I will be better equipped to communicate an integrated method for the bass' composite pitch system.

This project is intended as a practical, instrument-specific tool. It neither replaces nor departs from the previous work and raw materials of fellow bassist-composers, but is meant to synthesize a pedagogical approach to natural harmonics

[1] Auditory Neuroscience: Making Sense of Sound, pg. 10

[2] We may also rejoice that the bass is a bowed instrument, a bow a tool that gives us more finite control over a broader range of harmonics than pizz.

with a different lens, within an alternative aesthetic context, focusing on expressions and organizations of pitch over breadth and variety of timbre. It is not meant as an objective research in acoustic properties. Likewise, we're not dealing yet with issues of tuning or temperament, as will certainly arise later, nor correlated technical studies of the bow, although in practice this is a stringent, prerequisite factor.

For now, I provide a scaffolding for the on-going development of a left-hand interface, beginning with half-scale technical drawings, followed by digital visualizations built with the Python coding language. This foundational project-within-a-project at NTNU is meant to geographically illuminate the full spectrum of pitch on the bass, discover and organize intervals, guide the development of new left-hand choreographies, inspire composition, and prepare to set the composite pitch system of the acoustic bowed bass into dialogue with electronics and chamber ensembles through my creative practice. I hope that as it develops, this project can bridge a gap in a collective interface, motivating others to explore the double bass anew.

Evolutionary background

Bassists place much pedagogical emphasis on *how* to visualize, map and choreograph this instrument. Considering the fingerboard's plentiful room for error, we must obsess. But another factor rivets us to the map: double bass is a veritable jack-of all-trades undergoing rapid evolution. *How* we map and choreograph the fingerboard has everything to do with what we each perceive in this bizarrely all-purpose instrument. As in other disciplines, we map according to a specified purpose – in what genre or style are we working, in what ensemble role, with which aesthetic priorities?

The options overwhelm: bass propels bluegrass and baroque, Stravinsky and Count Basie, free jazz, rockabilly and the romantic symphony orchestra. It increasingly shines as a solo instrument. Composers broaden and enrich the repertoire, and trailblazing improvisers stretch its timbral and harmonic palette. With advancing techniques and a rapidly globalizing pedagogical network, our collective level of playing keeps rising, expanding notions of what the bass can do.

Bass thus seems to be undergoing a Renaissance, "a period of explosive development similar in a general way to that of the other string instruments in the 19th century". [5] This has spurred a wealth of geographies and choreographies, each deeply correlated to the purpose at hand. It is useful to present a brief outline[6] of those that have coagulated into a pedagogy – specifically a "mapped" pedagogy, centring on a visual-spatial organization of pitch yielding left-hand positions and codes of movement – to demonstrate how harmonics increasingly work their way into a technical understanding, and then an aesthetic approach, to the bass.

In the United States, two contrasting pedagogical methods are widely used. From 1881, Franz Simandl's method develops orchestral technique, demarcating twelve distinct positions in the first octave of the string for strength and control in low registers. For Simandl, bass is the dry, punchy platter on which we put the orchestral cake. Alternately, François Rabbath's streamlined, soloistic fingerboard organization marks fewer, larger positions for more rapid vertical movement along the entire length of the string, with left-hand choreography designed to preserve resonance and a "singing" continuity for the bow.

Published in 1977, Rabbath's positions were likely the first to be intentionally organized around natural harmonic nodes (their sounding pitches are shown on the right in Fig. 2). Harmonics also guided bow placement – he pinpointed the point of contact for most optimal resonance, or "son premiere" around a harmonic node just past the end of the fingerboard. An autodidact turned virtuoso, François likely found that the unwavering coordinates of lower-partial harmonics provided an anchor during his decades of self-directed study.

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[5] Paul Brun: *A New History of the Double Bass,* Paul Brun Productions, 2000, p. 92.

[6] It should be noted that I come from a specifically American lineage of training, so my points of reference may not reflect the pedagogical progression experienced by a bassist completing training in other parts of the globe.

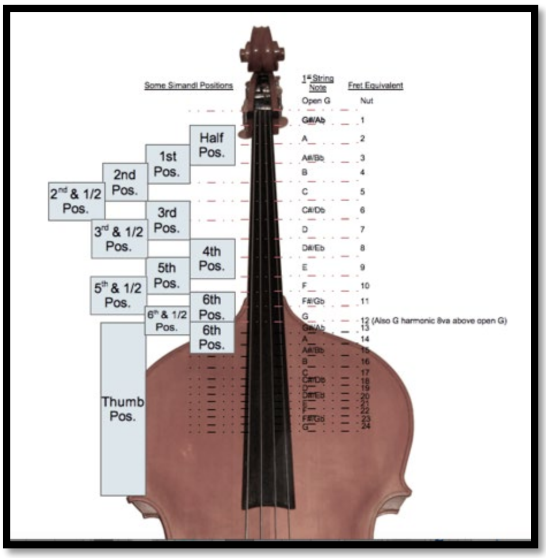

Figure 1. a Simandl position chart (Christopher-j.net)

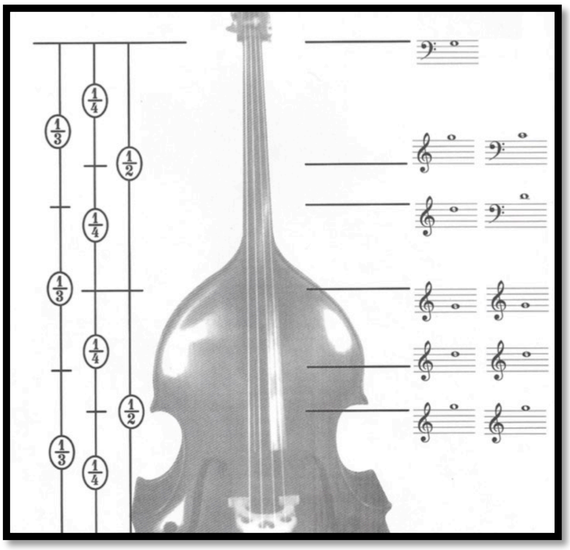

Figure 2. Rabbath position chart (Vance, page 5)

With increasing reference to harmonic nodes, new mappings have condensed axioms of Simandl and Rabbath to support the virtuosity of new generations, such as David Allen Moore's system of *Fractal Fingering* (2019). Moore divides the string into 6 equal parts. When repeated, this same physical distance contains stopped-note intervals of a m3rd, M3rd, P4, P5, and P8, respectively (Fig.3) – a phenomenon of fractal mathematics, around which Moore builds detailed hierarchies of position and movement, informed by years of methodical work decoding the advanced, idiosyncratic left-hand techniques of bass virtuoso Edgar Meyer. Hence, we have an interface built for precision and speed in soloistic, stopped-note playing, emulating the capabilities of higher-pitched stringed instruments. [7]

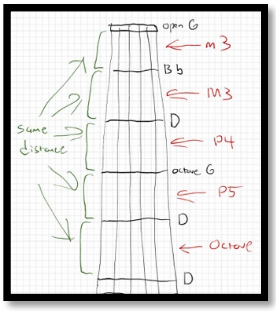

Figure 3. Diagram of the principle behind *Fractal Fingering* (provided by Jason Heath, doublebassblog.org)

As modernizing musical styles increasingly focused on timbral diversity, harmonics moved from a tracking device to a destination and began to attract more detailed research. Mark Dresser's fastidious video-mapping *Guts* (2010) breaks

[7] The majority of my formal training came from this lineage – a distinctly American school of technically analytical playing and teaching, deeply informed by the philosophies of movement and sound production of François Rabbath. This technical community was spearheaded in the 1980s by Paul Ellison of Rice University, and now includes performers and pedagogues Nicholas Walker (Ithaca College) Ali Yazdanfar (McGuill University) Scott Dixon (Oberlin & CIM) and David Allen Moore (USC).

open the Pandora's box of harmonic techniques, sounds, and systems on the bass and demystifies their acoustic premise, nodal locations and musical potential. *Guts* is perhaps the first documented method to systematically reveal the sheer, applicable omnipresence of harmonics throughout the entire fingerboard.

Dresser asserts that an understanding of the natural phenomena of string vibration is central to his creative process of exploring sound on the contrabass.[8] Harmonic nodes form his grammatical super-structure, supporting a whole dictionary of more complex, personalized harmonic techniques,[9] cultivated via decades of experience in jazz, improvisation, and contemporary music. Many improvisers and composer-performers share this lexical approach to the instrument, grounded in expanding one's timbral palate.[10] By assembling pedagogy around this grammar, Dresser gives modern bassists a pivotal technical tool, transforming our understanding of the instrument across musical communities.

Dresser's work augments that of his predecessor at the University of California San Diego, Bertram Turetzky, who mapped harmonics along a single axis indexed to staff-notation (Fig.4). Turetzky mapped as far as the 10th division of the string, a fairly high partial. Dresser dared up to the 19th (see Fig 5).

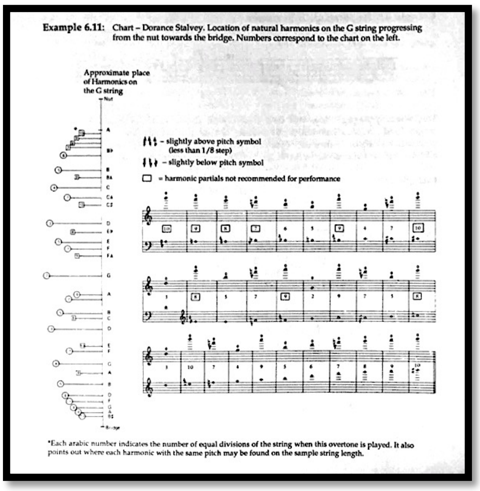

Figure 4. The Contemporary Contrabass (Turetzky) pg 109

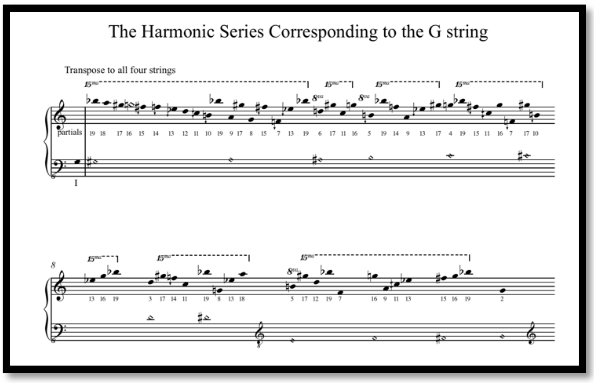

Figure 5. Excerpt from Mark Dresser's document "Harmonic Correspondence – G string" accompanying *Guts*

Both documents show essentially the same information, mostly differing in extent and format – a nice example of the bass community's collective interface, wherein both lineage and innovation are upheld. No two mappings are mutually exclusive, creating room for dialogue and (sometimes rapid) evolution.

Even methods as seemingly disparate as Dresser and Rabbath's tread much common ground. In their case, as in many cases, it's the harmonic – for a harmonic's location is a tenacious mathematical fact. Simultaneously a guidepost, destination, and fundamental principle of physics, harmonics intimately affect all sound produced on the double bass. Our collective mapping becomes increasingly oriented to them for good reason. They offer us a thread of continuity, a touch-point between varying geographies.

[8] from the accompanying written notes to *Guts*

[9] artificial, multi-nodal, or flautando harmonics; subharmonics, multiphonics, or bitones

[10] Joelle Léandre, Barry Guy, Stefano Scodanibbio, Jiri Slavik, Håkon Thelin, I could keep going, the generations of bassist-innovators keep rolling in

Interestingly, they're also the fault line along which new geographies form – as in, you map according to your treatment of harmonics, and in turn, one treats harmonics according to how one perceives the instrument's essential character. Like others, the character I perceive originates *beyond* the bass, in something sonically larger than the monophony of Simandl's cake platter, Rabbath's singing belcanto, Moore and Meyer's bigger funkier violin, or Dresser's explosive dictionary. To me, the bass is an organ – a sound that engulfed me weekly for almost 20 years, while growing up attending a Presbyterian church.

Around age twelve I absconded from violin to bass: no coincidence, in retrospect. Its resonant, overtone-ridden bow sound, so evocative of those engulfing pipes, mesmerized me. Later I became engrossed in its peculiar timbral nuances, almost as varied as the stops of an organ, and the latent harmony and polyphony between its pitch layers, like the organ's multiple manuals (keyboards). Its an instrument I can live inside, that owns the room in all directions, standalone and mysterious.

Harmonics breathe life into this sonic blueprint, but bass may transform into a chordal, multi-line instrument only when they are treated as a fully-fledged pitch system, in synchrony with stopped notes. I've been chasing this transformation for some years. My approach has the most in common with Norwegian bassist Håkon Thelin, who's solo compositions display dense polyphony, and his mentor, the late Stefano Scodanibbio, whose live presence was compared to that of an entire orchestra[11] – both composer-performers working closely with the instrument's composite pitch system. Thelin writes beautifully of the technical inner workings of Scodanibbio's music:

> "The novelty … lies in his refined use of harmonics on every part of the string, also in the low and middle positions of the fingerboard. In his music, narrative and rhapsodic phrases are formed through an interchanging of ordinary tones and flageolets. This constantly changing motion between low and high sounds creates multi-dimensional rooms where sounds and fragments of melody can evolve."[12]

Thelin goes on to claim that the evolution of the natural voice of the bass, with Scodanibbio's use of harmonics, is drawing near to completion.

> "The full potential of harmonic sounds on the double bass, as it is realised by Scodanibbio and others, may very well be *the final step in the development of the historical double bass.* All major divisions of playing techniques have now been defined, and exploration of the natural inherent possibilities of the instrument itself has reached its final evolutionary stage... Indeed, it is within its expressive range of timbre that the modern double bass has truly found its voice. "[13]

I would add that within this final evolutionary stage, we must not stop at viewing harmonics as a key to timbral plurality, or as linear melodic tools forming interchangeable melodic fragments. They are the flip side of the pitch coin, the omnipresent parallel universe, the arm outstretched from the bass to the organ. They are what make the bass larger than the sum of its parts, and their role in the duality and simultaneity of pitch and place is one of the least explored yet most fundamental, natural, inherent possibilities of the instrument.

While using I am using the same raw materials, in my work the evolutionary tree again branches off[14], with voice as the catalyst: I sing with my bass. Both the presence and orchestration of voice has drawn a primarily chordal harmonic expression from the instrument, even as the role of voice changes in my music. I used to melodically and timbrally forefront the voice, with chordal bowed bass accompaniment. Now I want to subvert these hierarchies (the singer-songwriter factory-default), and sink the voice *into* the instrument, weaving melody and harmony equally between stopped note, harmonic, and voice, exploring the tension and release of consonance and dissonance.

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[11] Referencing a quote from Terry Riley regarding Scodanibbio's playing, from "Press" on stefanoscodanibbio.com
[12] Håkon Thelin, "A Folk Music for the Double Bass" pg. 2
[13] Ibid., pg. 2

This search for richer three-part harmony, homophony, and polyphony has asked more and more of harmonics on the bass *as a pitch system*, contributing to a wider *bed of sound* within which to sink a human sound. Voice is indeed lurking there in my blueprint: the hymn-singing congregation melting into the organ, the expressive power of something biological yet fused, almost "electronic" – the sound much larger than the sum of its parts.

I wax poetic in order to collect energy for the task ahead, illuminating this immense galaxy on the instrument. I suspect that, if I step inside its many constellations, the whole character of the bass could evolve for me yet again.

Defining goals for the interface

In light of these purposes, existing mappings have some limitations, especially in the treatment of harmonics. Many good resources outline their pitch content, approximate locations, correspondence to stopped notes directly under them on the same string, etc. [15] using mostly demonstration, and various forms of staff notation – but their geographic *mapping* remains incomplete. If and when a map is made, it tends to be linear, vertical, along the length of one string. Second, the scaling is often approximate, imprecise, despite the exacting mathematical nature of harmonic nodes. Most significantly, apart from their use as anchors (ie. the nodes that a lower-partial harmonic shares with a stopped note) harmonics are charted in overwhelming isolation and self-reference, rather than locally or laterally, in deep spatial and intervallic dialogue with both correlating and surrounding pitches.

Why insist on a mapping, anyway? I'm talking about a diagram; a map; a third-party visual-aid apart from human and instrument; a star chart. For me, format is important. Loose position charts, tablature, staff notation, and video demonstrations are like various keys or indexes to an imagined map – they don't fill the function of the map itself.

Remember, this thing is a "wilderness" – no pre-installed points or pathways, as on a guitar, nor broadly-encompassing hand positions, as on a violin. On the bass, to hit almost any new target, you have to *move*; so you must have an accurate mental picture of what you're moving through. To complicate matters, harmonics can be finicky targets. You either hit it or you don't – there's no consolation prize, no "out of tune". In the case of harmonics, there's simply too much at stake to substitute geography for a kind of disembodied short-hand, when actually *plotting* the terrain can quickly orient us. [16]

Another roadblock: when deferring to staff notation as primary pedagogical means, we create several cumbersome layers of translation when it comes to actual pitch content. The fact that bass is already a transposing instrument (sounding an octave lower than it's written pitch), and our current system of notating harmonics is a kind of tablature not correlated to sounding pitch, means that staff notation is pretty ill-equipped to help us grasp the instrument's full range of pitch content across its composite pitch system. Staff notation is just that – notation. A system of symbols or ciphers, awaiting translation. It's quite effective in communicating a series of events in a piece, but proves a poor pedagogical tool, unable to orient us within a composite pitch-field unless indexed to something more direct. In this context, I believe finding a way to communicate pitch graphically would be most effective.

Above all, I am searching for a form of documentation most aligned with the materials in-practice. With this in mind, the first step in the creation of a new mapping was to define some goals.

What information should it contain?

Nodes: Exact mathemathically-derived location of each harmonic node, each stopped note, accompanied by detailed information on pitch (both class and octave) partial number (division of string) and frequency (Hz).

[15] For example, Mark Dresser's *Guts*, Bert Turetzky's *The Contemporary Contrabass*, Knut Guettler's *A Guide to Advanced Modern Double Bass Technique,* Jean Pierre Robert's *Le Modes de jeu de la contrebasse*
[16] How much easier is it to glance at a street map than to remember and follow written or verbal directions? Look at a cross-section of the human body and find your own spleen? And a hundred other rhetorical questions

Intervallic Relationships between: harmonic layer on 1 string, harmonic layer across 2 or multiple strings, harmonic layer and stopped note layer on 1 string, harmonic layer and stopped note layer across 2, 3 and 4 strings – all imaginable combinations, both physically playable as double stops (organized by hand position) and playable as linear intervallic movement with or without a shift.

Hand positions: how to show placement and movement of the left-hand, both influenced by and influencing the expression of this density of nodal information?

References: Should this eventually be referenced graphically to multiple existing schools/ways of organizing left-hand position on the fingerboard, to give others a familiar frame of reference to dive in? Perhaps a question for a later or more pedagogically-oriented version.

Extent: Should it focus on block-position (the area of the bass where the registral content and resulting intervals are most salient to my music) or should it span the entirety of the fingerboard?

What should it do?

Tuning: Should be able to change the tuning of any individual string, which adjusts all pitch information on that string as well as the relevant intervals that string is involved in. Important to note that any geographic information does not change (partial number and location of nodes) only pitch, hz, and intervallic information.

Filtering of information: We should be able to display different organizations of the composite map, in order to be able to visually focus on specific functions or attributes of the system. For example, we should be able to display/activate different data sets within pitch and intervallic information, filtering according to type of interval (show me all the minor 9ths hiding in here!) hand position (show me all the intervals accessible across x number of strings in this hand position) the type of pitch information (perhaps I want to see every node in terms of Hz only) or partial number (to explore the way a certain partial interacts with stopped notes in its multiple locations). Should we be able to isolate all phenomenon within a certain frequency range? Click on an interval and be indexed elsewhere to its staff-notated form?

Sound: Should or could this map sound on its own? At first I considered this unnecessary, but perhaps being able to sonically play around with the possibilities away from the bass but still connected to the geography would be useful. If, in this fashion, I hear an interval I can't yet produce technically, perhaps this would be horrendously motivating.

Interface: I asked myself early on, is this an interface in the more literal sense of the word? Especially considering the thorough mapping of frequency content, could it eventually receive, organize, or filter signal input? Should it? What would allow this to function as more than a technical or compositional reference tool, and in that case what could it do?

How should it look or be designed?

Design: Should there be two versions? A more simplified 3-dimensional grid version, with cubes and rectangles defining the distances, and the proportions accurate along the X and Y axis, but approximated for the Z axis (which contains the dimension of "elevation" between layers) AND a version truer to life, with the distances and spaces that actually exist between layers and the curvature of the fingerboard and bridge taken into account? In imagining the visual presentation of this tool, it's a matter of what is most useful or effective, visually, spatially, in-practice.

Perspective: We should be able to drag this mapping around in "3-dimensional" space and look at it from different angles, but the main orientation should be from the angle at which we stand at the bass and perceive the fingerboard in the mind's eye.

These parameters I have simply transcribed from my chicken-scratch notes, in order to set a detailed stage defining what I was after, and why. To now share the interface in-progress, I will take you along through my early process.

Toward dimensionality – rulers, calculators, and code, people

I began mapping this instrument with a tape measure and a sudden understanding that I had forgotten how to do basic fractional mathematics. Harmonic nodes live at equal divisions of the string. To calculate their exact positions for early sketches of this interface, I would have to do math, specifically division, and we may all sense that a bass player and math make for an unlikely romance.[17] The string length of my double bass is approximately 101 cm, an un-fun number to divide. Also, the biggest paper I could find was 80 cm wide. Thus the story of how I ended up with a model string length of 60 cm, a measurement that followed me off the paper and into the digital realm.

The first objective was to map how harmonics and stopped notes relate to each other on *one string* – and to do so in a way that was immediately grasped by the eye, rather than the intellect:

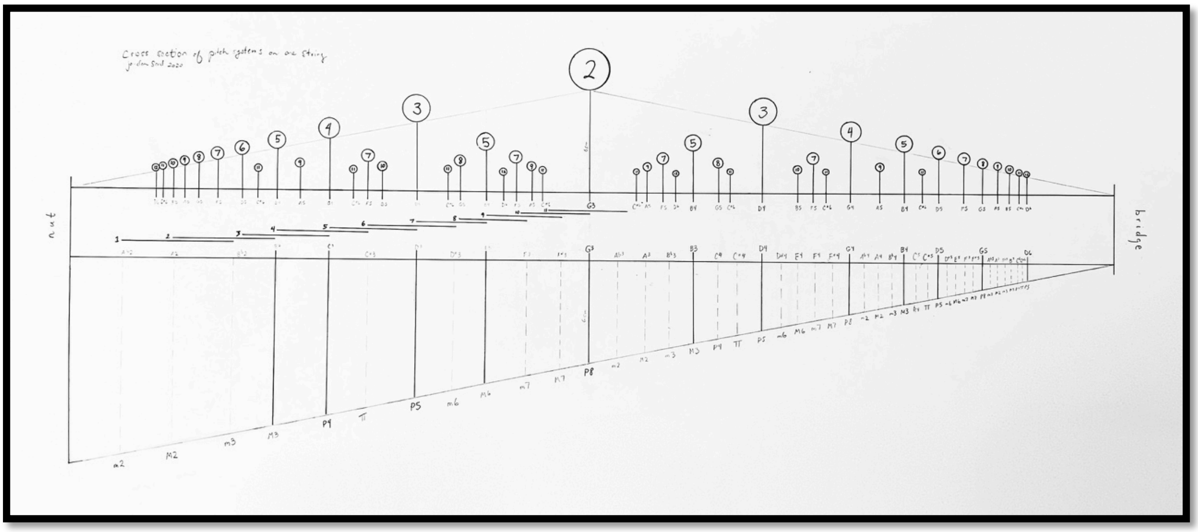

Figure 6. Cross section of pitch systems on one string

The two horizontal lines, at 60 cm long, represent stopped note (lower) and harmonic (upper) planes of the string. The vertical lines extending above and below these planes intersect at exact nodal locations, or divisions, of the string, with lengths proportional to sounding pitch – the longer the line, the deeper the note. By translating pitch to visual size, we can get quick impressions of where unisons or wider intervals may occur. The same is true of the circular markers on the harmonic level, which correspond to partial number. At a glance, we may ascertain where the stronger, lower partials lie (numbers 2-6) and in effect, also understand instantly the relative difficulty to sound each note. This cross-section shows some of the same information as Dresser's "Harmonic series corresponding to the G string". In addition, we get precise, proportional visual information about the location of harmonic nodes, and don't have to transpose or switch clefs in order to grasp intervallic information.

At the halfway point of the string (refer to circular node 2 in Figure 6) the sounding pitch of both the harmonic and the stopped note is G3. Similar unisons continue to occur as we go higher up the string (see, for example, the straight vertical lines descending from partial numbers 3-6 on the right side of this diagram, and note that their lengths match the lengths of the corresponding stopped-note nodes directly below them). However, in the lower half of the string, on

[17] Unlikely – not impossible! I know a bass player who does an hour of probability every morning before a 6 mile run, so… takes all types. (But in my case, it's unlikely.)

the left side of this diagram, the disparity of sounding pitch is much more pronounced, and the intervals wider and less predictable. I am most intrigued by the intervals in this area, and will focus the beginnings of an intervallic mapping here.

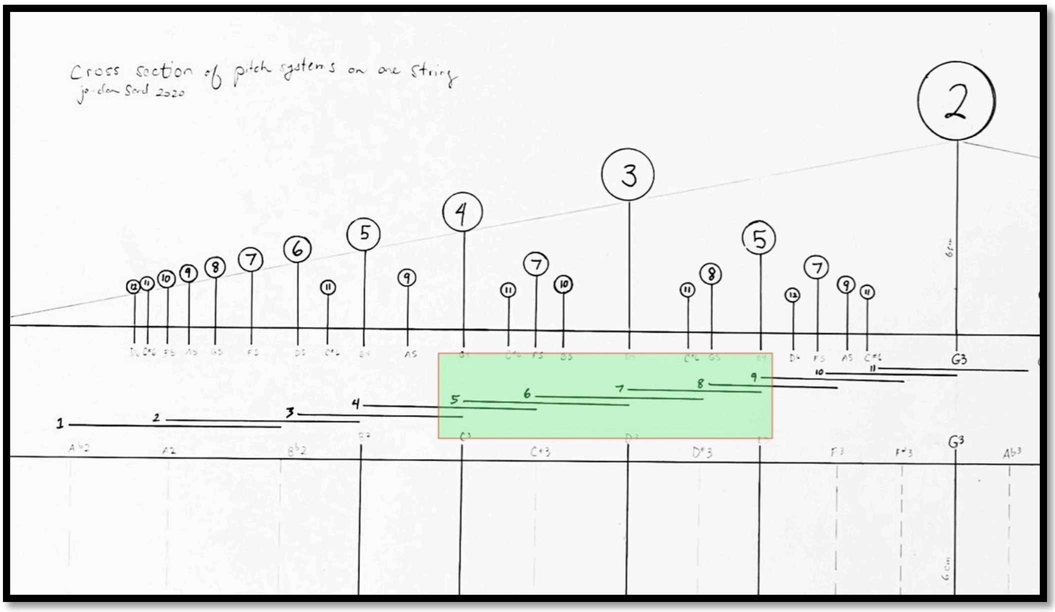

Figure 7. showing the range of hand positions 1-11 with staggered horizontal lines, placed between the two planes

A closer look reveals how we might begin to choreograph the use of these pitch systems together. The staggered horizontal lines represent the range of individual hand settings in the lower half of the string. (11 distinct positions draws from the Simandl approach, wherein displacing the hand by even one half step constitutes a new position.) If I place my hand in the 3rd position, for example, I can reach every note that falls within its range on both planes without moving or shifting my arm. Positions 5, 6 and 7, highlighted in Fig. 7, are especially interesting to me, because they fall right around where the neck meets the body of the bass ("block position") an important tactile anchor for the player. Although I plan to do this for every position of the bass, and across two and three strings, I chose to begin connecting the dots in these three positions on one string to get an impression of just how many intervallic relationships are living in each small territory, as demonstrated in Fig. 8.

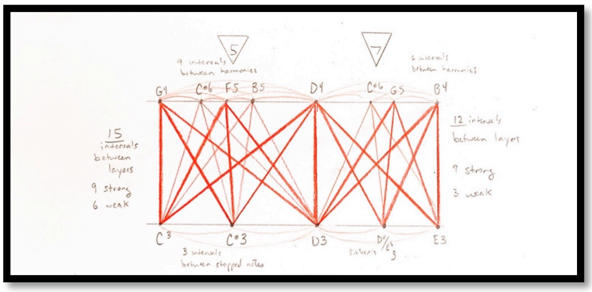

Figure 8. On one string – all possible intervallic combinations between planes within each hand setting

Of course intervals existing on one string, although they have melodic potential, can't be played together as a dyad. The logical next step was to take these connections and explore their workings between two adjacent strings. How many different dyads can be sounded within one hand setting across two strings? Again I am most interested in those dyads occurring between planes (position 5 in Fig. 9), but there are also dyads created harmonic to harmonic (shown in position 7 in Fig. 9) and stopped note to stopped note.

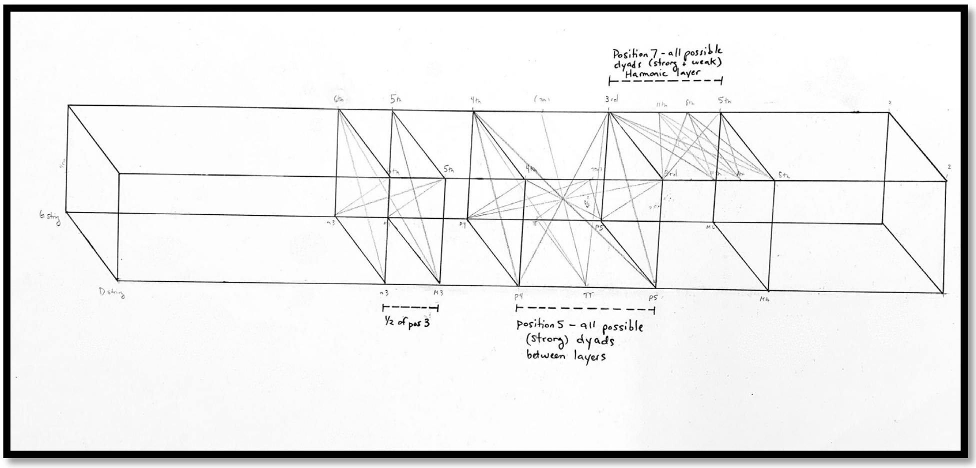

Figure 9. Beginning of a 3-dimensional look at how these pitch materials relate to each other

A static drawing of these relationships across strings quickly becomes a visual mess. To make it clear, it needed to be interactive, in moveable space somehow. I briefly considered making an actual physical 3-d model of it, like middle school science fair. Before I busted out the playdough and pipe cleaners, my supervisor pointed to an online visualization tool (Glowscript.org) that would require a bit of coding – a horrifying prospect that turned out to be a lot of fun, and generated new ideas about the possibilities for this interface.

Beginning anew, I took his suggestion to plot the center of the string, or 2nd partial, as 0 on the x-axis, with the open string (or nut) at -30 and the bridge at 30. Because the harmonic series is expressed in a mirror-image of itself from the half-way point of the string, this would generate data sets that were flexible and easy to keep track of when plotting harmonic nodes.

```
partials = [
    [0],
    [-10, 10],
    [-15, 15],
    [-18, -6, 6, 18],
    [-20, 20],
    [-21.4286, -12.86, -4,286, 4.286, 12.86, 21.4286],
    [-22.5, -7.5, 7.5, 22.5],
    [-23.334, -16.667, -3.334, 3.334, 16.667, 23.333],
    [-24, -12, 12, 24],
    [-24.545, -19.091, -13.6364, -8.1818, -2.7273, 2.7273, 8.1818, 13.6364, 
19.091, 24.545],
    [-25, -5, 5, 25],
```

Figure 10. Lists of locations of partials 2-12 along the length of the string (x axis, from -30 to 30)

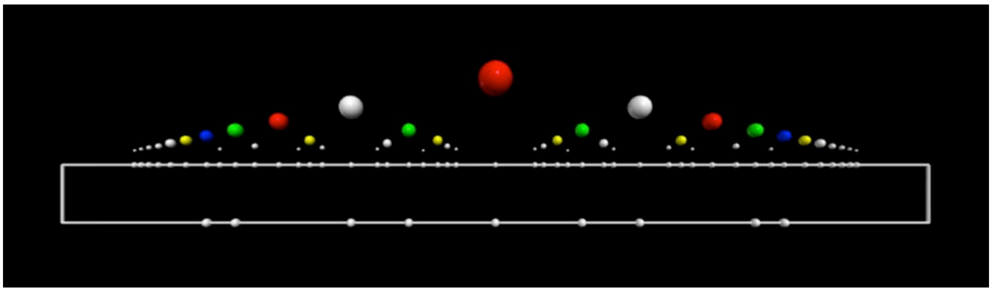

Figure 11. first digital rendering of two pitch planes, one string

Nodal locations on both planes were represented with small sphere objects directly on the string on both planes, rather than as vertical lines that intersected the string as in previous drawings. The larger spheres connected to the harmonic nodes, with sizes and heights proportional to the sounding pitch, were retained for visual tracking purposes. Handsettings were delineated with the color of the curve objects connecting these nodes, rather than separate visual objects. Fig 12 below shows all connections on one string within positions 3, 5 and 7.

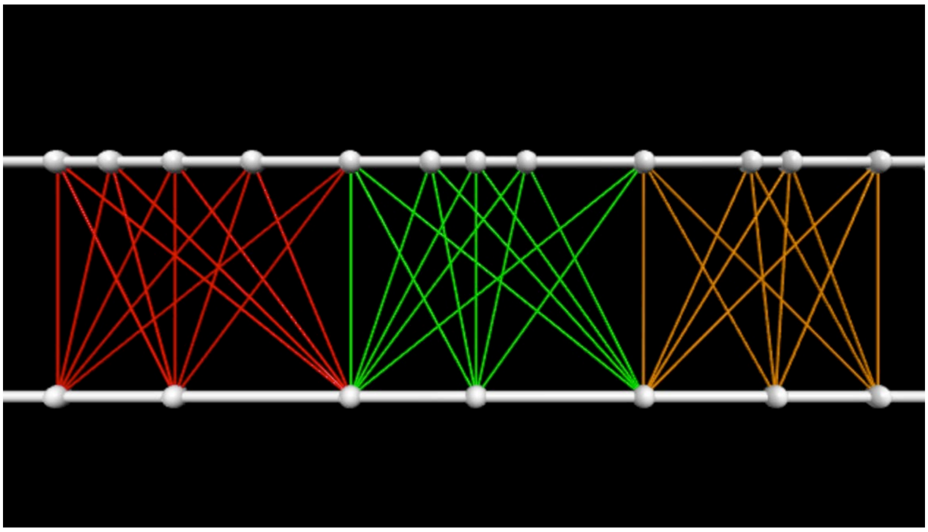

Figure 12. Showing relationships

It is noticeable by now that many complex kaleidoscope-like shapes are being drawn to represent intervals, but no intervals have been qualified as of yet – “that line is a minor 10th, this a major 7th plus an octave” etc. That’s because I would like this interface to automatically compute this for me, because I am lazy, and because there are literally hundreds of these intervals to discover, catalogue, and create with. I quickly realized that my primitive coding skills, barely one week old, would get me far enough to create a visual model. But I did not have the chops to design code that could accommodate my future goals, that was flexible and powerful enough to handle the integration of data sets and allow me to arrange and rearrange it as the concepts behind this interface progressed. What if I wanted to highlight all the minor 9ths available between layers? Or reveal only intervallic connections used in a specific piece, to scrutinize their spatial relationships? How about filtering nodes or connections based on register, partial number, or playability?

So I got out the big guns and called my little brother, who is a computer programmer with a much bigger brain than me, exhibit A:

Figure 13. Little brother, big brain

Over approximately 8 cumulative hours working together on Teamviewer, we were able to build a tool kit that would both render the desired 3-D visualized outcome and set up a “3D” data structure, wherein every partial node is connected or points to the partial series via a series of classes and the objects manifested through them. For the time being, only attributes meant to be rendered visually (such as height, radius, color, points, partial number) are contained within the PartialSeries class. Future drafts of this project can delineate and assign more attributes, such as sounding Hz, calculated according to a flexible fundamental pitch and the partial number, or pitch name and class.

```
class PartialSeries(object):
  '''
  Contains static configuration data for a partial series
  '''
  def __init__(self, number, height, radius, conrad, color, points):
    self.number = number
    self.height = height
    self.radius = radius
    self.conrad = conrad
    self.color = color
    self.points = points


class PartialNode(BaseNode):
  '''
```

```
Represents a single harmonic node and
reference to the partial series that contains it
'''
def __init__(self, series, position, level, string):
    super(PartialNode, self).__init__(position, level, string)
    self.series = series
```

Figure 14. Excerpt of more recent code behind digital rendering of interface

The ability to visually connect clear pitch information to nodal location, in addition to being a prerequisite for automating intervallic calculations, can fill another notable gap in our collective knowledge-in-practice. Although the sounding pitch of bass harmonics has been much documented and notated, it is usually only vaguely understood in practice due to a system of tablature-ish staff notation that references only the playing location, not the sounding pitch, of the note (also convoluted by the fact that bass is a transposing instrument.) We should be able to spatially observe nodal locations of harmonics, together with information about their sounding pitch, in order to have working clarity about the real range of this instrument, which is insane. For example, from this model I know now that the 7th partial of the G string is an F5 – my highest vocal note.

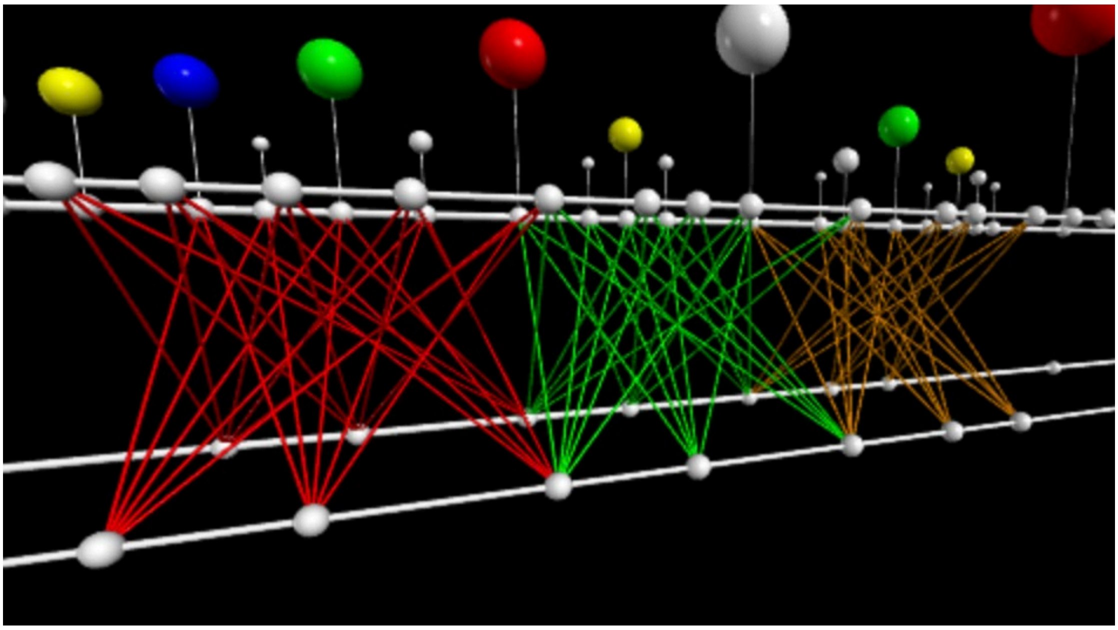

Figure 14. Hand positions 3, 5 and 7

An interesting perspective that Austin contributed was the removal of the fixed plane for the harmonic level along the y axis. What if the stopped note level remained constant, but the harmonics floated in space according to their partial number, and the connections were drawn accordingly, as in Figure 15? It was interesting to experiment with the impact that different visual organizations of the information could have on my relationship to these hand positions, when looking at different versions of the diagram with bass in hand.

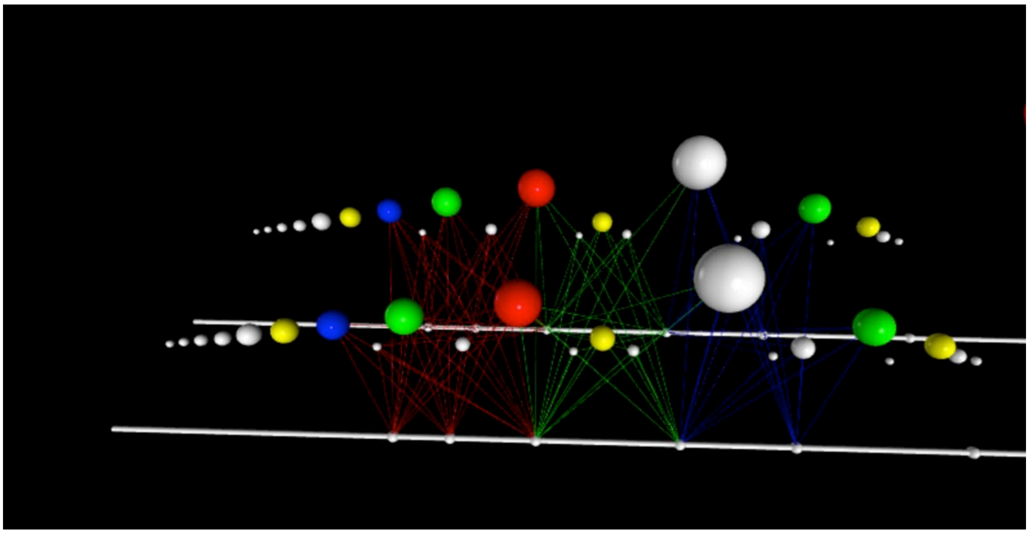

Figure 15. A variable height to visualize nodal locations and relationships, no fixed "harmonic plane"

Surely all these lollipops don't have anything to do with actually playing the bass? What is this good for? The answer is, almost nothing without the further integration of pitch information, extreme flexibility in examining and filtering information, and, most importantly, a lot of energy spent translating newly revealed spatial realities into the body and instrument in practice. Precise choreographies must be developed – not just of the left hand, in fact, but of the bow as well. Harmonics and stopped notes require very different bow speed, placement and pressure. One needs an extremely nuanced and accurate approach in order to simultaneously sound two disparate beasts across many octaves. Existing left hand positions, designed primarily for stopped note playing, may only go so far to express and control a composite pitch system. Many upper partial harmonics exist in smaller, more irregular spacings that our hands are not used to in lower positions, and must be practiced with hand settings developed specifically for them. In my playing, these choreographies have been partially developed through intuitive, obsessive stubbornness, but there is much deeper, more organized work to do regarding the development and documentation of choreography. This model will provide a basis for this work.

Further work and future versions

Future versions will integrate data sets (pitch name and class, partial #, hz, handsetting) and become more interactive. Could this have implications in live processing, or help to design or automate customized EQ for these complex resonances in live performance? How, and under what circumstances, will it impact my or others' compositional approach to this instrument? Could there be automated compositional applications of this interface? Could it be used as a graphic mediator or interface between the acoustic presence of the bass and its amplified/electronic equivalent?

There are many pipe-dream applications of this interface that I will enumerate in a later version of this paper, but they basically come down to two categories: How could this project develop into an actual electronic interface, mediating the acoustic signal of the bass with an amplified or live-processed realm? And what potential could it have to automate or randomize playable compositional frameworks with these pitch materials – in other words, in addition to showing what's there, helping the mere mortal to imagine what could be created with it?

All brainstorms aside, the most important and immediate next step is to apply the map to the terrain and *play.*

Acknowledgements. Thanks to Øyvind Brandtsegg for much patient guidance, and to my brother Austin Morton for his engaged and spirited collaborations.

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Gurpreet Chana

TABLIX for International Conference on Live Interfaces

Performance Paper

Video of presentation can be found here

TABLIX

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Introduction

TABLIX is a continuous study of Digital Technology[1] through the language of the Tabla[2] aimed to develop and support synergistic musical expression in relationship to the artistic process, performance technique & ergonomics of the Tabla musician (Tabla-ji / Tabla-chee / Tabla-ist / Tabla-wala).
TABLIX was initiated with a creative desire to digitally pitch shift the Purra. Tuning the Purra or Dayan (treble drum of the Tabla) to the tonic of the musical piece one is playing or the musician(s) they are accompanying is the first step in the artistic process of conversing musically with the Tabla.

In its current form, TABLIX is a digital Tabla interface. An acoustic Tabla augmented with software and hardware enabling the Tablaji to digitally pitch shift the Purra to any desirable monophonic or polyphonic group of notes (up to 4 voices) in real time via MIDI[3] protocol. Connecting and conversing with MIDI in this manner opens up the Tabla and musician through their artform to ideate, compose, edit, perform, explore, and collaborate with MIDI based artists and processes in unique and evolving ways.

Tabla background

Providing a thorough legacy of the Tabla and its language would be far beyond the scope of this paper and my ability to do so. However, I will share some important and relevant features of the Tabla and my relationship with them to provide context for TABLIX.

[1] Origin: early 17th century from Greek ***tekhnologia*** ‘systematic treatment’ from tekhnē ‘art, craft’ + logia ‘study of’. Thus my interpretation of digital technology is the study of the digital artform
[2] Sadanand Naimpalli, ***Theory and Practice of Tabla***. Popular Prakashan, 2006, p.8.
[3] MIDI is the acronym for Musical Instrument Digital Interface https://www.midi.org/, https://en.wikipedia.org/wiki/MIDI

Tabla History & Characteristics

There are many theories in regards to how the Tabla was invented. The most common being that the Tabla was developed by Amir Khusro Ji approximately 250 years ago[4], evolving from splitting the Pakhawaj; a two headed barrel shaped drum in half. At this time, the primary vocal style of music was transforming from Dhrupad, for which Pakhawaj was used; to Khayaal, for which the Tabla was developed. The Tabla was a new instrument, however the language, concept, technique, rhythmic patterns and oral tradition of the Pakhawaj was utilized and modified to explore it.

The Tabla is a melodic percussion instrument comprised of two, separate, vertically facing drums; a Purra which produces treble sounds and a Duggi which creates the bassier sounds. *(ICLI Video Reference - 5:03).* The Pakhawaj also has a bass and treble side but as opposite faces of a horizontally played barrel drum.

Tabla Construction[5]

The body of the Purra is made from a tapered cylindrical piece of wood approximately 5-6" in diameter at the top, wider at the bottom and approximately 12" high. The wooden body is usually hollowed out around two-thirds of it's length; leaving an approximately 4" solid enclosed base and open face with an upper rim of about ½" thick.

The enclosed body of the Duggi is constructed as a spherical looking pot with a shell thickness of approximately 1/16", face diameter opening of 9-10", and approximate height of 12". The Duggi body was initially made from clay but these days steel, brass, or copper are the more common materials used for manufacturing.

Both the Duggi and Purra faces are covered with a Pudi[6]; a three layered goat skin which is stitched together with a braided rim known as the Gajara. The main layer of Pudi (drum skin) is known as the Maidan on which a Shyahi is applied. The Pudi is placed over the face of the Duggi or Purra and fastened to the body of the respective shells by a strap made from goat intestines known as Badri. The Badri fastens the Pudi via the Gajara to the drum body in a lacing type pattern that continues in a repeated circumferential manner creating stretch and tension of the Pudi over the face of the body.

[4] Eric Phinney, *TABLA: Drums of North India* https://www.bsmny.org/instrument-discovery/tabla/#:~:text=Whether%20that%20is%20true%20or,style%20of%20music%20called%20Khayal.

[5] David Courtney, *Tabla Making in the Deccan* http://chandrakantha.com/tablasite/articles/tblamkng.htm

[6] David Courtney, *The Tabla Pudi* https://chandrakantha.com/tablasite/articles/pudi.htm

The Shyahi[7] is a black circular spot made from iron filings, rice paste, and ink. The particular ingredients of the Shyahi compound varies with each Tabla maker. The Shyahi is systematically applied in layers while wet to achieve desired pitch, sound, and tonal qualities for both the Purra and Duggi respectively. The finished Shyahi paste dries to a cement-like consistency and naturally forms cracks creating small grains & particles within itself during the hardening process. These grains vibrate against each other and resonate at the fundamental frequency of the drum which can be precisely tuned to enhance tonal characteristics.

On the Duggi the Shyahi is offset from the centre of the Maidan. The Tablachee uses this extra exposed Maidan skin to apply pressure with the heel of their hand and bend the Pudi skin to adjust pitch while striking it with their fingers. On the Purra, the Shyahi is in the centre of the Maidan. The pitch of the Purra is tuned to the same note around its circumference by controlling and adjusting the tension of the Badri + Pudi + Shyahi; hence the frequency at which the small particles of the Shyahi vibrate against each other.

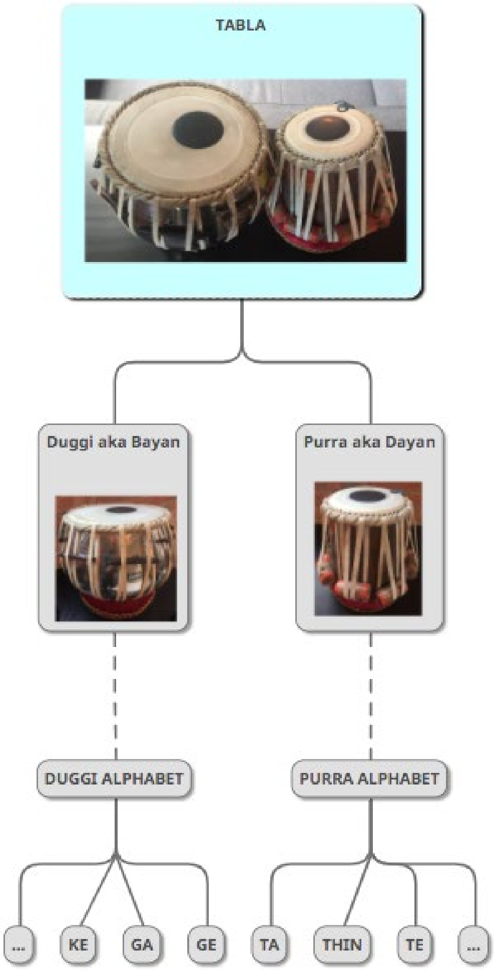
Language of the Tabla *(Video Reference - 5:20)*

The Tabla is known as a talking drum. This is based on the language of Tabla and the idea that the Purra and Duggi are having a conversation with each other, the Tablaji, other musicians, and the audience. The language of the Tabla Is a syllabic, Bol (Varan)[8] based musical language passed from Guru (Teacher) to Shishya (Student) through an oral tradition that started getting codified in Vedic literature between 4000 to 1000 BCE.[9]

This language is similar to the modern day concept of Beatboxing. Each Bol (syllable) is a vocal representation of the hand position, finger stroke, & technique used by the player in relation to the Tabla and the resulting sound which is created.

The following Figure shows how the Tabla alphabet and language is structured *(Video Reference - 5:53)*

[7] David Courtney, *The Syahi* excerpt from *The Tabla Pudi* https://chandrakantha.com/tablasite/articles/pudi4.htm
[8] David Courtney, *Basic Strokes and Bols* http://chandrakantha.com/tablasite/bsicbols.htm
[9] Ken Hunt, Simon Broughton, Mark Ellingham, James McConnachie, & Orla Duane, *Karnatic Instrumental Music* from *World Music Volume 2: Latin & North America, Caribbean, India, Asia, and Pacific.* Rough Guides Ltd., 2000. p. 79.



Combining Duggi & Purra Bols/sounds/strokes expands the Tabla alphabet and language to create words and phrases. *(Video Reference - 7:10)*

GE + TA = DHA
GA + THIN = DHIN
KE then TE = KIT
KE then TE = KUT
TE then KE = TIK
TE then KE = TAK
TE then TE = TIT
TIT KIT TIK TAK

Combining these Bols in different ways enables one to create phrases & sentences known as Taals or rhythmic cycles as shown in samples below. *(Video Reference - 7:45)*

Samples of RHYTHMIC CYCLES or TAALS

6 Beat Dadra
DHA THIN THIN TAK DHIN DHIN

7 Beat Roopak
THIN THIN TATA DHIN DHADHA DHIN DHADHA

8 Beat Kaherva
DHA THIT THIN THIN TAK THIT DHIN DHIN

16 Beat Rhythmic Cycle
DHA DHIN DHIN DHA DHA DHIN DHIN DHA
DHA THIN THIN TA TA DHIN DHIN DHA

These and other sounds from the Tabla alphabet can further be combined to create compositions of paragraphs, short stories, poetry & prose of varying emotions, complexities, and lengths in the form of Peshkaars, Kaidas, Relas, Uthaans and more. *(Video Reference - 8:36)*

A Tabla student who understands and has built a relationship with this percussive language can then apply the Tabla hand/finger technique or adapt it to perform on other instruments, MIDI controllers, sound objects, and more to create sounds and patterns.

Tuning and other Melodic Properties

Tuning the Purra is a critical first step of the Tabla process and practice. The Tabla is a melodic percussion instrument and the Purra is generally tuned to the root note or tonic of the song the Tabla musician is performing or the musician(s) they are accompanying. Once tuned, the Tablachee then starts to play the Bols, Taals, rhythms, & melodies on the Tabla. *(Video Reference - 9:40)*

Each Purra has an approximate tuning range of about 2-3 tones. However, the instrument maker generally constructs each Purra to sit at it's proverbial sweet spot or natural tuning.

This natural tuning is determined based on the size of body, quality of Pudi, and the amount, quality, and application of the Shyahi. For optimum and better life and use; it is advised to keep the Purra at its natural tuning and not adjust too often or unnecessarily.

Tuning the Purra and Duggi is carried out by a hammer. *(Video Reference - 9:45)* Coarse tuning is controlled by adjusting the Gittay (dowels) which are placed between the outer shell of the Purra/Duggi and underneath the Badri. The Gittay are struck down for more tension/higher pitch & up for less tension/lower pitch. The rim or Gajara is struck for fine tuning; down for higher pitch & up for lower pitch.

A Tabla player will sometimes take two, three, or more pre-tuned Purray of different notes to a rehearsal or performance depending on what situation requires. Tuning before/during a performance to the collaborating musician and space is expected within reason, particularly for fine tuning to the lead instrument in relation to the space. Extreme or drastic tuning can distract from the performance atmosphere, at times prove to be a laborious process, and not always successful, especially if the target note is outside the tuning range of the particular Purra. If major tuning is required, it is usually done between pieces or breaks in the performance.

Tabla Tarang *(Video Reference - 9:54)*

Tabla Tarang is the artistic practice of simultaneously creating melodies and rhythms with the Tabla. Usually one Duggi and a certain number of Purray are tuned to specific notes of a song or scale. The Tablachee then plays Tabla Taals, repertoire, and compositions while striking the differently tuned Purray to express melody.

Why TABLIX *(Video Reference - 10:42)*

TABLIX was birthed at a time when all my other forms of communication were moving towards the digital realm. Simultaneously digital technology for ideation, production and performance was becoming increasingly more accessible and ubiquitous in the world of music. The creative goal instigating TABLIX was to digitally pitch shift & compose, edit, perform Digital Tabla Tarang.

My broad experience of learning, playing, collaborating, and performing with the Tabla for over 35 years has informed the philosophy, design, and development of TABLIX. The Tabla, its language of Bols, and the technique used to play those strokes are part of my innate character. This relationship with the Tabla is the foundation upon which I explore music and other instruments and sound objects from around the world.

The Tabla language, artform, performance technique, and ergonomics are at the core of the research and development of TABLIX. These meaningful, creative guides, and parameters helped provide me with a focused decision making approach & strategy throughout the process.

I believe this has resulted in a synergistic integration of the Tabla artform with digital music production technology providing opportunities for the purpose of musical creation, connection, communication & collaboration. This foundation hopefully serves as the starting point of continuing TABLIX conversations through the language of the Tabla with MIDI and the digital realm.

How Does TABLIX Work? *(Video Reference - 18:19)*

TABLIX is an augmented Tabla; the Tabla itself remains as the main performance instrument/interface for the musician. The Duggi (bass drum of Tabla) & Purra (treble drum of Tabla) each have pickups (puD & puP) respectively installed on them. The Duggi also has an internal mic (imD) installed inside its body. These connect to the audio interface (RME Fireface UFX) where the audio signal is converted from an analog to a digital signal which is then sent to the digital audio workstation (DAW) Ableton Live.

Once in Ableton, the puD signal and puP signal are each processed in their separate audio tracks. The imD signal is routed through its own track and then to the puD track inside the DAW so that all software processing for the Duggi is done on one audio track.

TABLIX as a software is a 3 component Max/MSP device hosted in Ableton Live. The Duggi component of the device (D-TABLIX) is hosted on the puD track. The Purra component of the device (P-TABLIX) is hosted on the puP track, and a third Tabla MIDI track (TMDt) hosts the MIDI-TABLIX component of the device.

Other equipment which form the TABLIX interface are:

- In ear noise cancelling monitors for my own personal mix to hear only the processed digitally pitch shifted Tabla and whatever else I want/need in my in ear mix. This helps mitigate the effect of any latency issues arising from TABLIX processing and furthermore prevents me from hearing the acoustic unpitched acoustic Tabla sound.
- I perform standing up and have my Tabla and other components placed on a table. As a result I can make use of my feet while performing. I use a USB MIDI foot pedal

(Keith Macmillan SoftStep) to further alter my desired input or output sound via effects, looping, or MIDI control of other parameters within my DAW.
- Touch based MIDI controller (touchable) used to launch sequences, clips, compose, edit, record, and change parameters within my DAW.

Digital Pitch Shifting ***(Video Reference - 14:50)***

The input note for the analog Purra is tuned to C; generally C3, but the exact octave of what the Purra is tuned to is flexible and arbitrary. P-TABLIX is programmed to know that it will be receiving a C tuned Purra. The input note for the Duggi is less critical due to its low frequency, but if/when possible I aim to keep this tuned at C or G.

MIDI note messages are used to convey what the desired output pitch (monophonic) or chord (polyphonic upto 4 voices) should be for Purra. The same is applied to the Duggi in all examples below, but we will focus on the Purra as it is the treble and more tonal drum. For example: if we want the output pitch of the Purra to be F then a MIDI note message of F would be required. If we want the output of the Purra to be the G Major Chord then the MIDI note messages of G,B, & D would be required. The MIDI note messages are hosted on the TMDt and can be sent realtime by the Tabla performing artist themselves or by a collaborating artist. The velocity amount of the MIDI note message(s) does not affect the sound or intensity of the output pitched sound in any way. Therefore the performance dynamics are controlled and expressed through the playing and emotion of the Tablachee as it would be on an acoustic Tabla.

As a solo artist I pre-program the desired output pitch or chord messages in a 1 bar long clip. I launch this clip with the setting for it to be continuously looped until I stop the clip. The MIDI-TABLIX device reads the MIDI note message and communicates the desired output pitch to the P-TABLIX device. The P-TABLIX device calculates and applies the amount of transposition or pitch shifting (chord shifting) required and outputs the digitally pitch shifted Purra (from puP track) and Duggi (from puD track) sounds to the master channel in the DAW. There will be no sound output from the puP track if the TABLIX-P device doesn't receive MIDI note message(s) information from the MIDI-TABLIX component. Similarly there will be no sound output from the puD tracks to the master if there are no MIDI note messages being received by the TABLIX-D device. There will also be no sound, regardless of MIDI note message condition if the Tablachee chooses to mute the acoustic Tabla as part of their standard performance technique.

Digital Tabla Tarang *(Video Reference - 1:00, 16:08, 17:20, & 21:30)*

This is a process and performance technique in which the Tabla-wala can create and express melodies and rhythms simultaneously with TABLIX. The process is the same as described in the digital pitch shifting above however the MIDI note messages are continuous as they would be in a MIDI composed/edited melody or chord progression. It is important that the MIDI note messages of the melody or chord progression are continuous such that there is no break from one note message to the next along the timeline. Any small or large space between subsequent MIDI note messages would cause a break in the signal processing that TABLIX is undertaking and result in an unpleasant sound dropout and digital glitch sounds.

MIDI Connectivity

MIDI connectivity also allows the TABLIX artist to sync MIDI clocks with collaborating musicians to maintain time based effects in a collaborative setting with other electronic or MIDI based musicians. It also provides external control to collaborating musicians (who are also using Ableton Live) for launching clips within the TABLIX Ableton Live session.

Sound

TABLIX provides optimized sound design, mix, control when working live performance or recording sound engineers. In essence the engineer receives a separate left and right XLR and/or ¼" output audio signal or submix as they require direct from TABLIX audio interface.

Logistics

A lighter and smaller setup allows for more efficient and cost effective travelling and touring. The TABLIX setup and teardown is also improved and quite flexible for environments where it is the preferred choice over the conventional Tabla setup.

TABLIX Now and Beyond

TABLIX enables me to expressively imagine, create, and perform in wanted, expected, and unexpected musically evolving ways. As a Tablawala I can still use my familiar, expressive, artistic Tabla technique but TABLIX is undoubtedly a new instrument and interface; and one that I would only use for certain forms of musical expression, collaboration, and performance spaces and spheres.

Over time, I have realized how TABLIX in turn has started informing what I play and how I express my intentions and emotions through sound, music, and technology. This is not entirely different from what happens between musicians and their instruments in other cases where the depth of the relationship becomes the expression as opposed to musician, technique, or instrument alone.

The important factor here is that the onset of my conversation & relationship at the precipice of the digital world, particularly as an analog/acoustic Tabla musician started with an artform and expression that was familiar, deeply meaningful, and synergistic to my being. If these can be considered intrinsically beneficial qualities of beginning a new, honest, engaging and hopefully continuous relationship with technology or otherwise, then creating TABLIX and other musical interfaces in this purposeful manner is in itself a meaningful and rather important exploration for the musician and their respective artform.

As with any conversation or relationship we learn, adapt, incorporate or dismiss ideas, concepts, principles, methods, information, knowledge and more in pursuit to have conversations we can and want to continue. The next phase of the TABLIX conversation I would like to continue with the digital world is leading me down a path to research and develop an expressive hardware or digital instrument/interface that can sound like a natural Tabla if & when the Tablachee prefers or to use it as a MIDI controller to control other sounds and parameters that respond to the natural language and technique of the Tabla.

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9) MIDI Association https://www.midi.org/, https://en.wikipedia.org/wiki/MIDI
10) Ableton Live
11) RME Interfaces
12) Cycling 74, Max/MSP

Support Links

1) Red Bull Music
2) Academy - TABLIX demo/talk/performance
3) TABLIX Guthman Music Competition Video
4) Nagma Ishq Live at Koerner Hall
5) Discovery Live at Koerner HallTABLIX Description 2017.pdf
6) More details about TABLIX
7) TABLIX Pictures

Performances

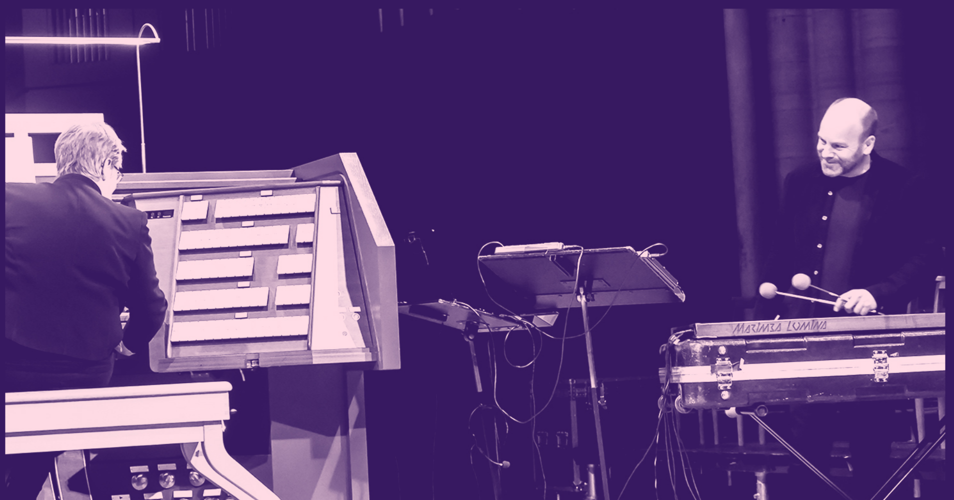
21

Petra Bjørkhaug and Øyvind Brandtsegg

Pipe organ and computer

Performance

Video of presentation can be found here



Pipe organ and Computer
Nancarrow Piano Studies, and Improvisations

Øyvind Brandtsegg[1, *] and Petra Bjørkhaug[2, **]

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About the concert

Conlon Nancarrow (1912– 1997) is well known for his studies for Player Piano, as the intricate compositions would often exceed human performer limitations. He coded the music on paper rolls to be performed by the mechanic instrument. In this manner, he created complex, jazzy and hypnotic compositions based on algorithmic techniques and complex mathematical relations. These techniques influenced the melodic, rhythmic and tempo relations in the music. Still:

> *"My essential concern, whether you can analyze it or not, is emotional; there's an impact that I try to achieve by these means."* (Conlon Nancarrow)

In the current project, some of these studies are orchestrated for Pipe Organ, Disklavier and electronics by Øyvind Brandtsegg. The work with the Nancarrow Studies also instigated further exploration of improvisation with these mechanic instruments in combination with improvisation software written by Brandtsegg.

As each Pipe Organ is unique, the orchestration is necessarily also unique for each instrument. Two concerts of this material (in Stavanger Concert Hall and Nidaros Cathedral) show how differently the music is shaped to match the possibilities of these two instruments and venues. Nancarrow's music requires a quite extraordinary degree of articulation due to the rhythmic passages and high tempi. Sometimes an individual adjustment of each single note would be required, due to slight differences in timing between organ pipes. These differences stem in part from the acoustic construction, but even more it is due to the different positions of pipes in the room. The speed of sound is rather slow, and a spatial difference of 10 meters between pipes (which is not uncommon) can result in a time difference of 30 milliseconds. Compensating for such time differences has been crucial for precise rhythmic articulation and synchronization between voices.

Algorithms and automation are ubiquitous in our modern society, and Nancarrow's compositions allow an interesting perspective on automation and mechanization within an expressive aesthetic context. It also sheds light on the necessity of manual labor of implementation and adaption to make the algorithms matter for human communication.

Famous quotes on Nancarrow:

> *"The stuff is fantastic... You've got to hear it. It'll kill you."* (Frank Zappa)

> *"Conlon's music has such an outrageous, original character that it is literally shocking. It confronts you."* (John Cage)

Daniel Formo

The Orchestra of Speech, a performance and installation

Performance

Video of presentation can be found here

Performance and installation proposal: *“The Orchestra of Speech”*

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The Orchestra of Speech

“The Orchestra of Speech is a part sound installation, part instrument and performance concept coming out of a recent artistic research project exploring the relationship between music and speech, particularly that of improvised music and everyday conversation. Not *what* we are saying, but *how* we say it – how the intonation, register, tempo, rhythm, dynamics, and voice quality form a communicative layer of its own in speech. These features have pragmatic functions in aspeech for signaling turn taking, highlighting important information and for interpreting intention, but from a musical point of view it is also interesting to see how these structures also can make recognizable and meaningful patterns in music.

In both music and speech, we tend to make use of different *genres* as formal frameworks when constructing utterances. In speech, these genres include choice of words, but also musical traits like certain registers, dynamic ranges, tempi etc., that taken together forms a musical character that communicates something about the social situation and relation and thus give a context for interpreting intentions: *small talk, pillow talk, baby talk, interrogation, public address, report, confession,* etc. are examples of speech genres where the form is part of the meaning. A musical exploration of such genres is one of the main themes in this project.

In order to do this in practice I have developed a metaphorical *“orchestra”*, an *instrument-like* system for analyzing, abstracting and orchestrating musical features from speech in real time. Collections of different speech recordings are analyzed, processed and played back through this system. This instrument can be used both as an extended instrument, as well as an interactive sound installation reacting to input from audiences

When used as an instrument, the system can analyse input from speech or piano, and when presented as an installation, an analog telephone set connected to the system rings from time to time, inviting members of the audience to pick up the phone and interact with the orchestra by speaking to it. The system analyzes the input and uses machine learning to respond with semantically nonsensical but musically probable responses, thus allowing a kind of meta-dialogue between speech and music.

Another theme explored in this project is *sound*, and how sound source and sound quality affects the perception and meaning of sound. The software instrument system is connected to a setup of transducers attached to acoustic instruments, resulting in a physical electroacoustic orchestra that blurs the line between electric and acoustic, voice and instrument, and between virtual and real. The sound of an acoustic instrument somehow *means* music, and creates a frame of reference that invites musical listening, while a voice mediated through a loudspeaker have connotations of broadcast and public address. The invisible sound wall of stereo loudspeakers creates virtual sonic spaces. New perspectives for listening appear when these sonic realms start to blend in an orchestration of different sound qualities and physicalities.

The theme of perception is another focus in this project – how far can speech be abstracted musically before the communicative features are lost? Does the listening focus always switch between semantic and poetic/musical meaning, or is it possible to perceive both the same time? On a more general level it can also be considered an exploration of meaning in music, and the many ways music and speech can make sense.

Federico Ghelli Visi and Aqaxa

You have a new memory

Performance

Video of presentation can be found here

"You have a new memory"

Federico Ghelli Visi[1] and AQAXA[2]

[1]GEMM))) Gesture Embodiment and Machines in Music
Luleå University of Technology, School of Music in Piteå, Sweden

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Thursday 18 July 2019

My phone beeps. A notification on the home screen says "You have a new memory." It happens at times, unsupervised learning algorithms scan your photos and videos, look at their features and metadata, and then you get a nice slideshow of that trip to South America, or those shows you went to while you were in Hamburg or London. There is something ridiculous about this (the music they put on the slideshows, for example) as well as something eerie, something even slightly distressing perhaps. I guess it could be about the way your recent memories are automatically lumped together into categories, or how different moments are juxtaposed in unexpected ways, or just because you'd rather be the one in charge of deciding when "you have a new memory."

Sunday 28 July 2019

Idea I got while showering: what if I collected the sonic memories of this past year – like audio messages, audio from videos I shot while travelling, recorded journal entries, the music I listened to... – chopped them into very short fragments, use unsupervised learning algorithms to map them out, and then played them back using corpus-based concatenative synthesis or something similar?

Wednesday 4 September 2019

At Goldsmiths working on reinforcement learning (Visi and Tanaka, 2020). Looks like RL could be useful for exploring different ways of interacting with complex synthesis engines. I'll see if I can apply this to the sonic memories corpus idea. Ideally, I could interact with the corpus with a Myo sensor armband and give feedback to the artificial agent while I play using another device. I could implement gesture recognition on a second Myo, but even just a clicker would be sufficient.

Thursday 24 October 2019

RE: memory corpus idea: it might be quite difficult to structure such a complex corpus of diverse sounds. I should ask Jonas about the work he has done with self-organising maps and CataRT (Margraf, 2019).

Saturday 9 November 2019

In addition to the audio from messages, videos, etc. I could try obtain a list of my most played songs on Spotify and see if I can add them to the corpus. I wonder if there would be copyright issues with that. I should check out that paper by Sturm et al. (2019)... I think I'll use the stems of the tracks I made with my long lost sibling AQAXA instead, we own those after all, they're ours.

Today is the 30th anniversary of the fall of the Berlin wall. Sometimes when I walk through Mauer Park or I pass by Berneauer Straße I try to imagine how things used to be back then. Remembering and preserving memories is extremely important.

Sunday 10 November 2019

I filmed[1] the performance of the memory corpus piece, I think I will call it "You have a new memory". I will need:

- a projector;
- a table;
- a chair;
- a desk light.

I'll play everything through my audio card, so I'll just send a stereo pair to the PA.

Tuesday 12 November 2019

I submitted the piece to ICLI 2020, I did it in a hurry, primarily because I used most of the time I had before the deadline to write a full paper about the reinforcement learning approach I used (Visi and Tanaka, 2020).

I feel I should dedicate more time to putting the research I do into practice. It is so fundamentally important to situate music research into actual practice, that's how you really understand the *ergodynamics* of the tools you're building. Thor really nailed it with that word, I enjoyed reading his book (Magnusson, 2019) during the summer.

I look forward to reading the comments of the reviewers for both submissions, I don't know what to expect.

Friday 20 December 2019

The piece has been accepted =) Happy about the positive feedback I have received from all the reviewers, particularly about the fact that they recognised the purpose behind this unusual way of writing an abstract for a performance.

Acknowledgements. Thank you G. for listening, and for helping me remember. I can't wait to see you.

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[1]Video: http://www.federicovisi.com/you-have-a-new-memory/

Trond Engum and Carl Haakon Waadeland

Magnify the sound

Performance

Video of presentation can be found here

Magnify the Sound

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Abstract.

The duo "Magnify the Sound" will present a musical performance exploring the interplay and live processing between drums/percussion, electric guitar and recordings of environmental sounds. The music will be improvised, and the processing will combine live processing, adaptive processing and cross-adaptive processing through an interface constructed for this specific performance. Live input from the instruments and environmental sounds are analysed, and attributes from these sounds are further mapped to control effect parameters inserted on the different sources in real time. This enables a scenario were all sources change expression depending on choices made to the live input, and as a consequence opens up for a different artistic intelligence within live electroacoustic improvisation.

Keywords: Live electronics, interface, cross-adaptive processing, artistic intelligence, free improvisation.

Background

"Magnify the Sound" consists of Trond Engum on guitar and electronics, and Carl Haakon Waadeland on drums/percussion. They have performed together since 2010 in various constellations exploring the interplay between acoustic instruments and live processing in a free improvisation context. These musicians/researchers have participated in the projects "T-EMP Communication and interplay in a electronically based ensemble" (2011 – 2014) https://www.researchcatalogue.net/view/48123/48124 and "Cross-adaptive processing as musical intervention" (2016-2018) http://crossadaptive.hf.ntnu.no/index.php/about-the-project/index.html both projects conducted at the Norwegian University of Science and Technology (NTNU).

A basic method typical of the later project was practical experimentation in the studio where various applications of cross-adaptive processing were tested and evaluated in the light of the effect these modulations had on the communication between the musicians and the musical expression as such.

"Magnify the Sound" combines a continuation of experiences from these different experiments with an aim of developing a new artistic expression through an interaction with a specially designed multi-instrument and a new interface.

Interface and Mapping

The interface consists of live inputs from guitar, drums /percussion and pre-recorded environmental sounds. The sounds from each input are analysed, different features are extracted, and these are further mapped to modulate different processing back to the same sound sources. The mappings within the interface are set to act both adaptive and cross-adaptive, depending on the interaction from the inputs at any given time. This multi-instrument facilitates the following scenario: The sound of the guitar is live processed by the performer, the output from the instrument controls effects applied to the drums and the environmental sounds. The sounds of the drums control effects applied on the drums, guitar and environmental sounds. The environmental sounds control effects on the guitar and drums.

From Artistic Challenge to a Potential of New Musical Expression

In the ordinary, usual way of performing music, each musician interacts with her or his instrument in a communicative interplay with the other musicians, and this has been made possible as a result of years of practice through which the instrument has become a prolongation of the musician´s body. However, in musical interaction with the presented multi-instrument this interlocking relationship between musician and instrument is radically changed. – Each musician´s interaction with the individual instrument has consequences for the sound of the instrument of the other musician, in unilateral or bilateral ways. Thus, the musician loses control of her or his instrument, and the unified body of musician and instrument is chopped up. This might, indeed, be a very frustrating challenge, - your usual, habitual and embodied interaction with your instrument might now *not* give the musical result that you want and expect.

In “Magnify the Sound” we investigate how we can turn this challenge into an exciting potential of musical expression related to *a change in our roles and the way we interact with our instruments*: In stead of *I am performing on my own instrument* we shift to *we are performing on our common instrument*. In this way the existential experience is not my instrument being a prolongation of my body, but rather an extended instrument, consisting of the total music-technological-setup, being a prolongation of an enlarged body of all participating musicians.

If we succeed, we thereby not only “magnify” the *sound*, but also enlarge the possibilities of new applications of artistic intelligence and facilitate *new musical expression* within live electroacoustic improvisation.

Franziska Baumann

The Echo I Touch

Performance

Video of presentation can be found here

The Echo I Touch

Solo Concert for Voice & Sensor Live Electronic
De- & Embodiment in spatial Vocal Performance Art

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Abstract

Franziska Baumann's solo concert reflects relations between embodied acoustic voice and disembodied spatialized voices by means of gestural communication via SensorGlove interface. The interface between her as a singer and the performing system is part of an integrated system which serves communication. Spatially expressed gestures and the sound processes coupled to them allow for many relationships of vocal embodiments and disembodiments and open up multi-layered staging categories and parameters of gestures controlling vocal sound or compositional parameters. Benders, accelerators, gyroscope and ultra-sonic sensors connect the real world of physical phenomena and gestures via serial port to the computer. To a certain extend the specific characteristics of sensors and their respective expressiveness ask for certain gestures. The singer is free to add additional meaning through gesture communication. This interplay of "necessary movements" and communication of ideas through music and gestures opens up various artistic perspectives on body sculptures in movement and sound, an esthetic of a hybrid emerges. The sensor glove becomes a costume, a prop, a visual performance in itself, which can cause different expectations and bewilderment among the audience. Unlike wireless applications, it communicates a specific presence and technological expression.

The music follows a precomposed dramaturgy but is played with an improvisational attitude exploring the interplay between acoustic voice, precomposed sound ideas and live processing with Ambisonic spatialization. The transformation of the sound through processing and spatialization are at times specific (e.g. linked to a direct gesture) and other autonomous (e.g. the machine makes random or precomposed decisions.)

SensorGlove and Mapping

The mappings are made in STEIM's software JunXion and mix up several possibilities in combinations:

- One to one relationships: Fixed assignments of control and result are designed one-dimensionally.

- Diverging: One gesture is assigned to several parameters. A one-dimensional input is split into numerous results.
- Converging: Many gestures are assigned to one parameter. The multidimensional input is mapped onto only one output parameter.
- Multimapping: several gestures are assigned to several parameters at the same time

Background

As "artist in residence" at the STEIM "Studio for Electro Instrumental Music", Amsterdam, Franziska Baumann developed 2001 the first SensorLab based glove with built-in sensors. Together with Andreas Litmanowitsch, an electronics engineer in Bern, she developed 2015 the current version of the SensorGlove Interface. During an Artist Residency at ICST (Institute for Computer Music) in Zurich in 2017/18 she extended her gesture compositions linked to spatial movement. For nearly twenty years Franziska Baumann is composing for voice, disembodied voices linked to gestures in a scenario where she explores vocal presence and the role of the body with gesture-controlled live electronics in spatial performance art.

Keywords

Contemporary Vocal Art Practices, Performing Gestural Live Electronic Music, Interactive Staged Music Performance and Movement, Composing with 3D Ambisonic, Acousmatic and Disembodied Voice, Custom Musical Instrument (DIY), Digital Musical Instrument (DMI), Extended Vocal Techniques, STEIM, Sampling Practices for Vocal and Musical Improvisation, Improvisation and Real-Time Composition, Digital Score, Vocal Personas, Vocal Sound Dance, Imaginary Vocal Body, Aesthetiv of Uncertainity and In-Between, SensorGlove as Instrument and Body Extension

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https://www.academia.edu/23688396/_Schnittpunkt_zur_erweiterten_K%C3%B6rperlichkeit_._Die_Vokalperformerin_Franziska_Baumann_im_Gespr%C3%A4ch_mit_Stefan_Drees

Baumann, Franziska «Interfaces in Live Performance» in *Klang (ohne) Körper,* 2010. Bielefeld: Transkript Verlag

Tone Åse

I am voice. I am technology

Performance

Video of presentation can be found here

I am voice. I am technology.

Tone Åse

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Abstract: Performance with voice and live electronics. The performance is exploring the identity/identities of the vocal performer when the sound of the voice does not come directly from the body anymore. How does the nature of voice sound, when recognized as different levels of meaning, influence our experience of technology, as performers or listeners ?

Keywords: Mediation, identity, body and technology, presence, liveness, voice as meaning, the role of technology in human expression.

Introduction

I am voice
I am the sound of my voice
I am also not the sound of my voice
I am, and I am not, the strange, twisted sound of my voice
I am not the machine
I can control the machine
I can even be surprised by the machine
I play with the machine, and the machine plays with me.
I am technology
Me and the machine

I am voice. I am technology.

My voice, when recorded, can be experienced as artistic or musical 'material'. It can speak to me in different ways -literally, poetically, or as abstract sound in many shapes. The voice is mine, and not mine at the same time. I can have a dialogue with the history of my own voice. With traces of my own voice. I could never do that without this combination of technology. Me: the larynx, the lunges, the diaphragm, the vocal chords, the resonating spaces in my body. The microphone, the loudspeakers , the computer, the DAW, the plugins. My hands, the sliders, the pads, the knobs, the sensors. There is so much complexity in these processes. So many calculations. I do not think about these calculations. Not about how messages are being sent from my brain when thinking about a tone, and how my whole muscular system is working to produce that exact frequency, that exact resonance , that exact volume. Not about how MiDi signals are produced and sent from controller to computer. Not how sound is analyzed and processed through filters and patches. I do not think about those things when I play. It would be something like thinking about how my tongue moves while talking. We are technology, and we expand our expression through technology. But even though the experience of seamless and tensionless connection between performer and technology might be an ideal, it is not necessarily true or possible at all times- neither for the performer or for the audience. Or even wanted. There are several issues to be considered in our discussions around technology and flow, embodiment and tacit knowledge. Besides skills, experiences and interfaces, it is also interesting to look at the material in use. The experience of ”naturalness” and ”meaning”, has been pointed out as important parameters in experiencing voice in acousmatic music (Bergsland 2010) , and thus in the musical play with voice and live electronics. (Åse 2012). How does these qualities in musical material affect the dialogue between body and technology in a live performance? How and why do we experience differently, as an example, the live performance with a keyboardist playing the synthesizer, the live performance of (non- vocal) noise sounds, and the live performance of the vocalist using live electronics with processed and recorded voice as material? If we do experience them differently: could this difference be connected to our experience of 'meaning' in musical material ? Does the quality of 'meaning' make performers and listeners more aware of the tension between performer/body and machine technology? Could one reason for this be that a machine cannot produce human meaning by itself ? And is this tension also experienced by the performer in the act of performance, or can the machine technology producing 'meaning' still be experienced as a part of the performers' musical identity ? And if so, is the performers identity experienced as 'one', or as multiple identities ?

Several performers are continuously investigating these questions through their artistic practice. Pioneer Pamela Z (San Fransisco), Alex Nowitz, (Berlin), Franziska Baumann, (Bern), Maja Ratkje, (Oslo) to mention some of them. These are all composer- performer- improvisors working with voice and technology, within the scene of experimental vocal performance art. They have been involved in creating or customizing different setups and devices that makes it possible for them to use voice sound solely as artistic material though sampling and processing in unique ways. In a bigger perspective, it is easy to recognise their performative practices as constituting a personal musical and artistic identity through their implemented use of technology. Still, from my experience, their live performances also play with multiple identities.

Instrumental setup

The idea behind my setup is to have the many possibilities of a DAW and Max, and at the same time have visual oversight and physical access on one level, to avoid looking to much at the computer screen. I use a tactile set of controllers (faders, pads and knobs, supplemented by simple gestural controllers through the Wave ring and the infrared function on the Roland sampler.) The setup makes it possible to improvise with both pre-sampled and live-sampled sounds, and process the voice in real-time. It is physically rigid and conventional compared to using gestural controllers only, but has proven to be effective for me, also in order to be used for different musical projects (solo, duo, theatre music, band etc.) :

MacBook Pro with Ableton Max for Live 10 and GRM tools
Fireface UC
Novation RemoteZero SL
iControl S
Korg Nanopad 2
Korg Nanokontrol
Genki instruments Wave midi ring
Roland SP 555 sampler

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– *now you see me, now you don't*- Artistic Research in voice, live electronics and improvised interplay, NTNU, Trondheim

Marije Baalman

the machine is learning

Performance

Video of presentation can be found here

the machine is learning

Marije Baalman[1]

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Abstract. The theatrical performance *the machine is learning* questions the labour involved in the process of training a machine with realtime gestures. In an attempt to livecode with gestures, the performer finds herself directed by the machine to repetitively make movements to generate data samples for the machine to learn from.

Keywords. machine learning, realtime gesture recognition, theatre, livecoding

Program notes

The performance *the machine is learning* is a theatrical performance highlighting the process of training a machine with realtime gestures: the labour that is absent from most dialogues on machine learning. In an attempt to livecode with gestures, the performer finds herself directed by the machine to repetitively make gestures to generate time series data samples for the machine to learn from.

Machine learning is both hailed as the solution to our current day problems, as well as claimed as one of the biggest threats to 'life as we know it'. The popular discussion on AI criticizes issues of privacy with regard to data collection and the use of this data to take decisions that affect the life of people in possibly negative ways. At the same time, with the possibilities of AI further automating work, jobs are at danger and the fear is that this will leave many without a job in the future. On the other hand, the labour involved in making machine learning algorithms work, is less prominent in the popular discussion. The labour involved in AI consists not only of designing and programming algorithms, but also in generating and categorising these data samples. The working conditions of these tasks are generally not known.

Background of the performance

the machine is learning is a performance developed in the context of creating a gestural live coding language: GeCoLa[1]. The key concept of this coding language is that the code is written by gestures, rather than by written text based language. Gestures are defined for keywords/operations in the language and variable names are defined as gestures learned on the fly.

It seems to be a simple approach: just use some machine learning algorithm to detect the gestures and have detected gestures evoke keywords and variable names. But it is not that simple. Time-based gestures (rather than instantaneous poses) are not easily learned by a machine and certainly not when they are not predefined and linked to a large database of templates of said gesture.

The teaching of the machine is a lengthy process and requires a human to repeatedly make a gesture so the machine can learn to recognise the gesture and accurate labeling of type, start and end of gesture. The performance *the machine is learning* focuses on this process and the dialog of the human with the machine to record and train the machine, so that it can then recognise the gestures.

The training of machines and the hidden labour of humans involved in generating, labeling and validating the data fed into machine learning algorithms is a topic that is often missing from (even critical) dialogues about machine learning, even as awareness about assumptions in algorithms and data bias is rising.

1. For more information on this language, see https://marijebaalman.eu/projects/gecola.html

Figure 1: The performance at ICLI 2020.

Though the original purpose of GeCoLa was to create a gestural language to livecode music with, the performance *the machine is learning* must be regarded as a theatrical performance.

Realisation of the performance

The performance is realised by the use of wireless motion sensors (the 3-axis accelerometer ADXL345, and later LSM9DS1 sensors, a 9 d.o.f. sensor with a 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer) using the Sense/Stage sensing platform (Baalman 2017; Baalman et al. 2010). The sensors are embedded in gloves that were originally created for the performance *Wezen—Gewording*. The evolution of these gloves is described in Baalman 2016.

The data from these sensors is sent via XBee wireless communication to a laptop, where the data is received and translated to OpenSoundControl with the custom Sense/Stage software. The data is sent to SuperCollider, where it is parsed and formatted to be sent to a custom C++-program created based on the Gesture Recognition Toolkit[2] of Gillian 2007. SuperCollider also generates sound and sends commands to the voice synthesis program *espeak*[3].

The sensing gloves include 5 buttons per glove, which are used to control the state of the gesture recogniser: to select the keyword for which to learn a gesture, start and stop the recording of a sample, add the sample to the data set, retrain the model, acknowledge the recognised gesture, or cheat to bypass the system.

Context

The performance fits into a series of works of the artist that take a conceptual approach to livecoding and role of the body in the practice of livecoding: *Code LiveCode Live* (2009-14), *Wezen — Gewording* (2013-17), and *Etudes pour le Live-Coding à une Main* (2019).

The performance also relates to the artist's work *The Malbody Centre* (2014/17 and onwards), which takes a critical perspective at body based sensing (the body as the last frontier between privacy and big data),

2. http://www.nickgillian.com/wiki/pmwiki.php/GRT/GestureRecognitionToolkit
3. https://en.wikipedia.org/wiki/ESpeak

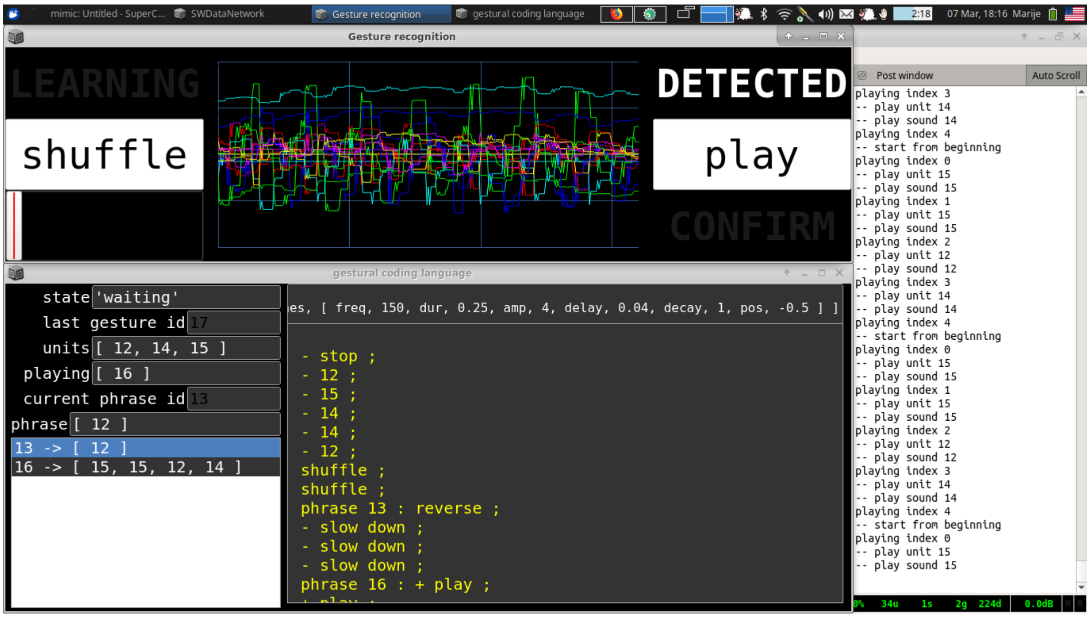

Figure 2: The screen layout as projected during the performance.

the control of artificial intelligence over our experience of the world (what if not only our news sources are controlled by this, but also our bodily experiences?) and how our society deals with people who divert from the norm (diversity in terms of ability and body).

While the performance takes its context from the livcoding scene and taps into the history of gesture recognition for musical purposes, the performance takes a theatrical approach to this topic and places it in a broader, critical context.

Acknowledgements

This performance was created during the Choreographic Coding Lab hosted by Fiber at Dansmakers in May 2019, and a two week residency at Sussex University as part of the MIMIC research project, in July 2019.

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Bernt Isak Wærstad

Ghost Doctor Duplicate

Performance

Video of presentation can be found here

Ghost Doctor Duplicate

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"Ghost Doctor Duplicate" is an improvised performance and also the name for an evolving digital music instrument system. Both the performance and the instrument system is part of an ongoing artistic research project at the Norwegian Academy of Music named "Instrument design using machine learning and artificial intelligence" (Wærstad 2020). The goal of this project is to explore and develop new digital instrument design strategies through techniques more idiomatic to the digital domain rather than attempting to copy behaviour or physical properties of acoustic instruments. By using both generative and adaptive techniques from machine learning, AI and computational creativity, this project aims to produce a fauna of adaptive and somewhat autonomous digital musical instruments. An artistic presentation of the project will be given with this solo performance for electric guitar and electronics, where the "Ghost Doctor Duplicate" system serve as an adaptive extension of the electric guitar based on my performance style and techniques.

Through my participation in "Cross adaptive processing as musical intervention"[1], I have worked with several MIR techniques for the purpose of doing adaptive processing. The approach we used in my collaboration with Gyrid Kaldestad and Bjørnar Habbestad, where to rather start with musical gestures than a specific analysis technique. Recording and feeding those musical gestures into a variety of analysis tools enabled us to pick the features which where best suited to identify and differentiate the various gestures. Building on my experience from that project, I have been exploring similar features for self-adaptive processing purposes. Instead of mapping the feature values directly to processing parameters like we did in the cross-adaptive project, I wanted to explore the effect of using machine learning to "pick out" the right analysis technique. For this performance, Im using a system which feeds an array of analysis parameters (MFCC, spectral centroid, RMS, etc.) into a GMM algorithm. I picked out and recorded 10 different musical gestures (using a bow, picking strings hard, using a rubber mallet, etc.) which where fed in to the system. The 10 categories coming out of the GMM algorithm could then be mapped to a variety of effect parameters. Since the algorithm always produces 10 likelihood values for each of the categories, you can get a huge space of variations to explore whenever you play something which is even slightly different from the original recorded reference gestures. The goal was to have a more open-ended system which had more room to explore though probably with a downside of being less comprehensible. I was not too worried about this downside, as my experience from the cross adaptive project where that understanding the cause and effect relationship was mostly important during design and testing, but quickly became less important when we started playing as we reverted from analysing what was going on to intuitively responding to the sounds produced and applied processing.

One of the potential issues of a responsive instrument is that it is constantly responding (i.e., changing). As a mean of counter this, a simple switch to freeze the analysis by toggling the GMM algorithm on and off. This made it easier for me to take back control when needed and quickly became an interesting musical effect in it self as a way of working with repetition. I also included an expression pedal to control the averaging of the likeliness output from the GMM algorithm making it possible to go from snappy response to smooth and gradual transitions. Another interesting musical effect that came up during rehearsals, was combining looped material with live input in to the same analyser. Somewhat similar to the cross adaptive project where the sound from one musician would affect processing of the other musician(s), only here my previous sounds would affect my current sound and visa versa. For the future, I also plan to explore this sort of temporal interplay in parallell having two sets of analysers and audio processors.

Wærstad, B. I., 2020, "Instrument design using machine learning and artificial intelligence", *Proceedings of the International Conference on Live Interfaces*, NTNU Trondheim

[1] http://crossadaptive.hf.ntnu.no/

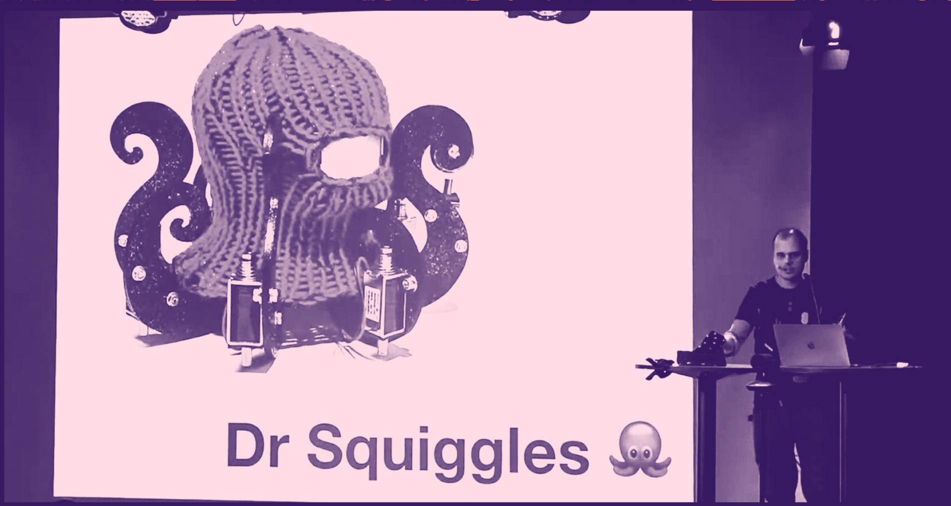
Installations

Michael Krzyzaniak,
Kyrre Glette,
Alexander Refsum Jensenius,
Frank Veenstra,
Çagri Erdem and
Michael Krzyzaniak

Interactive Rhythmic Robots

Installation

Video of presentation can be found here



Air-Guitar Control of Interactive Rhythmic Robots

Michael Krzyzaniak[1,2], Frank Veenstra[2], Çağrı Erdem[1,3], Alexander Refsum Jensenius[1,3], and Kyrre Glette[1,2]

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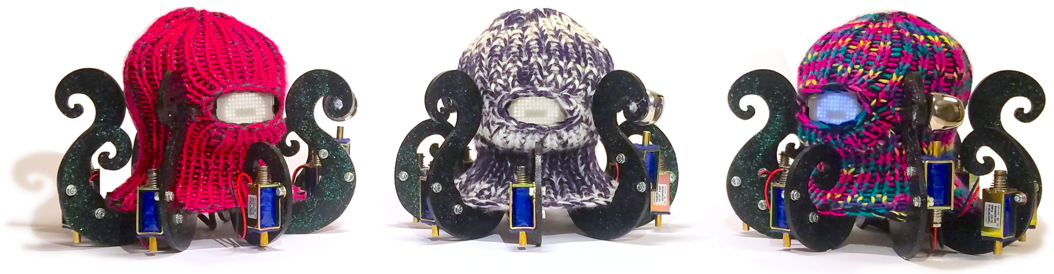

Figure 1: Dr Squiggles Interactive Tapping robots

Abstract. This paper describes an interactive art installation shown at ICLI in Trondheim in March 2020. The installation comprised three musical robots (Dr. Squiggles) that play rhythms by tapping. Visitors were invited to wear muscle-sensor armbands, through which they could control the robots by performing 'air-guitar'-like gestures.

Keywords: musical robots, Myo, muscle sensor, EMG, tapping, rhythm, HRI, CHI, HCI, interaction, air-guitar, art installation, music, sound, Dr. Squiggles, evolutionary algorithms, machine learning, tapping, octopus

Background

This installation brings together a few separate research projects within RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion at the University of Oslo. These are as follows:

Dr. Squiggles

Dr. Squiggles (Figure 1) is a robot that plays rhythms by tapping. It normally listens to rhythms played by humans or other robots, and attempts to play along. We are using Dr. Squiggles to study fun and enjoyment in human–machine interaction. What makes some interactive systems a pleasure to use, and why do people choose certain objects as the focus of lifelong hobbies? How should the robot behave in order to maximize enjoyment and help people gain musical skills?

Expressive Guitar Performance

A number of projects at RITMO focus on various types of human music-related body movement, including that of performance on acoustic musical instruments. We have recently carried out a study of guitarists, using optical motion capture, inertial sensors, and myoelectric sensors. The aim is to understand more about the links between overt and covert bodily expressions during music performance. The next step is to use this knowledge in the creation of new expressive digital instruments.

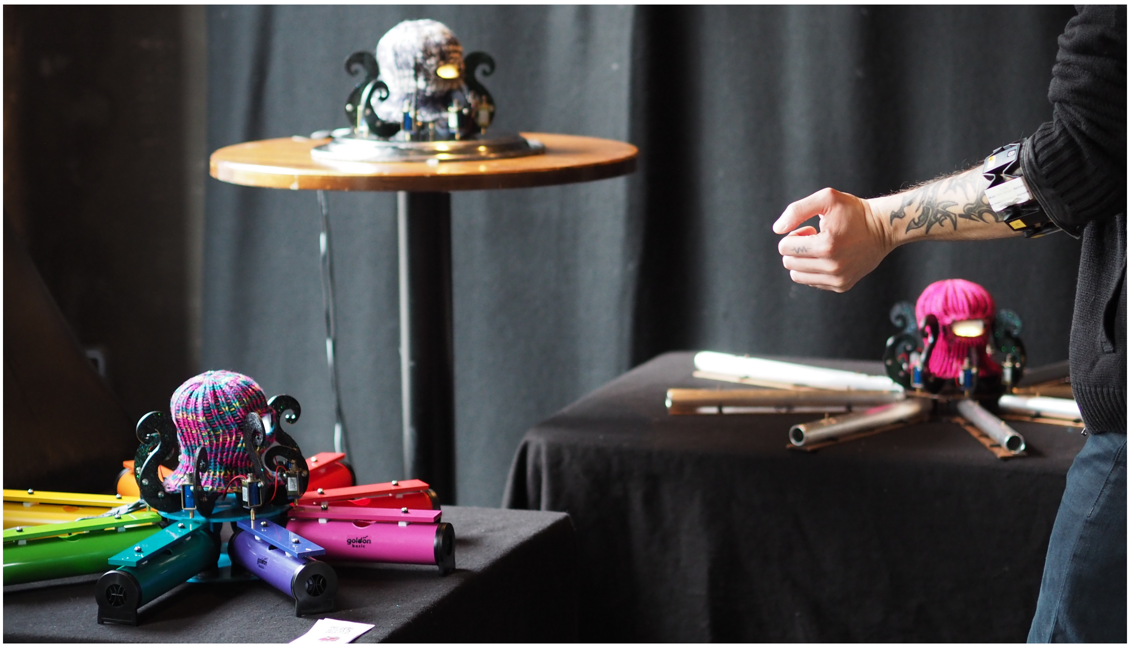

Figure 2: A human performer interacts with three Dr. Squiggles robots. Myo muscle-sensors can be seen on the arm of the human performer. The robots tap on metal rods on the table.

Rhythmic Algorithms

The algorithms employed in our installation consist of adaptive sequencers that send instructions about the generated rhythms to the robots. The aforementioned myoelectric sensors are used to interactively adjust parameters of the algorithms, which is again used to perturb the rhythms. An underlying question is how we can use artificial intelligence and optimization algorithms to make the rhythms produced by the robots more interesting?

Installation

This installation explores expressive bodily control of a collective of rhythmic robots. Visitors are invited to wear muscle-sensors on their arms and perform 'air-guitar'-like gestures: strumming, moving their fretting arm and fingers, and tapping their foot. The robots each independently generate some rhythms. They synchronize with each other and with the human performer in a way that is inspired by biological rhythms. Although each robot is fully autonomous, the overall music played by the ensemble is influenced by metaphors associated with the gestures of the human performer. For example, more strumming creates more dense music. The setup is shown in Figure 2.

Acknowledgements

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Peter Bennett, Jordi Solsona Belenguer and Martin Murer

ImprovCues: Musical Creativity and Ideation with Machine Learning

Installation

Video of presentation can be found here

ImprovCues: Musical Creativity and Ideation with Machine Learning

Jordi Solsona Belenguer[1], Peter Bennett[2], and Martin Murer[3]

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Keywords: Machine Learning, Creativity, Ideation, Improvised Music.

ImprovCues is an installation that engages the audience with machine-learning generated musical cues for group improvisation. The audience helps to train the system by suggesting new cues and trading them with the system - for each cue suggested by the audience the system generates a new cue in return. A spontaneous performance is created through the interplay of suggesting, interpreting and attempting to play the prompts. Our aim is that the installation allows the hands-on exploration of machine-learning mediated creativity. In particular, rather than asking if machine learning can be as creative as a human musician, we instead ask if machine learning can be an equal partner in the stimulation of human creativity. ImprovCues explores how the act of training machine learning can in itself lead to a creative feedback loop, where participants ideas and machine generated ideas become inextricably tangled, raising questions about creative ownership and the locus of creativity.

The ImprovCues installation centres around a table full of musical instruments, objects and noise making artefacts and a projection alongside displaying the ImprovCue system and performance prompts. A variety of different machine-learning personalities provide a diverse range of content for the prompts. An example set of cues may consist of the following:

"Play the sound of wind in the trees." (sound cue)

"Swap instruments with another player." (instrument cue)

"Start of a solo for a player. No one else plays." (game cue)

A keyboard invites the audience to help train the bots with new suggestions. Audience members are drawn in to become a rotating cast of performers, helping to realise the music suggested by the prompts. The person at the keyboard becomes the equivalent of the conductor, by suggesting new prompts to help train the bots and both guiding and shaping the development of the performance. Only a small selection of performance cues are shown at any time. Each prompt is colour-coded and labelled, showing it has been generated by a particular bot which was trained on a particular set of data. When suggesting ideas, the 'conductor' gets to choose which bot they are training.

The form of machine learning used is Natural Language Processing (NLP) using Markov Chains, where the probability of the next word is calculated from the previous. The bot for each card type has its own corpus, pre-seeded with text that gives it's personality. The game cues for example are trained on the prompts from John Zorn's game piece "Cobra".

ImprovCues iterates on a previous installation initially developed and exhibited at Schmiede 2019, a ten day long digital art event hackathon based on a "cooperative prototyping environment, focused on the arts, hacking and entrepreneurship". This previous iteration focused on the creation of novel digital art project ideas. In exhibiting this installation at the Schmiede final show, The audience were asked to suggest new digital art project ideas and in exchange were given a new machine-learning generated suggestion project idea from the bot. The suggestions would quickly alternate between practical and serious to the absurd, and we found that this humorous aspect stimulated creativity, whilst encouraging a deeper debate around the topic of AI and its role in creative practice.

Colloquial Papers

Nigel Guérin-Garnett

Machines in the Creative Process: Limitations Through Choreography

Colloquial Paper

Video of presentation can be found here

Machines in the Creative Process: Limitations Through Choreography

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Abstract

This practice-based project is a critique on our relationship with machines to foreground the necessity of continued human involvement. My approach is from the perspective of a classically trained ex-dancer in a design research context. Using choreography as a medium, I propose that affecting elements of the creative process with algorithms may illustrate a limitation to automated integration within society. I create accessories for dancers as expert users as one component of a human-machine-human communication system. My research focusses on dancers' visceral responses to the vibrating stimuli delivered by the wearable devices. Although I also use motion capture technology to collect source material, I exclude the use of avatars for interpretation by end-users. The live performance itself is used as illustration intended for insight into potential future societal machine integration.

Keywords: communication system, wearable, choreography, algorithm, machine

Purpose of the research and its importance to the field

In its rawest form an algorithm is like a recipe. I refer to them as *intangible* machines instead of digital as they do not necessarily have to have be computer generated. They are a series of instructions designed to execute a function. In theory, an algorithm does not cost money, need sustenance or get sick. But building them does, for the simple reason that humans are required to enable these processes. How long this remains equally symbiotic is currently anyone's prediction.

On the topic of Silicone Valley supercomputers amassing consumer data without financial benefit to their users, computer philosopher Jaron Lanier outlines during a televised interview, "…you might get free music but the possibility of you ever becoming a self-sustaining musician becomes more and more reduced. You might get free lessons but the possibility of you ever becoming a teacher becomes more and more reduced. Eventually this will apply to every profession because everything will become more and more software mediated as we get better at technology in this century." (Lanier, 2013). He suggests that the human-machine symbiosis has a shelf life. But perhaps shifting the weight between the components themselves may shed light on this doomed path to destruction?

It is this interrelation that I am suggesting requires deeper questioning in order to foreground the necessity of continued human involvement. And while this is already being asked by the science and technology sectors, I propose that artistic interventions may provide new information, equalise our discomfort with machine integration and spark further key questions. Situated within dance choreography as a medium, this project aims to address our pandemic fear of machines.

Brief survey of background and related work

The digital and choreographic spheres have been in conversation for several decades. In Choreography and Computers, A. Michael Noll outlines the, "… possibilities for the application of computer technology to problems in choreography and dance notation." (Noll, 1967, pp. 1) He mentions his preference for, "…some drastic changes in the present choreographic process which in the long run might be a better solution to many problems including ballet preservation and dance notation." He suggests that the computer ballet system he has devised would enable, "…certain portions of creative the process [to be] filled in by the computer which might be programmed to learn the choreographer's style. (Noll, 1967, pp. 2)"

He unknowingly described the tool Wayne McGregor designed to digitally affect choreography in collaboration with Google Arts & Culture. Entitled Living Archive, McGregor has, "…called it a performance experiment," (Easter 2019). For the world premiere at the Music Center's Dorothy Chandler Pavilion in Los Angeles, McGregor used their algorithm to choreograph The Dante Project (Inferno). Google developed an algorithm that predicts the next series of movements in each dancer's specific style by absorbing Studio Wayne McGregor's 25-year archive of choreography in the style of the ten dancers. It recreates their movements, tempo and dynamic in stick figures on a large screen for he and his dancers to engage with directly. "Presented with options for possible sequences of movement, the dancer could then either use the phrase, interpret it in their own way or use it to inspire improvisation. […] It's a real recursive process between the dancer and the AI system," the choreographer said. He explained the process: "It's exploiting opportunities in the data you can never see yourself," (Easter 2019). Google Team Lead Damien Henry adds, "This produces a total of 30 potential choreography sequences, which at the moment last about ten seconds, and which are displayed on a computer screen using a similar 'skeleton' visual. McGregor chooses which one he would like to use. Then, whatever the dancer does can be recorded again and re-injected in the machine…" (LePrince-Ringuet, 2018). Henry says that the Google tool is not meant to invent moves that have never been seen before. "The point is not to replace the choreographer […] but to create options in a very efficient and fast way, so that the creative process never stops. The creativity will come from the use that Wayne will make of these options," (LePrince-Ringuet, 2018). McGregor clarifies: "The choices are still mine. I'm the source, I'm the person at the beginning' […] I see this more as an opportunity – I love being in the game," (LePrince-Ringuet, 2018).

Noll suggests another way of overcoming the documentation issue would be using video footage as the source material. He explains, "Different camera positions could be used simultaneously so that the three-dimensional location of the dancers could be calculated by the computer. The films would be analyzed by the computer and converted into motion patterns," (Noll, 1967, pp. 2). While the technological capabilities of computers was obviously less developed in the 1960's his proposition is essentially what William Forsythe, Norah Zuniga Shaw and Maria Palazzi created in 2007 with Synchronous Objects. Forsythe's piece One Flat Thing, reproduced (OFTr) was the basis for the notation tool developed at the Advanced Computing Center for the Arts and Design and Department of Dance at Ohio State University. It was demonstrated at the 2009 Siggraph Information Aesthetic Showcase, "…to enrich cross-disciplinary investigation and creativity by revealing deep structures of choreographic thinking through a vivid collection of information objects in the form of 3D computer animation, annotation, and interactive graphics," (Palazzi, 2009). It was the prototype for the Motion Bank project the followed which is the choreographic tool available for public use (deLahunta, 2013). It contains several examples of 'dance scores' which have been created with this interactive application. Seeing a complex piece of award-winning choreography dissected into animated cues attached to each dancer is innovative and aesthetically interesting. This visual analysis does offer material production possibilities (dance scores) through a choreographer's interpretation of the tool, however it was originally composed for notation and documentation.

In their *chor-rnn* choreographic system Louise and Luka Crnkovic-Friis have built an algorithm that uses machine learning to acquire understanding how a given performer dances (Crnkovic-Friis and Crnkovic-Friis, 2016). The algorithm is intended to act as a choreographic tool to predict what the next movements might be in that particular style. Also using MoCap technology to capture the dancer's movement they tested their 'stick figure' avatar after approximately ten minutes, six hours and forty-eight hours of learning. Only after the latter did it begin to understand the joint relations, syntax and style well. When speaking of future projects they go on to say, "For comparison state of the art speech recognition models use 100+ hours of data (and it is considered to be a major bottleneck in that field of research) […]. It is currently limited to producing choreography for one dancer and cannot not yet generate the semantics in choreography," (Crnkovic-Friis and Crnkovic-Friis, 2016, pp. 123).

At the Second International Conference on Computational Creativity Mexico in 2011, Kristin Carslon, Thecla Schiphorst and Philippe Pasquier presented their version of a computer assisted choreographic system, Scuddle: Generating Movement Catalysts for Computer-Aided Choreography (Carlson et al, 2011). For their purposes they break dance creation into three stages: movement, sequence, choreography. Likely due to Schiphorst's involvement (Schiphorst, 1986, pp. iii) with the development of DanceForms (previously called LifeForms) they build on this system as it, "…focuses on all three stages of the choreographic process, allowing complex movement to be designed and viewed with a high level of detail," (Carlson et al, 2011, pp. 124). They contrast DanceForms and Scuddle with other existing systems in a chart (pp. 124) that includes Tour Jete, Pirouette (Yu and Johnson, 2003); Web 3D Composer (Soga et al, 2006); Genome (Lapointe and Époque, 2005); Dancing (Eckert, 2015); and Evolution (Dubbin, 2009) plus "Pre-1990 Systems". They break down each systems into which stage of the choreographic process they affect, the source material, the data-altering mechanism, the final selection method, how the choreographic data is shown and the level of level of movement fidelity.

Despite the various developments in computer-aided choreographic systems and processes, Noll anticipation of them to be a, "…completely new creative process, [that] might result in new dance forms" (Noll, 1967, pp. 2) unifies their differing intended applications through a common aspiration. His conclusion about the state of human movement notation and choreography, "…recommend[s] an investigation of the possibilities of the computer," (Noll, 1967, pp. 3) and this has clearly been taken seriously.

Description of the proposed approach

While I often employ music and sound to inspire my choreography and ultimately accompany a performance of work, I am intentionally excluding it from this study. There are already several components to consider:
- my choreographic outputs as source material;
- the MoCap system;
- the algorithm that processes the data generated by MoCap technology;
- the different wearables I build including the shape, size, intended placement (Figure 1.);
- the materials from which they are constructed (knit, moulded leather, latex, strapping, elastic, etc.);
- the type of physical stimulus embedded in the wearable (Figure 2.);
- the location of the wearable on the user's body (Figure 3);
- and the physicality, training and interpretation of the expert user (dancer) themselves.


Figure 1. (2018) Moulded leather accessory with elastic straps and plastic buckles

Figure 2. (2018) Pager motor suspended in silicone with e-textile as conductor; moulded leather casing on front abdomen


Figure 3. (2019) synthetic knit panel with leather casing attached with elastic

All of which present their own variables that may have an effect on each trial's results. Adding sound or music to this communication process would add an entirely new level of complexity when capturing the responses of the end-user. However, using a score may be helpful when demonstrating how the system works to an audience. For the time being I am leaving the question as to whether the viewer will be aware of the physical stimulus contained in the wearable or not open.

Due to my own conservatory-style training in ballet, Graham, Limón, contemporary and jazz techniques I have narrowed my user recruitment to adult professional dancers with similar histories. I am targeting dance artists who also have dance education at university level. This tends to ensure a common verbal and physical vocabulary, which is useful in effectively capturing the users' responses during observation and interviews. This background also encourages use of the whole body in physical expression. It also means capturing details of extension, articulation and dynamic are essential in understanding the dancers' visceral responses. Heterophenomenological approaches are proving effective for deeper response comprehension (Kozel, 2008).

The motion capture system I am currently using is OptiTrack software with a Rokoko suit. However I have already identified limitations relative to contemporary dance improvisation. The avatars created by the nodes on the Rokoko suit divide the spine in 2 sections plus the pelvis. The suit also does not go beyond the knuckles and the head is represented by a vertical bar. These do not offer sufficient fidelity for this type of dance work. There are other options available, like the Perception Neuron suit employed by choreographer Alexander Whitey in some recently published digital experiments (Whitley, 2020). A Captury Live system developed by Dr. Nils Hasler, Michal Richter, Svilen Dimitrov and Christian Theobalt may also be a possibility as it is marker-less, only uses cameras (Gibson and Martelli, 2018).

The aim here is to minimise the variables within each experiment for digestible analysis of the results. The algorithm is a variation of a prototype I co-designed with biostatistician Leah Gerber Davis at Duke University in 2016. However that example was designed to support the creation of garment silhouettes through polygon generation. This is an adaptation that also uses an algorithm as part of the creative process, however the intent, input and output data formats have been changed. Here, MoCap data in Python is being translated into morse code-like sequences of stimulus materialised through a battery-powered pager motor embedded in a wearable.

I am interested in dancers' interpretations to the stimuli and how my choreography would be expressed once processed by the algorithm. What movement languages might be created? What materials are best to build the wearable devices? How do the users feel about automation in society after being in this choreographic process? Would audiences change their perception of machine integration after experiencing a demonstration of the system?

Expected contribution

The existing choreographic systems and digital dance work have an aspect of animation or use computer to visualise the human dancers interactions. The human-machine interrelation they utilise are also concerned with ending up a visual in which the choreographer can transpose to their dancer(s). I do not yet see an example of a choreographic system that contains the physical instigation element. These systems appear to use traditional dance interpretation methods to retransmit the digital/virtual world back into the actual one: the dancers either watch the avatars and interpret the movement sequences in their own bodies. Or the choreographer analyses the movements or phrases presented to them by the digital avatars and makes creative choices with which to direct their dancers. In my project the visual aspect of my system comes through the dancer's visceral response to the wearable giving them a physical point of initiation or instruction. It may be the system's design itself that is yet unprecedented, perhaps because I am not using animation, avatars or other visual cues as components. I make the wearables myself, provide the choreographic source material, co-create the algorithm affecting the stimulus, and interpret the results manifested in the end-user. It is this specific positioning that I have not yet seen. The co-created algorithm specific to movement impetus may also be the contribution.

Progress towards goals

Over the progress of this project it has become logical to break it down into separate components. Although the system is intended as a chain reaction communication system, it has not been necessary to build each component in their intended reactionary order.

Key next steps are testing the wearables on actual expert user (dancers) with*out* the algorithm, record the responses and analysing the results to inform the next round of prototypes. The movement data capture methods (MoCap) need further exploring, likely via other resources due to the restrictions of OptiTrack and Rokoko. The algorithm is still in development with the biostatistician now that we have narrowed the language down to Python. I anticipate a subsequent study will be instigating the stimuli by the algorithm's patterns instead of manual inputs.

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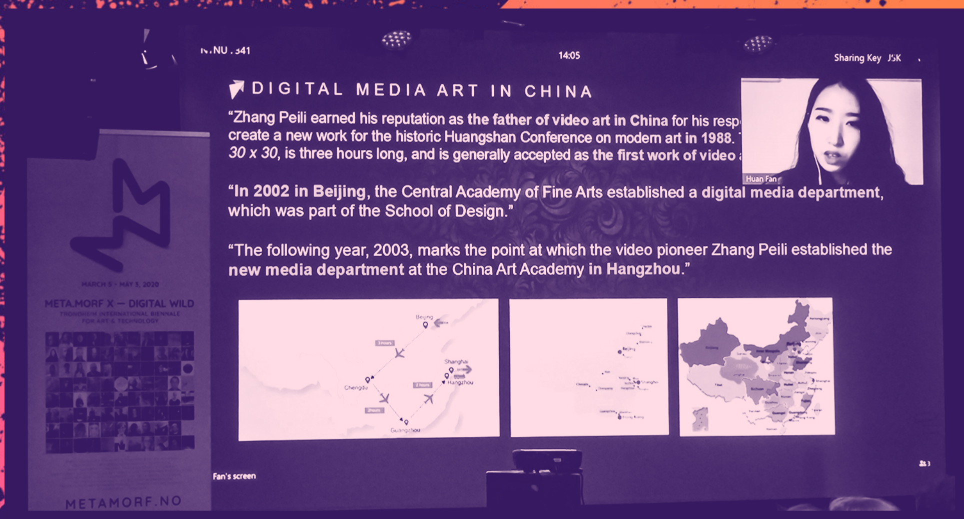
Huan Fan

Performance Liveness: Re-Creating the Every-Time

Colloquial Paper

Video of presentation can be found here



Performance Liveness: Re-Creating the Every-Time

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Abstract. To explore the definition and notion of liveness within the context of digital performance. Following the clues of Dixon to emphasize the humanism's meaning of this hybird creation. Two perspectives from the ontology and phenomenology of performance has been discussed to indicate the vital factor of time and position of audience which will fulfill the meaning of art in technological age. The behaviors of creation and re-creation mainly depend on the spectators, and their participation in the work of art will replace the physical presence by author's absence. The realization of this process gradually implies that there is a traction relationship between the application of technology and the emotions of the spectator.

Keywords: Liveness, remediation, performance, spectator

Introduction

The sixth chapter of Digital Performance (Dixon, 2007) is entitled Liveness. The author points out the notion of liveness from both the perspectives of ontology and phenomenology. Liveness in fact has been a long-debated issue in mediatized performance studies, which is the fundamental character that distinguishes it from other visual art forms in the sense of aesthetic pursuit. Dixon (2007) begins by explaining the feature of photographic images captured through optical lenses in electronic performances, leading to the controversial opinions between the replica and the original object, then draws the ontology of media and the concept of existence and absence in philosophy.

Digital Performance

The term digital performance is defined by Steve Dixon (2007) as something which "concerns the conjunction of computer technologies with the live performance arts." Two main parts, digital media and live performance, are included in digital performance. Digital media refers to projection, video, and computer technology to record or show off the content of the work. Live performance refers to the telepresence via screen of performers or on the stage in front of the spectator. The key role of technology played in the performance may raise the question: is the status performance art or video art?

Roland Barthes (1980) claims that photography is "a certificate of presence", a proof of something that once existed there, which "reproduces a moment in time that can never be repeated (Barthes 1980) " or "attests 'live' reality of a moment and presents it equally alive in a resurrection (Barthes 1980)". The photography hence provides more important meaning than its real-world referent. Dixon (2007) suggests that it can be further deduced in a philosophical sense in digital performance, "the media projection rather than the live performer that wields the real power, the sense of (aesthetic, semiotic) reality." Auslander (2008) also believes that "the dominant aesthetic force is the digital" rather than live performance, or that the live performance is a part of digital technology as a material.

Film is interested in "having the actor portray himself to the camera (Benjamin 2008, 18)", which sets the stage for electronic devices to become the most convenient and direct way to record personal emotions. While the blur borderline of art and modern life given a chance for everyone who can easily participate in "the performance as live in a temporal sense" (Sanden 2012, 5) via basic social media on a phone. This activity being assumedly done as the remediation and recreation of the daily events that occurred in real time and recorded by technology. In essence, it is a re-creation of daily events along with time. Whether it is high-tech or low-tech, the participation of each individual is the most important part of this process.

The Presence and Liveness

Performance scholars often “cite Benjamin as guardian of the incomparability of ‘liveness’” (Dixon 2007, 117), and enumerate his interpretation of reproduction. Benjamin’s argument is that reproductions loses the aura of the original. When it is extended to nature, recorded by photography it is “an invitation to a far-reaching liquidation” (Dixon 2007, 117), because the critical auratic elements in the scene are eliminated. The images captured here are not the real vivid object itself, but a visual choice of the lens. It can be noted here that the auratic elements mentioned by Benjamin are not just a visual scene, but also include the sound part to make the real world. That is, his “presence” refers to a scene that includes two senses and above, and much closer to the notion of liveness.

On the other hand, Dixon believes in the power of media and found the evidence to promote the positives of photography. He points out that Benjamin opines that the era of mass machine duplication not only changed the reproduction of objects, but also “the mode of human sense perception” (Dixon 2007, 117). Therefore, the reproduction also has its own meaning, and photography can be seen as an original work designed for reproduction (Dixon 2007, 117). Affirming the value of the reproduction supports the statement that the replica of presence can become liveness in digital performance. In a word, the term liveness needs two features: real-time and flesh-blood body present. It may include the additional one feature, digitally recorded, as a new modern way to create or spread. For example, in the artwork of *Video Walks* of Janet Cardiff, she recorded the view of the coming and going people in an old railway station. The spectator can wear the earphone to follow or return the view in the video in a new time. The moment recorded by video is then retraced in real time, so spectators experience the video recording and at the same time the live moment. The normal scene like the usual life has been recorded by the phone in advance. When the spectator joined the route recorded in the video, experience has been inspired to respond the video, and feel again the same live sense.

The Perspectives of Ontology

In postmodern culture context, mass media provides a free space for replicas to spread or consume, and the replicas recorded by the media or self-repetition have gained their corresponding aesthetic value. While the repica can not replace the original one for their different presence and sense.

Peggy Phelan (2003, 146) opposes the view to reproduction of the performance, and believes that the transient unrecordable disappearance is the essential feature of performance art. Once recorded, it will fall into the “circulation of representations of representations” (Phelan 2003, 146). Moreover, the recorded performance art will become other forms of art rather than performance. She used the performative and constative utterances to distinguish the describing words and real-acting. Supported by Derrida’s opinion that the performative writing promise is only to utter this promise (Phelan 2003, 150) . So, if the performance is recorded by words or video, it no longer can be the performance. On the other hand, her perspective to analyze and judge the ontology of performance is from an elite view of high art. High art has a feature that can not be replicated to spread via mass media to get more accessible attention from normal people. The situation is like the different price between painting and prints, even though the theme is the same one, the original painting will be more expensive than its prints. So, it is always the elite original one like the ephemeral performance mentioned by Phelan.

Dixon agrees with Auslander’s view on the disappearance of film moving images formed by visual retention and uses it to explain the ontology of media. By citing Auslander’s notions that “television’s earliest appearances, as an ontology of liveness more akin to the ontology of theatre than to that of film”(Auslander 2008, 12) and “disappearance may be even more fundamental to television than it is to live performance”(Dixon 2007, 125), Dixon gets a positive statement to argue the ontology of performance. The disappearance of the ontological characteristics of the performance art also corresponds to the ontology of the media. In other words, the disappearance can be regarded as the ontological characteristics of media and live performance.

The Perspective of Phenomenology

The perspective of phenomenology is closer to the concept of site proposed by Rosalind Krauss, which insinuates that an event includes the work and the spectator together happening in a certain space. Or the objecthood mentioned by Michael Fried, the attention and interest of the beholders belongs to the space to constitute the sense of the work. For the theater, it also tries to extend meaning beyond the frame, breaking the “forth wall” (Dixon 2007, 130) to invite the audience to participate in it. And, in some extent, the meaning of digital performance contains the body of the spectator which to fulfill a sense of interacting with the works. Interactive design, therefore, is a direct means for the author to control the behavior and mind of the spectators. There are two main ways to participate, one is the spiritual interest and attention to the performance content, and the other is the physical interaction with the actors or digital media.

For the audience, liveness is the “being there”(Dixon 2007, 129) with their attention or participate “as an extremely vital and equally dynamic element.(Sanden 2012, 15) ” Dixon talked about the relative relationship between existence and absence. It seems no answer and result if the participation needs to try to identify the audience’s attention in work. The audience for Dixon to discuss in book ought to be seen as an ideal group, who love art and may have established a strong background of art and can fully appreciate it in the context of art history. If their emotion is not specialized as this ideal one, the attention of the audience is also not the final proof of presence, because they may not have any participation in spirit or acting. Such interaction is a kind of false and form, not the one can inspire people’s spirit. To aim at the audience’s experience within the artwork need to try to create more meaningful content to fulfill the art rather than to seek technology for technology sake.

Conclusion

Liveness is a core problem in performance art, and can be one feature of the digital performance. The remediation of the performance will bring more positive meaning for the audience and spread the work in public and also give more creative space for the artist. Both the perspective of ontology and phenomenology are around the notion of real time, and the time for the performers to show and the audiences to appreciate. The display value of the work is replaced by the need to interact with the audience. The author’s ideas is no longer a single judging standard. The audience’s physical experience and the use of technological media carrier serve as an important part of this whole process of appreciation, so as to fully manifest and convey the author’s wishes.

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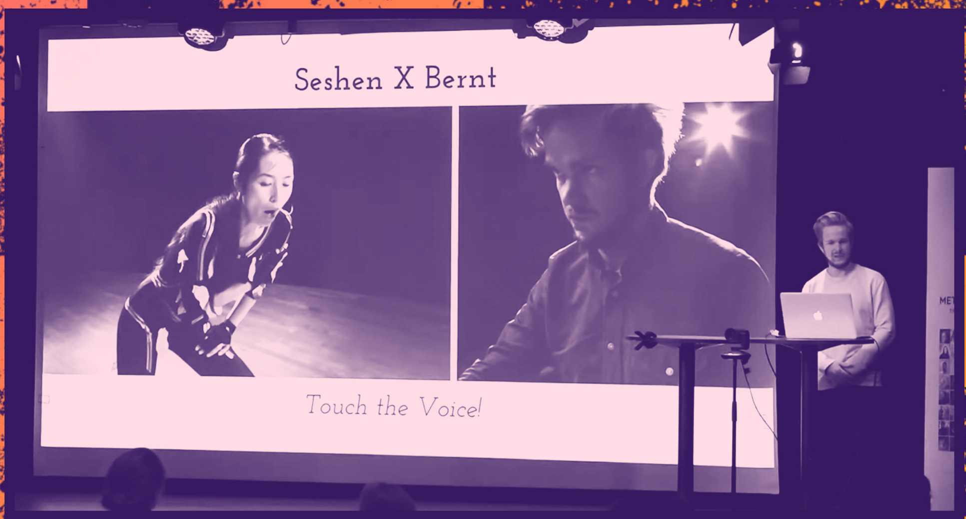
Bernt Isak Wærstad

Instrument design using machine learning and artificial intelligence

Colloquial Paper

Video of presentation can be found here



Instrument design using machine learning and artificial intelligence

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Abstract

The relationship between a performer and their instrument is an intricate one. To me, performing (together) with an instrument is as much about communication as it is about control. The instrument provides me with both resistance and inspiration in what I see essentially as a musical dialogue. There is something in this dialogue that feels fundamentally different to me when using digital instrument as opposed to traditional acoustic instruments. Digital instruments often tend to lack some of the response and resistance that is inherent in the acoustic instruments, while at the same time affording different modes of communication and interaction between the performer and the instrument. The purpose of this research project is to explore some digital instrument design strategies through analysis and exploration of those affordances. By using techniques more idiomatic to the digital domain like machine learning, artificial intelligence and computational creativity, I am seeking to both remedy the aforementioned shortcomings and facilitate new practices for performance and music production.

Keywords: Instrument design, Machine Learning, Artificial Intelligence, Computational Creativity

1. Introduction

I've been performing with a wide variety of digital musical instruments for the last 10 years. Most of them are hybrid instruments extending either my own guitar or traditional instruments played by other musicians. In either case, I often miss the tactile feel, haptic response and inherent resistance of acoustic instruments from my digital counterpart. These properties are important creative catalysers greatly affecting both the expressive capacity and the interaction between the instrument and the performer. This has led me on a search for resistance; some kind of dynamic response or feedback which can lead to new musical ideas or new ways of expressing them. Im also on the search for contact; a way of connecting and communicating with my instruments, where a performance can be as much a musical dialogue between me and my instrument as me solely *controlling* or *playing* the instrument.

Instead of trying to copy or mimic the behaviour and physical properties of acoustic instruments, like many have through for instance exploring haptic response and resistance through sensors, motorised controllers, transducers, etc, I want to focus on the strengths of digital technology. By using techniques from machine learning and artificial intelligence in combination with generative techniques and algorithms from the field of computational creativity, I want to explore instrumental designs that are only possible with digital technology and research modes of instrumental response and resistance that are more idiomatic to the digital domain. The project will explore and develop new personal strategies for digital instrument design based around my own artistic expression. These strategies will be both used to expand my existing instruments and to design new responsive and autonomous instruments.

As of now, I see two main areas in which I imagine machine learning and AI can be put to interesting artistic use for the purpose of creating reactive, automatic and autonomous musical systems. The first area to explore is combining techniques from the fields of Machine Learning and Music Information Retrieval to create adaptive instruments. I obtained a lot of valuable experience in this field as a participant in the research project "Cross adaptive processing as musical intervention"[1] which led to new insights in working methods in designing and using adaptive instrument (Brandtsegg, Engum and Wærstad 2018). This project will continue the exploration started in the cross adaptive project by exploring these different MIR techniques can be combined with machine learning algorithms, though mostly in a more pure adaptive fashion (not cross).

The second area is related to idea of autonomy and artificial intelligence. Or perhaps artificial artistic identity would be a better term. I want to explore instrument designs with a form of "personality" which

[1] http://crossadaptive.hf.ntnu.no/index.php/about-the-project/

can develop and evolve over time. In a way, this is already a natural part of the way I design and interact with digital instruments. They are constantly evolving and I tend to think of the design process as constant cycle (fig. 1) where each round around the circle is another evolution. But it's not only the instruments that are changing. As with all musicians and the instruments they are using, I am also learning and adapting; evolving together with the instrument in a sort of symbiosis.

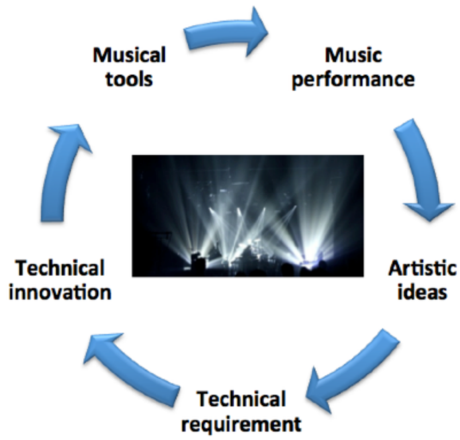

Figure 1. Cyclic instrument design process

I want to explore this relationship between me as a performer and my instruments over time further by designing autonomous instruments with a more explicit focus on its agency outside of a performance (what Bown et al. (2009) calls *memetic* agency). Im interested to find out what kind of musical dialogues this relationship will produce and what place both me and the instruments will have in the larger context of music culture over time.

In this context, I also find it very relevant to explore how we perceive the machine and it's output. What gives it a sense of agency and when do we interpret its actions as musical intent? In my early experiments, I found that even a simple smooth random walk produced a lot of, to me, meaningful musical ideas and initiatives. So introducing any kind of agency, even a random impulse, into the instruments are already giving me some sensation of autonomy from the machine, which directly affected my playing and encouraged a musical responses (a short excerpt can be heard at [2]). This project will therefor also explore generative and algorithmic processes like Markov Chains, Lindenmayer Systems, Cellular Automata and GANs as means of giving artistic agency to the machine. Combined with different MIR techniques and reinforcement learning algorithms, these techniques will be used to explore strategies towards creating a performance AI, which in the long run would turn in to one or several autonomous systems with its own artistic identities.

2. Related work

The idea of having autonomous and interactive music systems are by no means new and this project are based on ideas from early algorithmic music systems like "Voyager" by George Lewis (Lewis 1999) and "Improsculpt by Øyvind Brandtsegg (Brandtsegg 2001). More recent examples of relevant and inspiring projects are the machine improvisation system "PyOracle" (Surges and Dubnov 2013) by Greg Surges and Shlomo Dubnov, the AI performance system named "Tomomibot"[3] by Andreas Dzialocha, Tomomi Adachi and Marcello Lussana and Agostini Di Scipio's interactive music system "Audible Eco-Systemic Interface (AESI)" (Scipio 2003).

Other relevant and related work includes the Fluid Corpus Manipulation project (FluCoMA)[4], which are researching new ways of doing segmentation and classification of sounds and building different corpuses (Roma, Green and Tremblay 2019) and have recently also release a package of their tools for Max. Also in

[2] https://soundcloud.com/mrbernts/a-smooth-random-walk

[3] https://github.com/adzialocha/tomomibot

[4] https://www.flucoma.org/

Max is the MuBu toolbox[5] from Ircam which includes tools for audio analysis, segmentation gesture recognition and a few machine learning algorithms more. Also related is Charles Martin, a loose collaborator on this project, who is researching how to do creative predictions using recurrent neural network and has developed an interactive musical prediction system (Martin and Torresen 2019). Hugo Scurto has done some relevant and interesting work with interactive reinforcement learning in the project "Co-Explorer" (Scurto et al. 2019). Im also following the development of generative machine learning algorithms like WaveNet, SampleRNN and more recently OpenAi's Jukebox[6] project (Dhariwal et al. 2020) to mention a few. Other important tools include Rebecca Fiebrink's "Wekinator"[7] and Sam Parke Wolfe's encapsulation of the Rapid library as an Max MSP external, "RapidMax"[8].

3. Method

So far, I've started this exploration by expanding and enhancing my existing digital musical instruments both as a solo performer and in the duo constellation *Seshen X Bernt*. In the latter, where all sounds are based around sound manipulations of Seshen's voice, we have experimented with various segmentation and unsupervised classification techniques of a studio recorded corpus of acoustic vocal improvisations. This is an extension of the conceptual idea of using delays and live-sampling as a way of interacting with your past self. In our first tests we implemented a system where a sample of the real-time voice can upon activation be classified to pick out and play back similar voice samples. While our explorations have been quite rudimentary so far, it has already provided some interesting results and we plan on expanding this system to explore concatenative synthesis and musical mosaicing technique. We also want to explore adaptive processing techniques which could give back some of the control which Seshen has given up in this collaboration. The idea of redistributing control has already come up in our project "Touch the Voice!", which is a collaboration with Bob Pritchard and Kiran Bhumber at University of British Columbia working with their bespoke RUBS (Responsive User Body Suite) touch sensor suite (Bhumber, Pritchard, Rode 2017) to include movement as part of our improvisation and let Seshen control certain processing parameters through the sensors on the suite. A video produced by the end of a weeklong workshop at UBC in Vancouver in November 2019 can be seen at[9]

As a solo performer, I have explored adaptive processing combined with machine learning to extend my existing performance practise using electric guitar with various preparation techniques and electronics. The first public performance showcasing this exploration was given at ICLI 2020 where both the performance and the new instrument system was named "Ghost Doctor Duplicate" (Wærstad 2020). To not lean too heavy on old habits, I chose a dogmatic approach for this performance focusing solely on digital effects and letting the adaptive system control all the processing.

As mentioned in the introduction, the nature of my work process is cycling rather than linear, where musical performance produces artistic reflection which forms the basis of the continued technical development leading to an improved instrument with which another musical performance can take place. I also see it as important that different modes of musical performance (rehearsal, concert, studio recording) are carried out to have varied foundation for reflection. Discussion and reflection with collaborators, colleagues and audiences will also be an important part of bringing this project forward.

4. Future work

Having started up in September 2019, the project is still in its infancy with "Touch the Voice!" being the first public outcome and the contributions to this conference the second. The project is formally of limited reach so far being tied to a 20% research position for one year, though applications have been made for further funding. The focus for the last months before the current ending date for the project on 31sth of July will be to explore reinforcement learning and generative machine learning algorithms to start the process of building an autonomous performance system. I also plan on developing this project further with the goal of having it evolve into a more comprehensive artistic research project which would serve as the foundation for an artistic phd.

5 http://ismm.ircam.fr/mubu/

6 https://openai.com/blog/jukebox/

7 http://www.wekinator.org

8 https://github.com/samparkewolfe/RapidMax

9 https://www.youtube.com/watch?v=odrijbYc93M

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Marije Baalman

Mapping the question of mapping

Colloquial Paper

Video of presentation can be found here

Mapping the question of mapping

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Abstract. This paper proposes a method to study the question of mapping: the field between capturing what happens in an environment, the gesture, to what happens in an output medium. While motivations for creating interactive works that involve mapping are very diverse, within these works common techniques and methods are used to achieve unique artistic works. The method proposed provides a way to document these techniques and methods and place them in an aesthetic context. The aim of this method is to provide a basis for a common vocabulary among artists to talk about mapping.

Keywords. Mapping, digital musical instruments, interactive installations, interactive dance.

What is the question?

In interactive works where *gestures* in the environment affect output media, the main question the artist is dealing with is how to make a meaningful connection between the gesture and the output. These interactive works range from digital or augmented musical instruments, dance and technology performances, to interactive media installations.

The field between this capturing of what happens in the environment (the gesture) to what happens with the output medium is often refered to as 'mapping' (see figure 1).

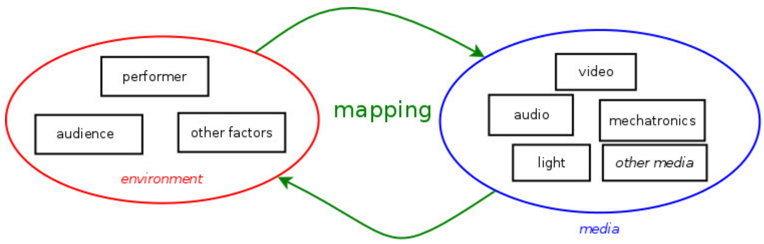

Figure 1: The question of mapping: the connection between a gesture in the environment to output media.

The term 'gesture' is used very broadly: these can be intentional gestures of a performer, but also ancillary gestures that occur, or accidental gestures. They can also be gestures of a phenomenon in the environment: the change of temperature and humidity over the course of a day.

The 'arbitrariness' of mapping is often criticized as 'anything can be mapped to anything' and therefor it is inpenetrable, but in fact this is where a significant part of the artistic expression is. To quote Michel Waisvisz, a pioneer in this field: "the algorithm for the translation of sensor data into music control data is a major artistic area; the definition of these relationships is part of the composition of a piece. Here is where one defines the expression field for the performer, which is of great influence on how the piece will be perceived" (Waisvisz, 1999)[1].

If we can distinguish styles and genres in how musical notes are placed in harmony or disharmony within musical pieces, we should also be able to distinguish styles and genres in how artists create these algorithms, these mappings. And to do so, we need to understand what is going on in these algorithms and the artistic motivations to use them.

[1]http://crackle.org/MW's gestural round table.htm

The answer to the question is manifold and the way artists approach the question for a large part depends on their motivation for creating the artistic work, but also on the technological means that are available to the artist at the time.

The field of HCI (Human Computer Interaction) deals with how humans interact with computers, and the tools and techniques developed in that field find its application in artistic works. There are however also distinctions: the interactions artists pursue are often idiosyncratic: either based on their own artistic needs (and not those of a separate 'user'), or the subject of the artwork is the interaction itself. Thus the validation of what a 'good' interface is, may be quite different than in HCI research, as HCI often aims to design for a large user group (the masses).

In digital musical interfaces, artists look for a performative way to control their electronically produced music: they shape their performative effort that will allow them to make their music. In dance, the motivation lies in creating different ways of experiencing (movement of) the body and space, or exposing and expanding choreographic concepts. In media art, the art might be in the interaction itself, a physical phenomenon might be the subject of the artwork, or the interaction might be used as a means to explore another topic alltogether.

The artistic motivations and the resulting works may be very different from each other; yet they use similar tools to achieve their aims and within these tools, many common methods and techniques are used to process, translate and map data to the output are being used. While the technology that is involved is continuously developing, these methods and techniques might stay the same, or can be transfered to new technologies. Artists have a need for a common vocabulary to talk about these methods and techniques, so that exchange may happen between artists who use different types of hardware and software.

With interactive technologies becoming more ubiquitous in our surroundings (e.g. Internet of Things and wearables that use biometric technologies), along with apps that promise us insight from the data that these 'smart' systems produce, the question of mapping also gains importance on a societal level: where is the border between providing insight from data through sonification and visualisation and artistic interpretation?

Related work in the artistic field

Miranda & Wanderley (2006)'s book provides a good introduction to the topic of mapping, though mainly focuses on the first part of mapping: gestures and how to capture the gestures and get the data into computers. The question of how this data is then used within the computer to map it to sound is only discussed in broad terms: explicit mapping strategies or implicit strategies making use of neural networks or pattern recognition tools. The book cites that the discourse in the literature on explicit mapping strategies "generally considers mapping of performer actions to sound synthesis parameters as a few-to-many relationship".

The proceedings of the NIME conference[2] are a valuable resource for publications about the topic, though as it is an academic conference there is a lack of publications on artistic work done outside of the academic world. Technical novelty tends to dominate over extensive artistic performance with the instruments. In particular papers on digital musical instruments that artists have built and developed and performed over many years (say 5 or more) are lacking in the discourse here. Other conferences of interest are the International Computer Music conference (ICMC)[3], and the International Conference on Live Interfaces (ICLI)[4]. ICLI also expands beyond music and takes a more philosophical, performative approach.

Kwastek (2013) presents an elaborate discussion on the aesthetics of interaction in digital art, which she places in the context of interaction as an aesthetic experience and the aesthetics of play. She provides an insightful method to evaluate interactive works, by identifying the actors, space, time, rules, phenomology, and materiality. These are then illustrated in several case studies. Other overviews of and reflections on interactive art are found in Wilson (2002) and Bianchini & Verhagen (2016).

Kozel (2007) gives a great insight into phenomonological aspects of performance incorporating technology, and how (interactive) technologies can change and question the perception of the body. Karreman (2017) writes about the use of motion capture in dance, and notes the contradictory desires from this technology: recognition and newness. The work on Motion Bank (deLaHunta et al. 2015) is aimed at using motion capture

[2]Available via http://www.nime.org
[3]Proceedings available via https://quod.lib.umich.edu/i/icmc
[4]Proceedings available via https://live-interfaces.github.io/liveinterfaces2020/proceedings/

technology to capture choreographic traces, that allow to study and transfer dance, and through that create new choreographies. Related conferences are organised by the Movement+Computing Community[5].

The references above provide great resources, though mostly stay within their disciplines (music, dance, media art), while many practicitioners move between these artistic disciplines, especially in collaborations. A cross-disciplinary approach would help the practicitioners (and those that study their practices) to support awareness of common methods and previous work, and insight into differences in aesthetic motivations in creating the works.

I find that there are still questions that need further study:

1. What is the connection between the aesthetic motivations of the artist and how is this aesthetic realised in the work?
2. How is this aesthetic implemented with the technology?
3. How do technological and aesthetic choices in this process influence each other in the artistic practice?

I believe that, by bridging the gap between the aesthetic and technological, important new insights can be gained and it would be made easier for artists entering this field, to build up on previous work (generated knowledge) from other artists.

A method for studying mapping

The methodology that I am proposing is a combination of interviews with the artists who created the instruments/works and an in-depth analysis of how the works are built.

In the interviews with the artists (and/or the engineers that are involved), I attempt to get an understanding of the artistic concepts that are behind the development of the work, how the idea evolved throughout the process of development and what choices were made along the way. I also discuss with them how the work is performed and how this relates to the artist's practice in general and how it changed their practice. In the analysis of the work I make note of what physical elements the work consists of, how these are interconnected and how they are positioned in space. How the work functions: which algorithms are used and what musical/visual/choreographical concepts is the work based upon. Which hardware and software is involved in the work, tracing how gestures are translated to output media.

I am currently applying and further developing this method both in case studies for the forthcoming book "Just a question of mapping" as well as in work sessions with artists (selected from open calls) under the title "Mapping my mapping". The outcomes of both will inform the other chapters in the book to describe these methods and techniques, both from an artistic and an technical perspective. I will work with graphic designers on creating a visual language to aid in documenting mappings.

Breaking down the process of mapping

Interactive works can often be broken down into various elements that are interconnected (see figure 2): (1) a gesture is performed in the environment, (2) which is captured by a sensor that translates the gesture into an electronic signal, (3) the signal is processed by an electronic circuit, often to digitize it, (4) after which it enters some sort of computational model that translates the data to parameters that control (5) an output medium such as sound, light, video or mechatronics. This is a simplification of the steps involved, and there may be various modifications to this general scheme. Nonetheless, breaking down the process of mapping in these steps may be a good start to understand these works.

One of the first stages in gaining an understanding of the mapping is identifying which physical elements are involved in the work and how they are interconnected. Which sensors or control interface elements are used, how they are mounted or placed in space, which circuitry is involved, what computers are involved and what software runs on these computers, which output media are involved and how are they controlled. Then identification of how these elements are connected: which cables run between them, what protocols are used for these connections, what kind of data flows through the elements.

After this physical exploration, the signals themselves are traced: how at each of these elements is the signal or the data translated to other ranges, gated, or compared with thresholds, combined with other data streams,

[5] Proceedings available at https://www.movementcomputing.org/proceedings/

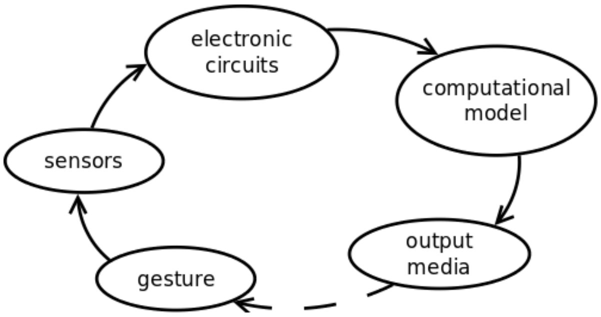

Figure 2: Steps in the mapping process.

feeding into computational models that generate new data, and eventually connected to one or more parameters of the output medium.

Computational model

The computational model can exist of several intermediate steps interlinked in various ways. These often include data processing methods like:

- translation between ranges (e.g. MIDI range of 0-127 to a standardized range of 0.0 to 1.0 to an exponential frequency range of 400 to 6000 Hz),
- the use of thresholds (e.g. for triggering or changing states), processing button presses and releases
- modal control or different states of behaviour
- deriving data or features (e.g. the mean or variation of a signal, spectral properties)
- combining various datastreams (e.g. gating a datastream with a button, or merging data from different axes of motion).

These can also include more sophisticated methods like programmed computational behaviours that are controlled by data derived from sensors, or various machine learning methods and/or gesture recognition algorithms.

Artist's choices and motivations

The choices at any of the steps above are based on artistic, technical and practical motivations, often coming forth out of experimentation. This is not always a linear process where an artist starts with a concept and ends up with an instrument according to this concept. Ideas may be discarded along the way, if they are not interesting to play. Technical options may prompt new ideas and directions. And throughout the process an artist may go back and forth between the different steps.

Choices made along the way are often based on accessibility: in cost, availability and familiarity to the artist. Or they may be based on coincedence: two ideas that just happened to come to mind around the same time and seemed interesting to combine.

Example: Erfan Abdi's NoteSaaz

As an example, the NoteSaaz from Erfan Abdi (Abdi & v/d Heide (2013)) uses the following main components (see figure 3):

- The physical controller consisting of four tubes with five five potentiometers and 8 buttons mounted on them. This controller is held and manipulated by the performer.
- An Arduino reading out the data from the sensors on the physical controller and sending this to Processing.
- A visual (computational) model of bows and strings programmed in Processing, that is controlled by the data readings from the sensors. From the visual model new data streams are derived from the

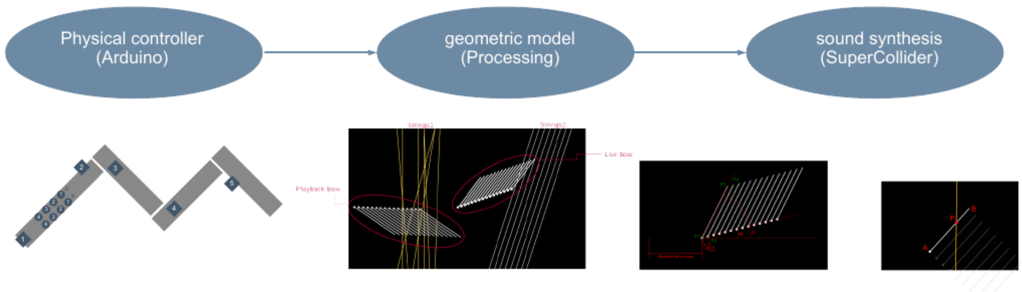

Figure 3: The three components in NoteSaaz (graphic created by Erfan Abdi during the work session in October 2019).

intersections of the bows and strings. The visual output is shown on a screen visible to both the performer and the audience.

- A sound synthesis engine running in SuperCollider that is controlled by the datastreams generated by the visual model. The sonic output is heard both by the performer and the audience.

The sensor data is scaled with linear or logarithmic range mappings, and the data from the visual model is again transformed to data ranges suitable for pitch, filter frequency, bandwidth and panning parameters of the sound synthesis (a formant synthesis algorithm).

The buttons allow for additional control over the visual model, and also enable the control over a second (visual and sonic) layer where movements of the bow can be recorded and played back.

The two elements of the visual model and the physical controller came together as Abdi had already been experimenting with visual models for controlling sound synthesis algorithms, but found himself in his studio without internet, and started to play around with some found sticks that were interconnected in an interesting way. Playing around with this object, he found that the object afforded a high dimensionality of movement, controlled just by two hands. This inspired him to create a similar object to sense all these dimensions and be used as a controller for his visual model.

First observations

From initial literature research and processing the first interviews for my case studies and the first two work sessions, I have made some observations, with which I want to conclude this paper.

The artists participating in the work session generally found this a really useful way of reflecting on their work: finally 'finding ways to talk about this'. One participant compared it to literary workshops, where the approach is that you 'first need to read in order to be able to write'. Another participant remarked that it helped to 'point out the blind spots in my project'. For several participants the work session gave prompts for further development, improvement or revision to the project, or provided the basis for a manual on the work, to enable troubleshooting in the future.

In the case study on Roosna & Flak I made an interesting observation: they stated that their use of a wireless accelerometer to control sound, has simply become one of the tools in their toolkit for making dance performances, rather than a novelty, interactive approaches are sometimes just an easier way of doing things.

From several of the projects (both in the case studies as in the work sessions) 'tourability' is an important aspect in the design of an instrument: this puts constraints on the amount of devices, replaceability, sturdiness, cost, size and weight of the elements that are used in a particular instrument, and sometimes result in the use of (surprising) workarounds for specific limitations that may give.

In several of the artistic projects analyzed, components have a long life and are used in a multitude of performative works. In some of the works analysed some of the components were exchangeable (like the physical controllers, or the sound content), and other components were put to new uses in new contexts with each new artistic project, thus becoming part of the artists' instrumentarium. Boundaries between instruments, performances and composition are sometimes hard to distinguish (see also Baalman 2016).

Conclusion

The process of mapping is an interdisciplinary effort and requires both engineering and artistic skills. While common strategies, tools and elements are used, each work is highly individual and often changing over time. New strategies, tools and elements are continually invented, embraced and (in some cases) abandoned again. The process is situated in time and relates to the available technical means and current artistic practices: it is connected to the music and other artistic paradigms embedded in available software and hardware, and how artists adopt, change, break and transcend these paradigms.

As such it is an enactive process of codevelopment of artistic concepts and technology. The resulting work may be seen as embodiments of the artistic concepts and performative expression of the artist. Conversely, the instruments are physical objects that allow the exploration and development of these aesthetic concepts (Magnusson, 2019).

In disciplines such as music (across genres), dance, media art and interactive art similar methods and approaches are used and artists often move between these disciplines. Therefore, it is necessary to look at these practices across disciplines, while at the same time discerning the different artistic concepts of interaction and embodiment in these different discplines and how these may influence choices for particular methods and techniques.

Acknowledgements. The purpose of this colloquial paper has been to elicit input from the community into my research. The research for the book project "Just a Question of Mapping" is funded by the Creative Industry Fund NL. For more information about the project see https://justaquestionofmapping.info.

The presentation of the paper at ICLI was supported by the Production Network for Electronic Art (pnek), Norway.

The artists/engineeers involved in the case studies are: Andi Otto, Frank Baldé (for the STEIM software and Michel Waisvisz' work), Jeff Carey, Roosna & Flak, and Jaime del Val. The participants in the first work session were Dan Gibson, Solomiya Moroz, Stelios Manousakis and Erfan Abdi. The participants in the second work session were Mads Kjeldgaard, Rafaele Andrade, Ari Trümper, Mári Mákó, Tejaswinee Kelkar, Luke Demarest, and Kristin Norderval.

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Elizabeth Wilson,
Gyorgy Fazekas and
Geraint Wiggins

Collaborative human and machine creative interaction driven through affective response in live coding systems.

Colloquial Paper

Collaborative human and machine creative interaction driven through affective response in live coding systems.

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Abstract. Co-creation strategies for human-machine collaboration have been explored in various creative disciplines. Recent developments in music technology and artificial intelligence have made these creative interactions applicable to the domain of computer music, meaning it is now possible to interface with algorithms as creative partners. The application of computational creativity research is beginning to be incorporated within the practice of live algorithmic music known as live coding. As music is inherently coupled with affective response (often defined as the general psychological state of an individual, including but not limited to emotions and mood), it is crucial for any artificial musical intelligence system to consider how to incorporate emotional meaning into collaborative musical actions. This work looks at bestowing live coding systems with the ability to autonomously create emotionally intelligent musical collaborations and examine new ways of interfacing with musical algorithms.

Keywords: human-computer interaction, live-coding, affective computing, co-creation, computational creativity

Purpose of research and its importance to the field

Although natural language and programming languages are ontologically distinct, programming languages provide a way of interfacing with computers and music technology in a *human* way. Language has historically been used as an artistic medium due to its capacity for emotional expression through uses of narrative and imagery. Music and language have also historically been symbiotic, with the contemporary artistic practice of musical live coding attempting to furthering this symbiosis. Musical live coding refers to an artist-programmer who writes and manipulates code in real time to generate music (Collins et al. 2003). The practice considers computer languages as a form of musical notation. There are currently multiple programming languages that have been explicitly designed for the expression of algorithmic music; for example languages such as Csound and SuperCollider, patcher languages like MaxMSP and Pure Data, or mini-languages such as TidalCycles (Tidal), Gibber and FoxDot.

Research in the field is becoming somewhat saturated with new programming languages for musical expression, each constructing their own linguistic representations for musical pattern. One potentially under-explored area within live coding is in the use of *virtual agents* or *machine musicians* as an interaction medium. Machine musicianship describes the application of intelligence concepts and algorithms to computer music systems, where systems have the ability to demonstrate and learn creative behaviour. Some notable examples include Patchet's Continuator which continues musical phrases based on user input (Pachet 2003) or the OMax system which uses factor oracles to learn in real-time typical features of a musician's style and plays along with them interactively (Assayag, Bloch, and Chemillier 2006). In particular, this research is interested in the application of machine musicianship in live coding. Opinions were obtained from practitioners in the live coding community about the possibilities of future integration of computational creativity practices, particularly with respect to the computer's creative autonomy (McLean and Wiggins 2010b). The results showed around half of respondents agreeing that autonomous code could produce artistically valuable outputs, but less agreement for the Turing style question of whether "a computer agent will be developed that produces a live coding performance indistinguishable from that of a human live coder."

Recent advances in the fields of music technology and artificial intelligence have allowed for growth of the field of machine musicianship. Interactive systems capable of generation of live musical scores have become more prevalent, however live human performance of these scores is subject to the fundamental drawback that this requires the completion of complex musical tasks such as live sight reading and performance. This makes it a difficult terrain to navigate, even for accomplished musicians. Live coding might be a way to circumvent this, due to its ability to automate processes. Magnusson describes a live coder as "primarily a composer, writing a score for the computer to perform" (Magnusson 2011a) and thus live coding provides an interesting framework to situate work in autonomous generation.

Boden addresses machine creativity in artificial intelligence, presupposing it as an inherently human trait and defining it as "the ability to generate novel, and valuable, ideas" (Boden 2004). For artificial musical intelligence to be successful in its aim of creation of valuable music, perhaps more focus is needed on the subjective human response rather than generation based purely on musical surface form. Approaching the task of music generation from a purely computational standpoint detaches it from its essence of inherent emotional expression. In automatic language generation this seems obvious, given most linguistic systems tend to consider the narrative and its intended message rather than simply generating based on syntactical information alone and thus the same considerations are needed for musical systems (Wiggins 2018).

Brief survey of background and related work

Many composers and computer scientists have attempted to create musical compositions through algorithmic processes. Mozart's *Musikalisches Würfelspiel* (musical dice games) is considered one of the first pieces of algorithmic composition, whilst the first piece of music composed by a computer was Hiller's *Illiac Suite*- using the Illiac I computer to compose for a string quartet (Herremans, Chuan, and Chew 2017). Contemporary algorithmic music practices span from Google's artificial musical intelligence project *Magenta*, which harnesses the potential of machine learning and deep learning to generate music, to mathematical and probabilistic approaches such as Markov models, evolutionary modelling or grammatical approaches.

One subset of contemporary algorithmic music practice, known as *affective algorithmic composition* (AAC), describes the process of combining computer-aided emotional evaluation and musical generation based on given sets of rules or instruction. AAC expands on current research on dynamics between music and affective response in interactive systems, for example Barthet et al. create interactive systems for collectively controlling and collaging music to express desired emotions (Barthet et al. 2015). Various practices are used to implement affective response into algorithmic composition. Two of the most common approaches are *categorical* (using discrete labels to categorise affective response states) and *dimensional* (affective phenomenon as a set of coordinates in a low-dimensional space). Russell proposed a two-dimensional modelling space, the circumplex model of affect (Russell 1980), which mapped affective states to the dimensions of *valence* and *arousal*- these are often posited in layperson's terms as *positivity* and *energy*. Many creative systems exist that use this dimensional approach for music generation, such as the *Metacompose* system (Scirea et al. 2016), which uses the circumplex model and evolutionary generation algorithms to create "a compositional, extensible framework for affective music composition." However, research on collaborative co-creation within affective algorithmic composition is somewhat sparser.

Given live-coding's grounding in human-computer interaction, it is unsurprising that the challenge of co-creation with machine musicians has already been attempted. Notable examples include *LOLBot* (Subramanian, Freeman, and McCoid 2012), a virtual agent that can collaborate with humans and Magnusson's autonomous live-coding virtual agent *Autocode* implemented in ixi lang (Magnusson 2011b). Further to this, (Xambó et al. 2017) consider how collaborative human and machine interactions situated within collaborative music live coding practice (CMLC) can be used in both educational and performance contexts. The authors examine how these practices can inform both students improving their programming practices and musicians augmenting their creativity. Within Tidal there have also been attempts at implementing machine musicianship, with an autonomous performer *Cibo* using sequence-to-sequence style neural net algorithms (Stewart and Lawson 2019), or using evolutionary algorithms to evolve musical patterns in Tidal using the Extramuros platform (Hickinbotham and Stepney 2016).

For the construction of creative systems within the context of live coding, Wiggins and Forth advocate for three key components (Wiggins and Forth 2017). The first is the ability of a computer to relate the meaning of a program to its syntax. Secondly, the computer should be able to model the coder's aesthetic preference. Then thirdly, the system should have the ability to manipulate the available syntactic constructs to take some creative responsibility for the music. The proposed approach for the research outlines how these ingredients are to be applied to the interactive system being designed.

Description of the proposed approach

This work looks at implementing machine musicianship and computational creative strategies through affective modelling, specifically within the Tidal programming mini-language. Tidal is a real-time embedded domain-specific language for live coding (McLean and Wiggins 2010a). It is implemented as an extension of the functional programming language Haskell (Thompson 2011). The symbolic nature of this language allows the live-coder to pair program fragments with their associated symbols and its type-checking system makes it suitable for real-time algorithmic composition, making it a conducive environment for the research outlined.

The proposed approach first looks to existing literature on music and emotion (Juslin and Sloboda 2001) and how this can be incorporated to build accurate models of affective response. The relationships proposed based on the literature seek to map intended target emotion-related parameters onto musical structural aspects such as tempo, loudness, rhythmic density, pitch register and modality. This is done using the circumplex dimensional model of affective response parameterised by valence and arousal, $v, a \in [-1, 1]$. Some literature suggests the use of three dimensional models for additional clarification (with added dimensions such as tension or dominance) (Scherer, Johnstone, and Klasmeyer 2003) however these are omitted from the current research at this stage.

Validation of the accuracy of these models in representing affective correlates will then occur through online listening tests. This will obtain data on how the intended mapping of affective co-ordinates matches with the perceived evaluation of the generated patterns' audio output. These models will then be incorporated as part of the algorithmic composition strategies employed by the creative agents to allow control over these structural aspects of the music. As Tidal is an extension of the functional Haskell language, functions or external modules and libraries provide the framework for implementing these models of affect.

On creation of a valid framework to situate affective algorithmic composition, these can then be implemented to create the collaborative machine musician. Strategies for computational creativity are being explored within the live coding framework of Tidal. Current research has begun with a focus on the inclusion of algorithmic composition strategies that can be used for autonomous composition of musical pattern. The application of these composition strategies have been examined, such as the use of first-order Markov chains and random walks, or implementations of neural network structures within the Haskell environment. This will be followed by an exploration of how to combine these affective models and computational creativity strategies, so as to implement affective algorithmic agents capable of creating some artistically valued contributions.

Figure 1 provides an overview of the implementation of a creative system within the Tidal framework, showing both the actions of the human and computer musician that are necessary for productive creative interaction. Babbitt outlines three representational domains for music: *graphemic*, *acoustic* and *auditory* (Babbitt 1965). These respectively represent written forms of music, the physical movement of air particles creating sound and its effect on the mind of the listener. The process of conversion from affect to code, from the conceptual to the graphemic, begins the process. This in itself is a complex process and readers are referred to (Wiggins and Forth 2017) for extended discussions on this. The produced code score is then synthesised as sound and is heard by the human musician which, in turn, can be used to re-initialise the process and further shape the composition.

The interaction modality between human and computer is highlighted throughout the figure. The affective data that is received from the human in the system is either from the live-coder explicitly stating the valence-arousal co-ordinates, or could be developed as an inference from an inverse mapping of the defined rule system. Patterns of code are then generated on the given affective data input values and then could either be autonomously executed as in (Stewart and Lawson 2019), or sent to the human coder to accept or reject, as in (Hickinbotham and Stepney 2016). This is sent to the SuperDirt synthesis engine to render from the graphemic to acoustic domain.

Finally these are then heard by the listener who responds accordingly either editing or changing existing patterns or developing new ones. There is also some scope for the computer to complete some evaluative process in this creative system, perhaps implementing some basic machine listening algorithms, as arguably a computationally creative system should be imbued with some of its own reflective qualities.

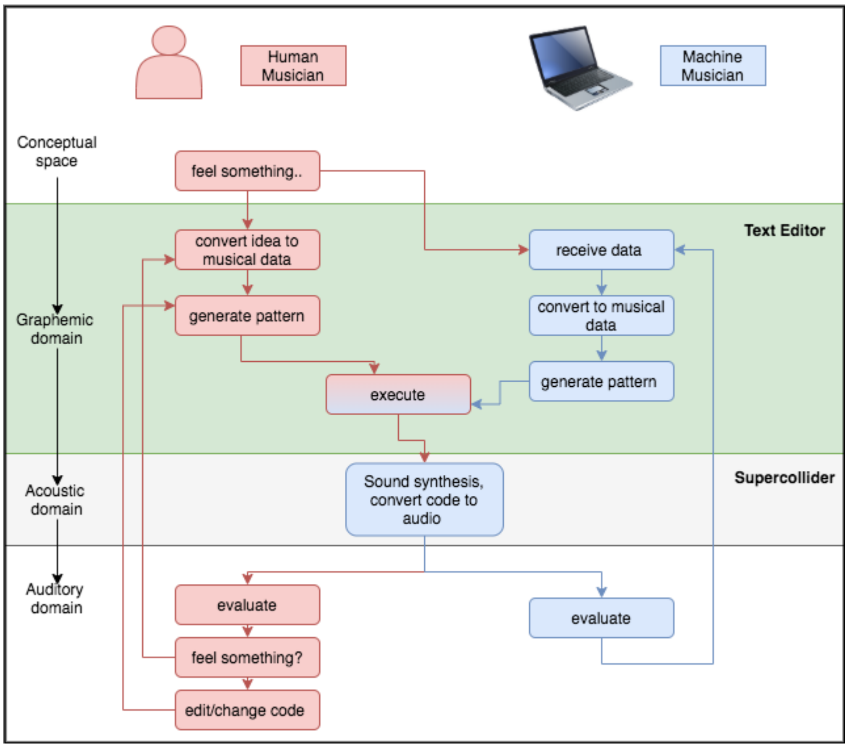

Figure 1: An system diagram of the proposed implementation of such a creative system. Items in red represent actions undertaken by the human, whilst actions in blue are representative of the computer's actions.

Existing research on language and system design in live coding can be used to inform the methodological approaches employed for this research. Kiefer and Magnusson obtain qualitative data through surveys on the design of language and environments for live coding (Kiefer and Magnusson 2019) by obtaining responses from practitioners in the field of language design and machine learning. The authors use a speculative approach, questioning both why people use live coding systems and what features enable them to live code successfully. Their results are broad in scope but produce various findings of interest, such as the success of live coding as not only a performance practice but a general way to converse with computers and explore emerging ideas. Similar methodological approaches could be applicable, where design of the system outlined in this paper would be informed by supporting qualitative analysis.

Expected contributions

This work will address research questions and perform exploratory studies grounded in and contributing to a wide span of research areas, including human-computer interaction, musical interface design, algorithmic composition and psychology of music. This work aims to contribute to these domains through exploration of live coding as an interface for providing meaningful musical interaction between human and machines and through exploration of artificial aesthetics and automated emotional intelligence.

Moreover, current research in interactive music and computationally creative systems makes limited use of formal evaluation methods and many systems are not described in sufficient detail for their re-implementation. As well as the design of a system for interaction with affective autonomous agents, this work intends to apply evaluation metrics to any musical output of the system. Some existing frameworks exist that aim to provide universal evaluation of computationally creative systems. Jourdanous proposes a Standardised Procedure for Evaluating Creative Systems (SPECs) (Jordanous 2012), its approach based around a set of 14 ‘components of creativity’ that evaluators should consider. Kantosalo also identifies this disparity between the production and evaluation of creative systems and proposes hybrid approaches from field of user-experience design and computational creativity research (Kantosalo and Riihiaho 2019). This work will aim to contextualise the existing research on evaluation of computationally creative systems within the framework of live coding. However, as the research on this specific domain is currently sparse, perhaps a significant contribution of this project is the application and adaption of existing methodologies to create new critical evaluation models of both musical output that is produced and the interaction between human and machine agents.

Progress towards goals

The first stage of this research has looked at developing strategies to implement some constructed model that can be used to simulate affective response in musical composition. Affective modelling equations based on the existing music psychology literature have been implemented. From this, various functions have been implemented using the Haskell language and embedding within the TidalCycles environment that aim to programmatically update musical structural parameters of the system, through the use co-ordinates of the two-dimensional model of affective response outlined by Russell as input values. This then provides the framework for autonomous production of musical phrases conforming to some intended target affect.

The research will then look at the validation of the chosen rules for this implemented model. To do so, a current ongoing research study is looking at whether the intended affective response is conveyed accurately to listener’s through patterns with target affect. The intended valence and arousal parameters will be verified against the listener’s perception, through use of statistical testing measures such as Pearson’s correlation. Once the implemented model can be verified by the results of listening tests, the next stage of the research is to look at integrating these models with various computational creativity strategies and then finally to apply evaluative techniques to attempt to measure the successes of such a system.

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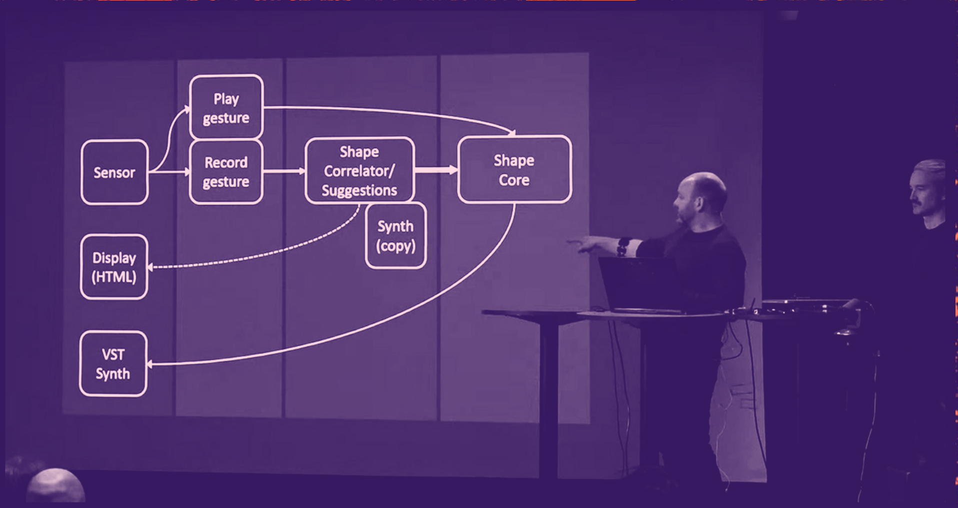
Øyvind Brandtsegg and Axel Tidemann

Shape: an adaptive musical interface that optimize the correlation between gesture and sound

Colloquial Paper

Video of presentation can be found here



{*Shape*: an adaptive musical interface that optimizes the correlation between gesture and sound

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Abstract. The development of musical interfaces has moved from static to malleable, where the interaction mode can be designed by the user. However, the user still has to specify which input parameters to adjust, and inherently how it affects the sound generated. We propose a novel way to *learn* mappings from movements to sound generation parameters, based on inherent features in the control inputs. An assumption is that any correlation between input features and output characteristics is an indication of a meaningful mapping. The goal is to make the user interface evolve with the user, creating a unique, tailor made interaction mode with the instrument.

Keywords. Gesture sensing, HCI, Artificial intelligence, Machine learning, Machine aesthetics

Introduction

The problem of mapping realtime performance data from an input device to control the parameters of a synthesis engine is common in digital music instrument design (Hunt and Wanderley, 2002). Designing explicit mappings allows detailed and precise control over the relationship between input device and synthesis engine, but we also recognize that this is a complex process. Using generative mechanisms such as neural networks allow for ways of managing this complexity. This has been done e.g. by Lee and Wessel (1992), Modler (2000), Fiebrink and Cook (2010), Martin and Torresen (2019) and Visi and Tanaka (2020). In the current implementation, we have used a gestural input device (Myo armband), although the methods could easily be adapted to any input device.

Gesture to audio interfaces has a long history, with one seminal work being Michel Waisvisz's "The Hands" (Torre et al., 2016), with a plethora of variations and methods shown in Wanderley and Depalle (2004), and a more recent artistic example the Strophonion (Nowitz, 2019).

One way of managing mapping complexity is to aim for a strong connection between the gestural qualities of a movement and the resulting perceptual parameters of the generated sound. This has been researched e.g. by Metois (1996). The perceptual qualities *volume*, *pitch* and *timbre* are commonly used, where the first two are relatively easy to describe but the last is much more ambiguous. Different approaches to defining and parametrizing timbre has been made by e.g. Schaeffer (1966), Smalley (1986), Wessel (1979), Bernays and Traube (2011) and others. Part of the problem may lie in the fact that timbre is a complex combination of temporal and spectral characteristics of a sound, but it is also related to the perceptual aspect. Perception happens in the individual, and as such also involves both psychological and philosophical considerations. An interesting recent approach to tackling these challenges can be seen in Magda Mayas' "Orchestrating Timbre" (Mayas, 2019) where perceptual timbre maps are created based on the personal artistic practice of the musician herself. As Mayas demonstrate, timbre can be adequately approached by a personal experiental approach in how it relates to nuanced performative expression on a musical instrument. Thus, it seems to make sense to take an experimental and explorative approach in designing new musical instruments with correlated perceptual mappings. Such an approach has been explored also by Visi and Tanaka (2020), Dahlstedt (2001) and others. In the current work with the instrument "{*Shape*", we have attempted to combine this approach with a mechanism to optimize the perceptual correlation between gesture and sound by means of feedback from audio analysis of the synthesizer output. Mappings with a higher correlation between trajectories of gestural and audio analysis features are presented to the user for further exploration. A noteworthy difference between

{Shape and many machine learning based mapping approaches is that *{Shape* does not require any user specification of target synthesis parameters. Rather, the system suggests these parameter values based on an analysis of the audio output from the synthesizer, effectively bootstrapping the mapping into existence. Our approach is to learn the mappings without having to specify anything else than a demonstration of a few starting gestures. These mappings are not static, they evolve with the user. This can free up the whole interaction design process by making it an inherent part of playing with the instrument. The cost is the time spent learning and evolving with the instrument itself.

Related work

The system has some functional similarities to the Gesture Variation Follower (GVF) by Caramiaux et al. (2014) in that it allows scaling and time variations to be induced from the performed deviations from learned gestures, and that these variations are used to align the mapping from input to output. Both GVF and our current system can do early recognition, and also respond to expressive deviations from learned gestures. GVF has outputs for scaling, rotation and time deviation. These can be used as transformative vectors in the mapping. *{Shape* achieves this by enabling a more dynamic mapping based on deep learning (LeCun et al., 2015). This is different from GVF, which uses a statistical approach. In our system, the time dimension is implicitly handled by the use of convolutional neural networks, which will be elaborated in the next section.

The mappings from gestural input to sound synthesis parameters are done in an auto-adaptive and generative manner in our system, based on analysis of the gestural qualities in the input. The algorithm attempts to produce an output sound that preserves the gestural qualities of the input without prior knowledge of the synthesis engine. A combination of classification and regression is used, to enable smooth transitions between the different multidimensional mappings learned by the system.

To seamlessly morph between sounds using neural networks has received attention lately, in particular with the WaveNet-based approach by Engel et al. (2017). However, their work was on morphing between instruments by learning from raw waveforms, and not being linked to another modality. The introduction of generative adversarial networks (GANs) by Goodfellow et al. (2014) has also seen applications within the audio domain, namely by creating more sophisticated audio by generating a lot of the audio properties (e.g. log-magnitude spectrograms) through the GAN approach (Engel et al., 2019). This mixture of neural networks and raw audio generation is hampered by computing power, but nevertheless interesting for mimicking real sounds - however, in this work we focus more on the creative applications that arise through synthesis.

The system

The system has separate operational modes for learning and performing. While these modes can be operational simultaneously, we have opted to separate them with manual control of mode switching in this initial implementation of the system. An overview of how the system works is shown in Figure 1, and will be elaborated in the following sections. Source code is available at the author's GitHub[1].

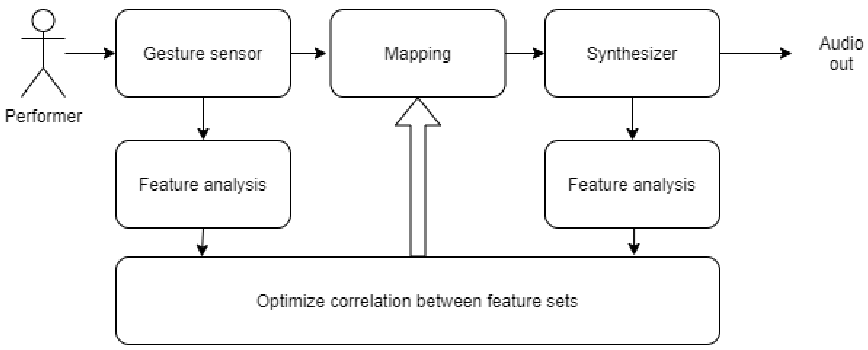

Figure 1: Simplified signal flow of the system

[1] github.com/Oeyvind/shape

Learn mode

The system starts in a "tabula rasa" state, and has to build up a library of movements and their mappings to synthesis parameters. The system is guided in this phase through a simple interaction mechanism with the user. Upon completion of a gesture, the system creates suggestions for parameter mappings that result in sounds that have similarities between the audio and gesture domain. The initialization of the mappings is done by randomly selecting one of the gesture input axes, multiplying it by a random number in the range $[0, 1]$ and then using the resulting vector as a synthesis parameter. This process is repeated for each of the synthesis parameters.

After the calculation of parameters and generation of sounds, the sounds are analyzed and sorted by which sounds are most similar to the gestural input axes. This is achieved by calculating the mean squared error between the different axes of the gesture and the various audio features that are analyzed after the sound has been created. For each gesture input axis, the most similar audio feature contributes to the mapping's overall similarity score. All the generated sounds are sorted based on the similarity score.

The user is subsequently presented the sorted list, and selects a preferred mapping. The system then learns the correlation between gesture input and synthesis parameters by using a neural network. There is a 1:1 relation between the sampling rate of the gesture input and the update frequency of the mapping, while the synthesis parameters are interpolated in between updates. The neural network is also trained to classify the gesture at each time step. Both the regression (i.e. output of synthesis parameters) and classification (of the gesture) are achieved by performing a 1D convolution over all the axes of the input signal with a specified history length. A recurrent neural network could also be used, like a bidirectional LSTM (Hochreiter and Schmidhuber, 1997). However, convolution neural networks are faster to train and more robust to noisy sequences, since they are translation invariant with respect to the input signal.

Play mode

When the system is in play mode, it continuously predicts the synthesis parameters and classifies the gesture. Note that the history length directly specifies the "memory" of the network, and therefore the stability of the predictions. This enables a fluid mapping from gestures into synthesis parameters and finally, sound.

Independence from application environment

The methods and the system proposed in this paper are independent of the type of gesture sensor, and also independent from the choice of synthesizer or sound producing engine. The system adapts to the set of input parameters that it is trained on, and as such can be used with a variety of gesture sensing technologies or other input devices. Similarly, it adapts to the output parameter set available in the specific synthesizer used in training. Due to the fact that optimization takes place by feature analysis of the sound produced by the synthesizer, the specifications and implementation details of the synthesizer becomes irrelevant to the mapping system. There are however two requirements to the synthesizer: it must have parametric control that can shape the resulting timbre, and for practical reasons it must be able to render sound in an offline fashion. Due to the large number of suggested sounds, the process would be very slow with realtime-only sound production devices. When rendering sound offline, this process can be sped up and automated with parallelization such that the learning process can be accomplished as quickly as computing resources permits. Our current implementation uses the Csound audio programming library for synthesis (csound.com, see also Lazzarini et al. (2016)). In addition to the freely programmable synthesis algorithms, it will also allow running off-the-shelf software synthesizers in plugin format so that the mapping system can be explored with the user's favourite audio generators.

Discussion

The system is able to create interpolations between different trajectories in the high-dimensional space represented by the neural network that embeds the gestures. This enables the system to suggest novel parameter mappings to the user when presented with novel gestures. These will sensibly combine with previously learned gestures and their corresponding synthesis parameters, and it is capable to do so because a deep learning model is used to learn this concept. Interpolations between combinations are most likely not linear, further suggesting the need to have a computationally powerful model that deep learning neural networks provide.

The synthesis parameter controlling perceived pitch is of special relevance in a musical instrument. In the cases where a clear pitch can be perceived, this will often take precedence over other timbral variations. This might mean that synthesis parameters affecting the perceived pitch might need to be given special consideration in generated mappings. In the current implementation, we have opted to make a manual switch to activate or de-activate mapping to these parameters.

The generative aspect of the work contributes to the field of computational creativity. It starts out in a random fashion, without any a priori knowledge of what the user likes. A continuing challenge is to enable a process of gradual development of a mutual vocabulary between the system and the user.

Future work

Since this paper presents a first version of the system, the operating modes are explicitly set by the user. However, a future goal is to make the system automatically select between play or learn modes. This can be achieved by a system that continuously predicts gestures, and is able to to discern when a new gesture is encountered. For instance, this can be achieved by using a deviance tolerance. The deviation tolerance can be set as a numeric value, or we can allow the system to use an adaptive strategy based on distance between the gestures already learned. The deviation tolerance can also be measured by the amount of prediction errors done by the already trained neural network. A combination of these might also be used, where the user also sets an absolute minimum deviation needed. This could help prevent the system from entering learn mode when a large number of gestures have been learned and their representations might start to overlap.

Another idea worth exploring is the evaluation of the suitability of generated mappings. Currently, this is done by the user through an interface. However, the system would operate more seamlessly if this process could be performed by another neural network, which has the role of learning the aesthetic preferences of the user. This neural network can then be trained alongside the selection of generated sounds, and the system learns predictions of what the user likes and dislikes. This could evolve into a crude form of aesthetic artificial intelligence.

A natural immediate prospect will be the exploration of a variety of input devices and different audio synthesis models. The use of a selection of off-the-shelf and well known synthesizers could be enlightening in comparing this mapping approach with other alternatives.

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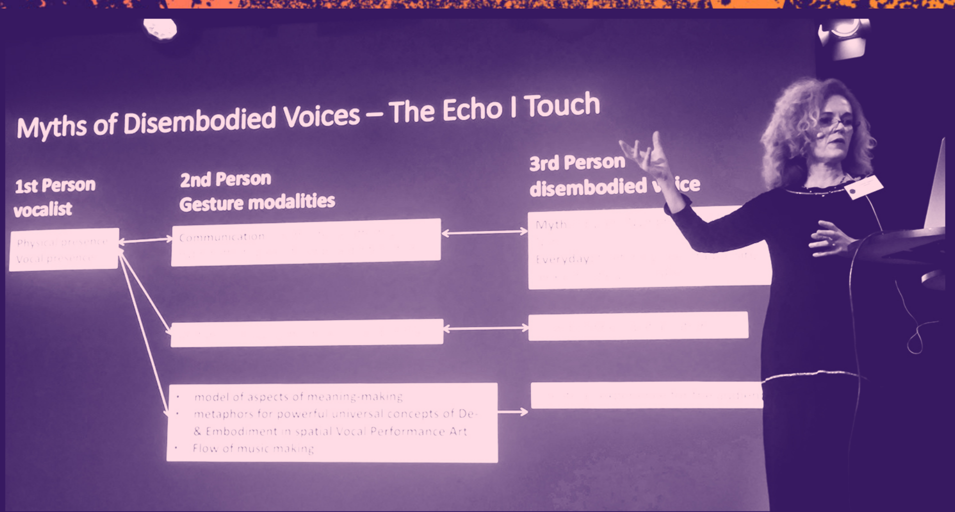
Franziska Baumann

"The Echo I Touch" De- & Embodiment
in spatial Vocal Performance Art

Colloquial Paper

Video of presentation can be found here



The Echo I Touch

De- & Embodiment in spatial Vocal Performance Art

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"The disembodied voice speaks to me, sings to me, enchants me, screams for my attention as if it is asking: listen to me, hear me, feel me! Don't be 'afraid of vocal experimentation! Come and sing with me! Touch the riddle of my body! Feel the skin of my resonance! Dance with me in the space! Throw me in the air and catch me again! Together we will be in the momentary of voice, body and space. I welcome that invitation, as much as I can.

Abstract

When using technology such as gesture-controlled live electronics, an expanded field of vocal art performance opens up with the potential to reveal a multitude of vocal extensions and compositional strategies that question the relationship between body, gesture and sound as we know it. The boundaries between the human voice, on the one hand, and the computationally manipulated, bodily and in real-time controlled, but yet disembodied voice, on the other, become increasingly blurred.[1] Through this practice a hybrid in the aesthetic emerges. Motion sequences, which are visible, can add an additional meaning to the sound creation. The gestural communication can serve the understanding, but can also contrast it, put it in a different light or even create a false conclusion (Trugschluss).

Most of performers use interfaces as controllers in the sense that it is supporting the music they want to do. My view is that we need to deepen the question of body presence of the vocalist and to ask about gesture composition and the meaning making of its mapping strategies. The possibility to compose with a mapping machine individual gestures connected to sound processes is a major enabler of creativity.

Tailor made interactions open up a hybrid field in the aesthetic perception. Motion sequences, which are visible, allow for an intuitive approach to the understanding of the energy control which deals with sound creation. Questions occur on the mediation between the presence of being a singer and on the other hand gesturally controlled dis-embodied voices (acousmatic voices).

Approach

From the perspective of a vocalist, composer/performer my main research objective in this hybrid field would be the question of how to integrate body and gestures using all sorts of sensor interfaces and inherent mapping strategies in a more efficient and creative way. Thus in the search for new compositional and performative strategies in spatialized vocal processes of embodied and disembodied voice.

My approach looks for implementation of models to define characters for gesture composition. Instead of starting from the musical gesture and its functional way of controlling I would like to begin to analyze and categorize the body presence and gestures of singers using interfaces in spatialized musical environments. Therefore I am looking for models and a vocabulary which allows composers and singers to expand compositional strategies for performing gestural live electronic vocal performance.

In a further step, this conceptual framework is also intended to provide a basis for gesture compositions in the field of gestural vocal live performance and machine learning based mapping strategies.[2]

Keywords:

Contemporary Vocal Art Practices, Performing Gestural Live Electronic Music, Interactive Staged Music Performance and Movement, Composing with 3D Ambisonic, Acousmatic and Disembodied Voice, Custom Musical Instrument (DIY), Digital Musical Instrument (DMI), Extended Vocal Techniques, STEIM, Sampling Practices for Vocal and Musical Improvisation, Improvisation and Real-Time Composition, Digital Score, Vocal Personas, Vocal Sound Dance, Imaginary Vocal Body, Aesthetic of Uncertainity and In-Between, SensorGlove as Instrument and Body Extension

[1] Compare Franziska Baumann: *Interfaces in der Live Performance*, in Harenberg/Weissberg: Klang (ohne) Körper, p.75: "Die Grenze zwischen natürlicher und elektronischer Klangerzeugung verschwimmt. Der Körper kann nicht mehr alleiniges 'Interface für die Lesbarkeit der Musik sein" [The boundary between naturally and electronically generated sound becomes blurred. The body cannot be the sole 'interface for interpreting music' anymore.]

[2] This project is part of a four year research application: *Anticipation of Musical Gesture in the Framework of Generative and Immersive Multimedia Spaces*. With Prof.Dr. Teresa Carrasco, Cathy van Eck , Cédric Spindler and Benoit Piccand, Bern 2021.

Brief history of the SensorGlove

As a singer, composer, improvisor my special focus lies on the application of gesture-controlled live electronics, namely the SensorGlove, the first version of which I built in collaboration with Frank Baldé and Jorgen Brinkman 2001 at STEIM, Studio for electro-instrumental music, Amsterdam. Their philosophy of body-close electronic instruments corresponded to my idea of combining electro acoustic composition & live processing with vocal performance on stage without being tied to a mixing console and faders. As I experience gestures as musical extension of the voice, I opted for an interface with sensors, built into a glove.

Figure 1. STEIM's SensorGlove & Belt
Krakau AudioArt Festival 2005

Since with the years the possible amount of processed data could be realized on smaller and smaller chips, it was possible to realize the former SensorLab application on one small Arduino chip. In 2016 the live electronic equipment has been completely new built from the bottom by Berne based Electro engineer Andreas Litmanowitsch and Arduino Programmer Stephan Rothe. If I had to wear additional to STEIM's SensorLab Glove a belt with several boxes, it has become possible to fix sensors and all electronic parts in the SensorGlove itself. This allows me to switch more flexibly between myself as an acoustic singer and a singer with live electronics.

Figure 2. SmartGlove Torun- PL, 2017

Another advantage of the new application is that with the new equipment I independently can compose gestures variabilities coupled to the sound process. With the old SensorLab software C++ every small change of compositional ideas between gesture and sound I had to let reprogram by programmer Daniel Repond. The STEIM's software JunXion endows me with great flexibility and playfulness regarding compositional ideas of gesture and related sound control and creation as I can compose the mapping of gestures and connected sound process myself. Nevertheless, even if it is possible to technically implement every idea we imagine, the respective surfaces of software guide our creative thoughts and form part of the respective "digital score"[3].

[3] Craig Vear describes "The Digital Score" as a paradigma shift from a place of documentation to a space for creativity.

Sensor Interface in Vocal Performance Art

A Hybrid in the Aesthetic Perception

Digital instruments and their respective interfaces are, with regard to gesture and sound, to a certain extend *Black Boxes* as the connection between gesture and sound is random and can be arranged freely. In the case of interface applications which permit gestural control, they force the performer to consciously opt for an artistic decision concerning relationship between gestures, sound production and control. Whether a poker-faced musician with a laptop generates high-energy music or a performer stages an imaginary sound ballet by using sensors: the connection between gesture and sound no longer reveals itself to the audience through the 'surface'.

Over the course of centuries, we have become used to a certain kinds of relationships between sound, the instrument and what we see in a concert. On a violin, the pressure and speed of the bow plays a major role in regulating the volume. The interpreter's images of movement and gestures, which are linked to the instrument have been established. In the process, the body itself has become the interface to the 'interpretability' of the music.

Sensors and their respective expressiveness

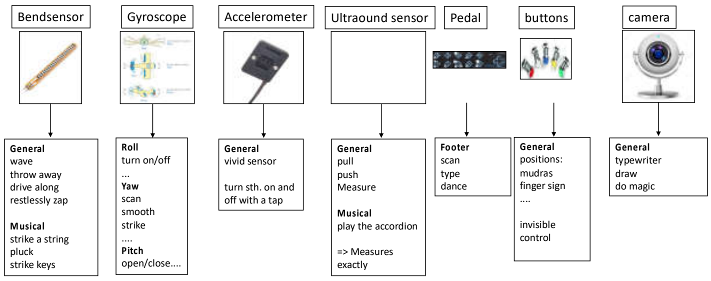

Figure 3. Sensors and their respective expressiveness

To a certain extend the specific characteristics of sensors and their respective expressiveness ask for certain gestures. For example with an accelerator it may be difficult to initiate precise controlling over a continuous linear parametrization. As this sensor measures acceleration it is better suited to hit something on or switch off with a gesture whereas for example with an ultra sound sensor one can measure something precisely within a linear distance. This interplay of "necessary movements" and communication of ideas through music and gestures opens up various artistic perspectives on body sculptures in movement and sound. [4]

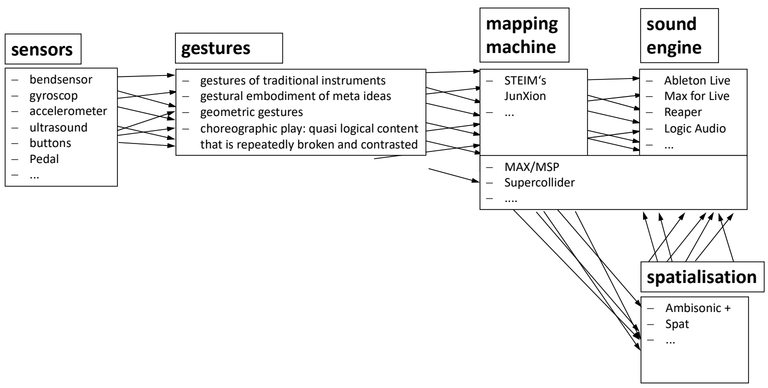

Figure 4. Model for gestures and mapping

[4] The term *body sculputures defines choreographic, instrumental, geometrical and meta ideas of gestures

Sensor Interface as an Instrument, Object or Medial Body Extension

Figure 5. SensorGlove as a prop

The SensorGlove interface itself creates an aura that creates certain expectations. The visual appearance creates affordances of inherent purpose, expected function and intention of the object itself like any sensor Interface whether it is a MIO wristband, video or motion tracking, standalone sensor objects etc.

Depending on the characters of gestures and related sound processes during a performance the SensorGlove Interface oscillates between instrument and body extension. As an object with its visual appearance it may refer instrumental character or a medial extension of the body. When I use instrumental gestures such as stroking, plucking, beating, the instrumental character comes to the fore. When the imaginary of voices in space and my physicality meet in gestural communication, the SensorGlove is rather an extension of the body.

The SensorGlove is an interface that I have to practice to articulate preconscious musical intentions, in the field of creative intention, acquired praxis, instinct, intuition and the magic of the moment. Technical processes have to be transferred to body-consciousness and I have to know all possible technical traps and mistakes in order not to fall out of the creative flow of making music during a performance.

Voice as a Special Case

The voice is in musical sense a special case as it provides us our most physical instrument without an external interface, while instruments are always used as a medial extension of the body. The breath in the function of the exciter is mediating between internal and external space of the human body. The interior of the body acts as resonance space, which is projected into the external space.

Disembodied Voice – Dance with the Unchained Voice

The acousmatic and spatialized voice opens up a more radical vocality than that of the acoustic voice alone. The voice decoupled from the body, from the person, could be seen as a new imaginary persona. The performer lends his or her body to the voices released into space. Theses voices are not only a sound emission of the performer's body, this disembodied voices may produce an imaginary body, a vocal double: bodyless voices in the room invite the listener to conjure up various imaginary bodies. These imaginary bodies can act as invocations brought to life by certain attitudes, gestures, facial expressions, hand, arm, and shoulder movements, as well as by the acoustic gestures that go beyond body images and visible attitudes. It is a virtual experience in which the vocal bodies created, respectively the echo of my own voice can be touched in space. The interactive technology, the interfaces, serve, among other things, to leave voiced fingerprints, or to express several acoustic personalities and manipulate them vis à versa.

In this sense I would like to claim that in interactive interface performance a combination of third person perspective (the imaginary vocal sounding body of the disembodied voices) and first person perspective (singer) is fundamental to reveal the position between body and sound.

The second person perspective would then be the relationship between the singer's body and the vocal body that is created in virtual space. This is done by composing gestures which locate body and gesture movement in the environment, so that I understand the vocal sound objects and their movements in space quasi physically as the action of a counterpart. This I - You relationship can provide a framework for the gesture as a communicative act or act of social interaction, entertainment and intentionality.

Myths of Disembodied Voice

In the myths we know disembodied voices such as those of Sybillen, Sphinx, Narcissus and Echo[5]. Imaginary bodies can act as invocations brought to life by certain attitudes, gestures, facial expressions, hand, arm, and shoulder movements, as well as by the acoustic gestures that go beyond body images and visible attitudes. The nature of these vocal sound bodies, however, depends on the reception of the viewer, or listener.

As a singer I quasi lend my body to the voices released into space. The interactive technology - the interfaces - serve, among other things, to leave voiced fingerprints, or to express several acoustic personalities and manipulate them reciprocal. Therefore disembodied vocal bodies remind us that the imaginary, the phantasy, is not only the result of a spiritual disorganized attitude, but always also an embodiment of it.

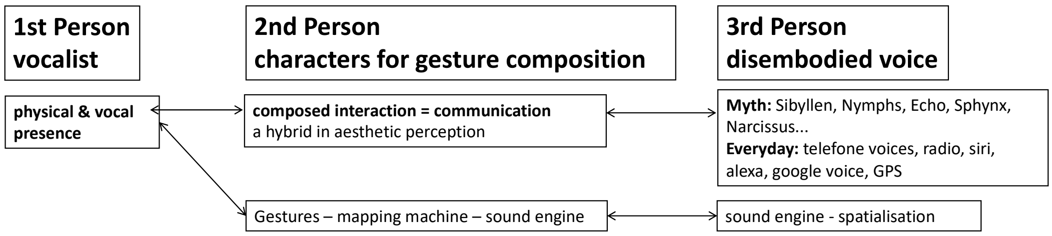

Figure 6. communication scheme for embodied and disembodied voice

Methods and expected Contributions

Case studies

Based on my earlier research of gesture qualities from instrumental, geometric, choreographic gestures and meta ideas I will hypothesize types of modalities of gesture composition for sensor live electronic interfaces. In case studies with a group of selected internationally known vocal artists using sensor interfaces I wish to analyze and categorize their body presence and gestures. According to the following points I will explore how various conceptions of live interface use might change meaning-making.

1) Artistic and Substantive Input of the Vocalist
2) The Body Presence of the Vocalist
3) Economy of the Interface Practice, Visual Surface and Technical Means
4) Gesture Vocabulary, Universally Recognisable Key- Gestures
5) Classify gestures of meaning making
6) Characteristics of Disembodied Voices & Sounds

Establishing Gesture Based Performance System

Practically I wish to get an overview of utilized commercially available sensor controllers like the HotHand, Wave Ring, MIO Sensor Armband, Apps for I-Phones, tablets etc.
In collaboration with our research group I will design a basic interface with gestural sensor controllers which can be mapped into clear and simple actions, and determining the number of parameters that can be held in mind without visual feedback. This interface system shall contribute with staged/theatrical context and with the need for mobility.

[5] Weigel Sigrid: *Die Stimme als Medium des Nachlebens,* S.28 in Kolesch, Doris und Krämer, Sybille 2006. *Stimme*. Frankfurt am Main: Suhrkamp

Practical Evaluation and Project Output with Vocal Ensemble

With this experimental setup I wish to work with a group of vocalists and observe how they interact with various controllers, and experiment with varying levels of gestural control of parameters, also with machine learning coding. With the development of such a modular basic sensor interface I wish to define new ways for gesture composition to bridge the gap between aesthetic and technology and how can they convey meaning in a new imaginary way apart from or as a combination of instrumental, gestural, geometric and meta- idea gestures.

In regard to embodied and disembodied voices I will design three steps of possibilities where the acoustic and the disembodied processed vocal signal as two separate instrument converging in one space. First I will evaluate and develop performative gestures based on heard sound gestures in 3-dimensional space and research how sound may invite gesture. Then I will design mapping strategies for the gesture options and third I will combine both and explore the communicative aspects in between 1st and 3rd person.

My overarching goal for this research project is to expand vocabulary and practical possibilities for gestural sensor live electronic interfaces in spatial vocal performance art.
I wish to design models of aspects of meaning-making for mapping strategies and compositional and performative strategies for powerful universal concepts of de- & embodiment in spatial vocal performance art.

Performances during the research project are documented. One public project a year and two symposiums will take place during the four year period. An exchange and cooperation with selected international partners is intended.

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Research Papers & Links

Trondheim ICLI 2020 All Papers on:
https://live-interfaces.github.io/liveinterfaces2020/program/

Baalman, Marije (2020) *Mapping the question of mapping*
Brandtsegg, Øyvind (2020) *An interface to an Interface to an Interface*
Brandtsegg, Øyvind and Tidemann, Axel (2020) Shape, *An adaptive musical interface that optimize the correlation between gesture and sound*
Guérin-Garnett, Nigel, (2020) Machines in the Creative Process, *Limitations Through Choreography*
Moore, Thomas R. Hybrid Conductor (2020) *Case Study and Analysis of Alexander Schubert's Point Ones*
Norderval, Kristin Electrifying Opera (2020) *Amplifying agency for opera singers improvising with interactive audio technology*
Visi , Federico Ghelli and Tanaka, Atau (2020) *Towards Assisted Interactive Machine Learning: Exploring Gesture-Sound Mappings Using Reinforcement Learning*

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Carrasco, Teresa, artist website: http://www.teresacarrasco.net/assets/player/KeynoteDHTMLPlayer.html#0
Fiebrink, Rebecca, Wekinator open source software: http://www.wekinator.org/
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Nowitz, Alex artist website: https://nowitz.de/
Norderval, Kristin, artist website: http://kristinnorderval.org/
Pamela Z, artist website: http://www.pamelaz.com/
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Kristin Norderval

Electrifying Opera: Amplifying agency for opera singers improvising with interactive audio technology

Colloquial Paper

Video of presentation can be found here

Electrifying Opera: Amplifying agency for opera singers improvising with interactive audio technology

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Abstract

This research project examines the technical, physical and pedagogical challenges that opera singers face in relation to the use of interactive audio processing technology in opera. It investigates acoustic and aesthetic conflicts between opera and electroacoustic music, explores reasons why opera singers have been slower than classically trained instrumentalists to embrace new technologies, and asks what types of sound design and interactive systems might reduce some of the barriers opera singers encounter in relation to the innovations of the digital revolution. The primary question driving this research is the following: What technical and aesthetic issues need to be addressed so that opera singers can incorporate the use of audio processing technology and improvisation in their performance practice?

Keywords: Opera, Sound design, Audio processing, Embodiment, Live interfaces, Sensors, Augmented instruments

Introduction

In October 2019 I began a PhD in Artistic Research at the Oslo National Academy of Art in the Opera department. My topic of research - Electrifying Opera: Amplifying agency for opera singers improvising with interactive audio technology - focuses on ways to incorporate audio processing into opera while maintaining the primacy of the acoustic voice and the agency of the performer. As a composer and classically trained singer, I have created numerous concert works that utilize live sampling and real-time audio processing. My attempt to create similar work for opera revealed challenges specific to the genre as well as some inherent conflicts between opera and electroacoustic music that need to be addressed.

Operatic technique focuses on developing a virtuosic voice of extended pitch and dynamic range able to project in large spaces without amplification. Opera singers are in effect playing to and with the acoustics of the space. Electroacoustic music on the other hand is dependent on amplification through loudspeakers, and with contemporary sound design one has the ability to digitally simulate different types of acoustics independent of the physical space. The design of traditional opera houses, which optimizes the un-amplified voice, presents acoustic and structural challenges for live electronic processing in opera. Additionally, the orchestral pit inhibits both sight lines and audibility between the orchestra and the singers and sets up a divided acoustic space. When electronic sound is used in traditional opera houses it can create a strange aural disconnect if the electronic sound is coming from mounted speakers that don't blend well with either the orchestra or the singers. The role of the singer as actor and the need for mobility in the space further complicates the creation of work that utilizes performer controlled live audio processing.

Purpose of the research

Nina Sun Eidsheim (2015) theorizes an expanded unpacking of what music consists of, where aural, tactile, spatial, physical, material, and vibrational sensations are all important elements. Regarding opera, Eidsheim writes that "... the unamplified power of the singers´ voices is part of the fetish that defines the artform."[1] Composer Hildegard Westerkamp asserted in a keynote speech at Invisible Places 2017: "sound experienced, produced and received as a physical process can be an effective counterbalance to attempts by commerce and technology to transform it into product and commodity." She elaborated further "One´s own sound output or creative expression not only lessens the authority of externally imposed voices but also offers a new voice of vitality and energy."[2] This foregrounding of vibration and physical process by both Westerkamp and Eidsheim highlights the fact that sound always occurs as an action and vibration within a specific acoustic setting, and that these actions and vibrations *do* something to both the sound-maker and the listener.

In opera the unique "something" - the *doing* that defines it - is the direct, unmitigated transmission of sonic vibrations from the singer´s body to the listeners´ ears. Operatic singing is both intimate and athletic, vulnerable and awe-inspiring, and somewhat magic. Unlike instrumentalists, who can be seen engaging in sound producing actions with their instruments, with singers only their sound supporting actions (movements for breath and articulation) are visible to the audience. The singer´s actual sound producing actions (air vibrating the vocal folds) are invisible. With the addition of language the singer embodies a role of both musician and actor. As a result (and in part because the singer´s sound producing actions are invisible) the singer´s body and hands have heightened semantic value; movements and actions are perceived in a theatrical context. In opera the singer´s movements and spatial location are also significant compositional and theatrical elements of the performance. All this complicates the question of controllers.

Many vocalist-composers, like myself, have been working with interactive technology and custom built controllers to expand the options for vocal expression. Both Franziska Baumann and Imogen Heap have designed sophisticated custom-built midi gloves and wearable controllers using a variety of sensors.[3] Pamela Z has developed multiple controllers, from those measuring electromagnetic signals of muscle contractions, to motion capture, to her most recent system incorporating sonogram technology.[4] Dafna Naphtali has designed an interactive system for controlling a GuitarBot and robotic percussion instruments using a hand held Wii controller.[5] Anne Hege has used a tether controller to process audio using the Wekinator interface. Although these vocalist-composers use their controllers to trigger sound processing in real time via gesture, they maintain a largely stationary position near the computer that is running the audio processing programs. This is partly a function of the type of controllers, but also, and perhaps primarily, a function of dependence on a visual interface to monitor the live audio processing. In concert settings this is unproblematic, but in opera, the dramatic implications of scenography, movements, gestures and costume must all be taken into account. Standing behind a computer and processing audio may be neutral in concert, not so in opera.

If the voice is to be used as a sound source in live interactive audio processing and real-time sampling, it necessitates capturing the vocal input with a microphone. Common practice for most vocalists currently using live electronics has been to amplify the voice simultaneously and mix the amplified voice with the electronic sound, matching the vocal volume level to the volume of the electronic signal – a similar principle of sound design as in rock, hip-hop and pop music. In opera, however, this design robs both performers and the operagoer of one of the primary characteristics and thrill of this genre: experiencing the power and beauty (or fetish) of an embodied unamplified voice resonating an acoustic space. Amplification also adds other potential problems to opera: loss of spatialization, loss of full dynamic range, and distortion of vocal timbre, especially in the higher ranges. The extreme dynamic and register range of the operatic voice presents challenges.

In this research project I am exploring strategies to deal with the issues outlined above. My goal is to design an electroacoustic interactive system for a new opera I am composing that will foreground and accommodate the unamplified virtuosic voice of the operatic singing-actor. The challenge remains to design an interactive system that can accommodate mobility in a dramatic performance, and where the choice making of the performer can be based on aural rather than visual cues.

Methods

Working together with computer engineers, a research assistant and opera singers recruited to be part of a voluntary Participatory Design Group (PDG), various configurations of real-time interactive processing and sound design systems are being tested to address the following questions:

> 1. How can we create a performer driven interactive audio system for opera singers that addresses their needs for physical mobility, dramatic coherence, and performance in an acoustic environment suitable for the unamplified virtuosic voice?
>
> 2. What kind of interactive systems, controllers and mappings might best enable opera singers to enact performer driven control of audio processing, and can we discover best practices through participatory design?
>
> 3. Since the ability to improvise is integral to the use of interactive systems, what types of training should be developed to re-introduce the practice of vocal improvisation to the field?

Based on initial research of existing systems, I am exploring what might be most suitable for controllers designed for opera singers, keeping in mind acoustic and mobility needs. I wish to design a system that can accommodate common embodied performer motions: hand gestures, the motions of handling a prop, playing an accompanying instrument, or engaging with a costume or piece of the set. I have begun to evaluate controllers and mapping options by testing them first myself as a performer, and subsequently with members of the Participatory Design Group. The Wekinator, an open source machine learning software created by Dr Rebecca Fiebrink,[6] is one of the machine learning options I am investigating. The Wekinator seems well matched to the aims and design processes for this research as it allows for rapid prototyping and exploration of mapping options through human-machine interaction, using the computer as a partner. It allows anyone to use machine learning to build new interactive systems by demonstrating human actions and computer responses, instead of writing programming code. It does not require extensive programming skills, but rather enables performers to create mapping through embodied interaction.

Electrifying Opera is a transdisciplinary research project. It spans the fields of operatic performance practice, interactive computer music and composition, sound design, machine learning and the emergent field of active acoustics. It also intersects with costume design and scenography. As a composer and a singer I am drawing on multiple modalities to investigate and develop innovative possibilities for opera singers to augment their voices with performer controlled interactive audio technology. Methods used include workshops in vocal improvisation, participatory design of data mapping, machine learning, prototyping, sound design, signal processing and musical composition. Documentation will include written logs, video and audio documentation. The final artistic application and outcome of this research will be to incorporate my custom designed interactive system into a newly composed chamber opera. A collaboration with librettist/designer Julian Crouch and the Ethos Percussion Group (both based in New York City) forms the basis of the external creative team for this newly composed opera, working title: *The Sailmaker´s Wife*.[7]

Description of the proposed approach

In this research I am exploring how various conceptions of sound design and real-time interactive processing systems can address some of the inherent tensions between opera and electroacoustic music. In regards to sound design, it is possible to capture vocal input without simultaneously amplifying the voice, by sending the vocal signal to the DAW pre-fader for audio processing, and then only amplifying the processed sound. One can thus combine both the embodied unamplified voice and the disembodied processed vocal signal as two separate instruments converging in one space, utilizing the room itself as a common resonator. Starting from the aesthetic point of view that electronic sound in opera should accommodate the acoustic singer rather than the other way around, I am investigating various strategies for the diffusion of electronic sound that would facilitate this, including localized loudspeakers, loud speakers embedded in scenography or costumes, active augmented instruments, and non-standard multi-loudspeaker diffusion systems (NSML systems). Although NSML systems are expensive and probably will not be directly applicable to my final artistic project, the concepts in the sound design offer many new possibilities for the combination of acoustic and electronic sound production.[8]

Localized loudspeakers parallel the way bass and electric guitar personal amps function in an acoustic jazz ensemble. David Lang did this in his recent "*Three Mile Opera*" where singers performed on a 3-mile stretch of an elevated former train line and were paired with their own individual loudspeakers. In her opera "Agora", Natasha Barrett used live electronics to turn an installation of membranes and aluminium bars into computer controlled mechanical acoustic instruments that mixed with electronic sound from multiple speakers. Long-term collaborators, singer Julie Wilson-Bokowiec and composer Mark Bokowiec have produced works where the performer, outfitted with multiple sensors and controllers, is placed within a "sensitized" performance space, a surround sound system of multiple speakers. Tod Machover has designed Hyperinstruments and sound producing controllers that invite the public to participate in collaborative music making in his operas. And composer-vocalist Pauchi Sasaki has designed a speaker dress[9] – a costume built of multiple small speakers that allows for mobility and localizes all the electronic sounds to her body. I have previously used both localized speakers (custom-built hemispherical speakers) and active augmented instruments in my work. In my opera *The Trials of Patricia Isasa* I used an upright piano with transducers mounted on the soundboard, as a loudspeaker. All the electronic sounds were played through this acoustically active augmented piano, allowing the electronic sounds to be localized in the pit with the rest of the orchestra and blend acoustically. I will continue the exploration of acoustically active augmented instruments to project sound. The exploration of the sound design, like the exploration of controllers, will include singers from the Participatory Design Group. A number of workshops are planned to test out excerpts from *The Sailmaker´s Wife* using these strategies.

Designing an interactive system that can be controlled “blind” necessitates determining both what types of audio processing can be mapped to clear and simple actions, and determining the number of parameters that can be held in mind without visual reminders. Investigating the types of choice making and audio processing that instrumentalists commonly trigger with controllers that facilitate signal processing without a visual interface (like pedal boards), I am testing possibilities for similar choice making with controllers that allow for mobility in the space. Working with singers from the Participatory Design Group I observe how they interact with various controllers, and how they respond to various types of audio processing parameters. Controllers that have been tested to date are the Leap Motion Controller, a smart phone, the HotHand ring, and most recently - following the recommendation of Tone Åse who performed with it at the ICLI 2020 conference - Genki´s Wave ring.

Expected Contributions

This research contributes to the development of emerging technologies in opera, to the development of the improvisational performance skills needed to engage with those technologies, and to the development of innovations in interactive sound design conducive to opera. Based on conversations with other opera composers and with opera singers, I believe there will be significant interest in this research.

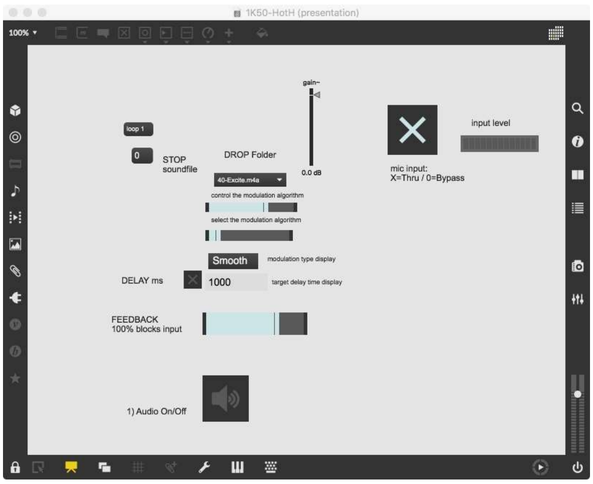
Looking at some of the technical and aesthetic issues that need to be addressed so that opera singers can incorporate the use of audio processing technology in their performance, I expect to address three things in particular that I think will contribute significantly to the field: 1. Determining what types of controllers can address both the theatrical context and the need for mobility. 2. Designing an interactive system that is not dependent on a visual interface. 3. Designing a sound diffusion system that can accommodate both the acoustic unamplified voice and processed electronic sounds. Of these three, I expect that the second may be the most challenging. It may also yield some unexpected pedagogical insights.

Progress towards goals

My research is in its initial phase. I have been corresponding with composer and performer colleagues, reviewing relevant documents and conducting an overview of interactive systems and controllers currently in use by composers working with live audio processing. I conducted initial experiments with an acoustically active augmented instrument – an antique taffelpiano – experimenting with it as both a loud speaker (with transducers) and as an augmented resonator (with contact microphones) that could be used in combination with the unamplified voice and processed audio created through real-time sampling and processing of the voice. I will continue to experiment with augmented instruments of different sizes (zithers, guitars, found objects) as alternative loudspeaker options.

The main focus in this part of my research has been on interactive patch design and controller mapping. I have designed several prototypes for interactive patches in Max and have been testing their suitability for remote control without reliance on a visual interface. With help from my research assistant Bálint Laczkó, various controllers have been mapped to these patches. We have experimented with the Leap Motion controller, smart phones, and a wearable sensor: the HotHand ring, which relays data from a 3-axis accelerometer. The range of motion that the Leap Motion controller is able to detect was too limited to enable mobility. Using a smart phone gave stable data but was awkward physically. For the presentation of this Colloquial paper at the ICLI conference in Trondheim, March 11, 2020, I settled on the HotHand ring, mapped to control 4 basic functions within a real-time vocal sampling and audio processing patch in Max. The four parameters were audio on/off, delay speed in milliseconds, feedback level, & signal bypass. My goal for the ICLI conference presentation was to get the mapping and gesture control stable enough to do a short vocal performance that included live sampling and audio processing while moving in the space, and without relying on the visual interface of the laptop. Two workshop sessions with one of the opera singers in the PDG confirmed that with the mapping we had programmed, control of these four parameters could be fairly easily learned and reproduced with the HotHand ring.

The patch I used for the ICLI presentation required some set-up in advance. It allowed for processing of soundfiles as well as the live signal, but the sound files need to be loaded and preset to a loop function if that option was to be accessed. The recording function for the live signal also needed to be set, as well as the type of modulating algorithm, and the degree of modulation. The modulation algorithms - designed by David Gamper years ago for an earlier interactive patch of mine - determined the amount and type of pitch shifting according to the interplay of delay time and feedback level. With higher feedback levels the sampled material continues to be modulated with successive pitch shifts. Shifts in pitch up or down (moving from one delay time to another) begin with a default octave shift. The buffer length is variable. Once the patch was preset for recording, modulation algorithms and sound file loop (if desired), the remaining four parameters could be controlled “blind” with the HotHand ring.



Screen shot of the Max patch used (presentation mode) for the ICLI 2020 presentation

The HotHand uses a 3-axis gravity sensor, providing three data streams. From these we could reliably derive 2-axis orientation (pitch and roll), however the unreliability of the third orientation axis (yaw) made it difficult to implement higher-level solutions for recognizing specific and repeatable hand postures. While experimenting with such implementation we experienced too many cases of unexpected alignment of the gravity values of two or more different hand postures. We mapped pitch (wrist flex up/down) to the feedback level, and programmed roll (palm up/palm down) as a start/stop switch for the Tap tempo that determined delay length. At 100% feedback the Max patch would block signal input, so that gave us 3 parameters: delay time, feedback amount, and signal bypass. Through experimenting with a variety of gestures we were able to map specific hand positions that could be recognized from the combined data from the 3-axis accelerometer to Audio on/off. Even though the yaw was unstable, we found this work-around usable. Having access to a fourth parameter of Audio on/off significantly improved the musical expressivity in improvising with this patch. We also programmed the patch so that if the hand was held in the Audio off position for a specific (predetermined) length of time it would not be possible to trigger Audio on again from the HotHand. This allows the performer to control the end of the piece. For the ICLI demo performance the length of time chosen was set to 10 seconds.

It was important for me to highlight in the ICLI performance the aesthetic and technical issues that I am investigating with this research: the importance of presence and embodiment, the tensions inherent in blending acoustic and amplified/electronic signals, and the issues around performer agency and control of audio processing with a non-visual interface. Although I sampled my voice in real-time, I did not amplify my voice. Since the space was quite dry, I arranged with the technicians that they would raise the heavy damper curtains in front of the windows as I began the performance. That improved the acoustics for my un-amplified voice. I started the performance at one of the windows and used the sound of the motor raising the curtain as a sound source to improvise with acoustically.

View of the hall with the damper curtains raised.

Performing next to a window in the middle of the hall.

A number of participants at ICLI commented that the blend of my acoustic un-amplified voice with the electronic signals gave an intimacy to the expression, and that my movements in the space highlighted the acoustic properties of the space and the emotional/dramaturgical effects of performer position in relation to the audience. I got confirmation that the audience members understood that I was processing my acoustic vocal signal in real-time and that my gestures were mapped to audio processing functions that I had control of and could repeat. Many commented on the contrast between the mobility of my acoustic voice and the stationary stereo position of the processed signals. As this research progresses I will investigate possibilities for performer control of spatialization of the processed audio signal.

Going forward I am incorporating participant feedback and lessons learned from the presentation. I am currently testing a new version of the Max patch with Genki´s Wave ring. From initial tests it is clear that the Wave ring is more promising. It has a stable 3-axis orientation (yaw, pitch, roll) and three clickable buttons, including a dedicated Audio on/off switch and two programmable buttons that make it possible to control parameters that needed to be preset with the HotHand (record on/off, choice of algorithm modulation). Additionally the software that comes with the Wave ring provides for machine learning and custom adaptation of gestures. All this is welcome news since HotHand has discontinued its development of its wireless MIDI ring and is focusing now solely on their voltage control ring.

An interesting footnote: When I reviewed the video of the livestream from the ICLI 2020 conference, I discovered that not only did my presentation highlight the tensions between the differing needs of acoustic and electronic sound, but those tensions also manifested in the video documentation. Due to a technical error, the acoustic sound in the room was missing from the video recording and only the electronic parts can be heard. For my performance, the interplay between the acoustic and electronic components was integral to the aesthetic of the work, but I had neglected in my technical rider to think about my documentation needs, and I had not specified that I would need a room mic to document the acoustic sound in the room. The version presented in the recording thus deviates significantly from the actual performance presented at the ICLI conference. In dialogue with the conference organizers, it was decided to publish the recording anyway, as they felt the presentation as a whole contributes significant value to the field, and the recording of the performance is an integral part of it. It was a good reminder that the working practices that are assumed in opera and in electronic music circles are different, and those assumptions need to be taken into account if one wishes to combine the two.

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[7] Based on a Japanese folktale, *The Sailmaker's Wife* is the story of a man's kindness to an injured crane who returns to him in the form of a woman and becomes his wife. She brings him a magical secret gift, at the expense of her wellbeing. The gift is requested one time too often, and her secret is ultimately betrayed. When her true identity is revealed the Crane-wife flies away. Since this opera deals with magical transformation, it is an ideal candidate for the magic of audio processing, unusual controllers, and the integration of wearable sensors and controllers into the costumes and/or scenography.

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