

**4th International Conference
on Live Interfaces**

Inspiration, Performance, Emancipation

IICLI
PORTO
2018

ICLI 2018
4th International Conference
on Live Interfaces
Inspiration, Performance, Emancipation

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Edited by

José Alberto Gomes
Miguel Carvalhais
Rui Penha

Design

Michelle Martins

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Foreword

Every creative process starts from a given seminal idea, lying somewhere between abstract thinking and engagement with material objects: let's call it the inspiration. The moment when ideas flow into and out of place, slowly building to become a cohesive whole. What are the problems we deal with in the early prototyping of interfaces for live performance? What technologies do we use and how do we choose them? How do these technologies inform and catalyse the creative process? How do we unlock their unique expressive potential?

Inevitably, the time for the highly anticipated first performance arrives. What strategies do we use to combine the live interfaces within the performance? How do we cope with the technical difficulties of integrating various technologies? What is the unique aesthetic potential of each of these technologies? How do they transfigure the performance reception from the audience's perspective?

Eventually, each live interface has to find its own path towards an emancipation from its first performative use. How do we repurpose live interfaces? How do we maintain the underlying technologies so that we can reuse or repurpose them? How do we build a repertoire for their use? How do we document and notate their technical and artistic aspects for future use?

These and other questions were debated at ICLI 2018 by circa 60 participants, including presenters, performers, doctoral symposium attendees and organising committee. Rajele Jain, the first keynote speaker, brought us From the Natyashastra, exploring how Indian

theory and practice on the possibility of conveying meaning is a rich source for an understanding of what an interface can be. On the following day, Andrew McPherson talked about Comparative Musical Instrument Design, reflecting on how individual designs can simultaneously serve goals of research and artistic practice. Three intensive days with paper sessions and performances distributed between Casa da Música and Passos Manuel, converged into a celebratory performative dinner, by our very own OPENFIELD Creative-lab, followed by an Algorave.

Hosting ICLI 2018 and its community in Porto has been an incredible experience for everyone involved. Already looking forward for the next edition!

The ICLI 2018 O.C.

KEYNOTES

From the Natyashastra

Rajele Jain

Films on Art Portugal



Photo credit: Nuno Correia

Abstract

How can a person who does not feel sorry, cry in pain? How can a miserable person appear joyful in happiness? When one feels sorrow or joy and shed tears or feels thrilled, that is called his emotion; and so the bhava is called emotional.

That which conveys the meaning intended by the poet through words, physical gestures and facial changes is a bhava.

There are four ways of expression (or acting) – physical, verbal, material and emotional.

Rasa is the cumulative result of vibhava (stimulus), anubhava (involuntary reaction) and Vyabhicari bhava (voluntary reaction). For example, just as

when various condiments and sauces and herbs and other materials are mixed, a taste (different from the individual tastes of the components) is felt, or when the mixing of materials like molasses with other materials produces six kinds of tastes, so also along with the different bhavas (emotions) the Sthayi bhava becomes a “taste” (rasa, flavour, feeling).

Rasa is the seed of all (Sthayi) bhava-s (of the spectators).

Based on the elements and functions of interaction and mediation fundamentally described in Natyashastra (Indian dramaturgy), a definition of interface is extracted that can also enrich current research on digital interfaces. Especially the consideration of the constitution of the audience and the importance of emotions, their triggers and carriers, are often neglected in the often technologically shaped discussions about interfaces, while in marketing applications it only degenerates into a simple manipulation strategy. Indian theory and practice on the possibility of conveying meaning is a rich source for an understanding what an interface could be.

Comparative Musical Instrument Design

Andrew McPherson

Centre for Digital Music, Queen Mary University of London



Photo credit: Andrés Torres

Abstract

The design of digital musical instruments (DMIs) serves many simultaneous goals, both aesthetic and technical. While most instruments are first and foremost artistic products, their creation and use can also yield insight on how musicians creatively interact with technology, and DMIs can even inform human-computer interaction research beyond the musical domain. This talk discusses a comparative approach to musical instrument design, in which two or more variations on the same instrument are created and compared in a performance context. Several case studies will be presented, drawing on the work of members of the Augmented Instruments Laboratory at Queen Mary University of London. In our lab, comparative instrument design has been used

to investigate themes including accessibility to novices, skill transfer for experts, perception of the audience, hackability and appropriation. The talk will present the specific instruments and what we learned from them, concluding with a general reflection on how individual DMI designs can simultaneously serve goals of research and artistic practice.

PAPERS

Ergonomics of Touch-screen Interfaces

The MP.TUI Library for Max

Vincent Goudard

goudard@lam.jussieu.fr

Sorbonne Université, Collégium Musicæ,
Paris, France

Abstract

The design of digital musical instruments, freed from the physical constraints of acoustics, is essentially driven by issues in ergonomics and representation related to the musical context. Moreover, the programmability of virtual instruments allows dynamic reconfigurations of mapping relationships between gestural interfaces and synthesis. In this respect, graphical interfaces stand on the edge between representation and control. Recently enhanced by the advent of multitouch, they allow all kind of tangible interactions. Their customization (behaviour, shape, colour, etc.) plays a crucial role, whether for the virtuosity of professional musicians, for the accessibility of people with disabilities or for particular contexts such as collective interaction on the same touch-screen. I will first raise a few aspects of visual ergonomics that inspired this research then present recent developments of dynamic, polyphonic and customizable touch-screen interfaces, based on the concept of “dynamic intermediate model” and an ad-hoc protocol for expressive control.

Keywords

HCI

Visual interface

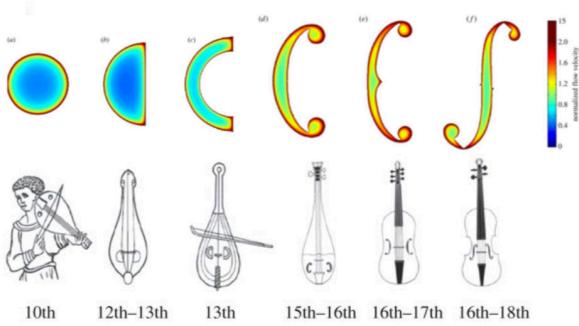
Multi-touch

Polyphony

Max

1. Visual aspects of instrument design

Instrument design encompass several aspects which are subject to ergonomics and that affect its visual appearance. I will run through a few of these aspects, taking examples from the acoustic instruments, as a retrospective on what led us to the developments we are carrying out with digital musical instruments (DMI).



(cf. Figure 1, right). This system of keyword decouples the gesture topology from the airflow and resonance topology. By using shafts and finger plates, it enabled to enhance sound by making larger holes and placing them at adequate locations for the resonance, while the keys could be placed at convenient locations for the flutist's hands.

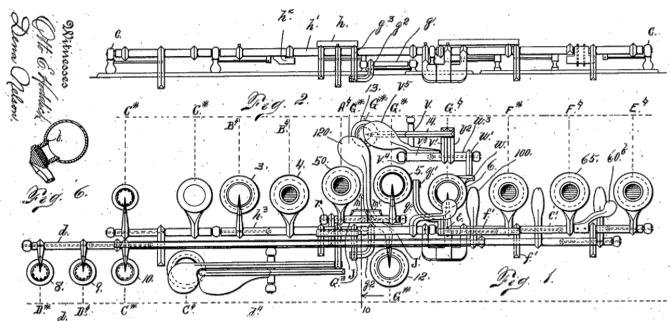


Figure 1. Left: The evolution of air resonance power efficiency in the violin and its ancestors (Nia, Jain, Liu, et al., 2015). Right: Extract from patent by J. Djalma on “Improvements to key system Boehm flute”, 1908.

Adapting to sound

Instrument design is concerned with the quality of sound. While this is most obvious in acoustic instruments whose shape has direct consequences on the sound output (as exemplified in figure 1, left) the peculiar shapes that came out of traditional lutherie also gave rise to a number of iconic elements (e.g. f-holes) and form factors (e.g. bigger size yields lower pitch) associated with the idea of an instrument. Moreover, DMIs may embed acoustic transducers, such as piezo microphones or tactile speakers, that influence the acoustic design of their hardware parts.

Adapting to the body

The instrument also adapts to the body. An interesting example is the evolution of the traverso to the western concert flute, with the help of the Boehm system in the years 1840

The Boehm system can be called an “intermediate model” between the gesture and the sound production, made of a mechanical system in this case. Most instruments combine various such “intermediate models” to amplify, enrich, displace, focus, multiply performers gestures and generate movements outside the scope of the human body’s possibilities : bass drum pedals, piano hammers and dampers, bows and plectra, etc.

Adapting to music theory

Music instruments also embed elements of music theory. For instance, the upper part of a keyboard (black and white keys) represents the chromatic scale, while the lower part (white keys only) represents the diatonic C-major scale. The sizing and positioning of these keys is an interesting tradeoff between the mechanical constraints of the hammer system and a

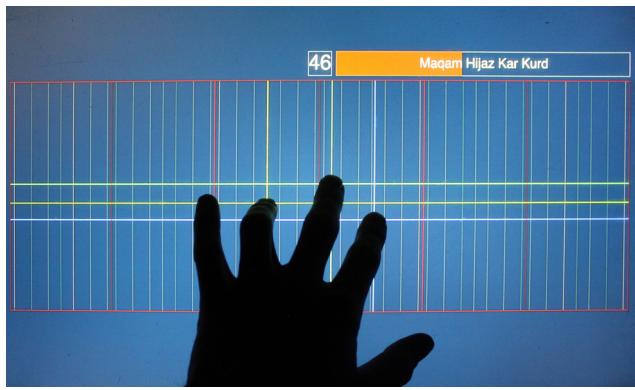
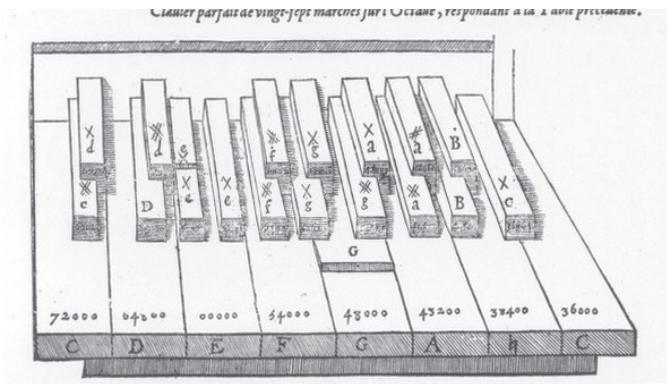


Figure 2. **Left:** Twenty-seven-steps keyboard invented by Mersenne (1636) **Right:** A pitch-space with a micro-tonal scale representation made with mp.TUI. Brightness of the bars representing pitch quanta will fade in/out depending on the amount of quantization.

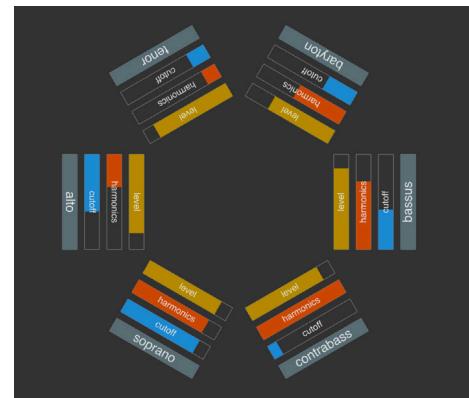


Figure 3. **Left:** The First Book of Songs (Dowland, John), Edition : London: Peter Short, 1597. Source : IMLSP **Right:** Simple sliders GUI for 6 players located around a common interface.

uniform representation of both the diatonic and chromatic scales. Moreover the octave width is such that it fits under a stretched hand, allowing to play any interval within an octave with a single hand, somehow reflecting octaves equivalence. Keyboards have been subject to many experimentations with micro-tonal pitch systems, intonations and note layouts, using hexagonal grids or several layers of keys (figure 2). As a symbolic system, such music theory can be easily encoded in computers. Music production softwares contain so many functions and rules based on music theory that these hardly fit the interface. Thor Magnusson talks of “epistemic tools” to describe the DMI, stating that it is designed with “such a high degree of symbolic

pertinence that it becomes a system of knowledge and thinking in its own terms” (Magnusson, 2009). As such, this “system of knowledge” is an imaginary landscape to be explored, a sonic territory for which the instrument’s interface and mapping can metaphorically stand as a map.

Adapting to the context

If we stretch a little bit the notion of musical instrument to simply consider them as tools to make music, then scores, concert halls, audience and more generally, the performance context also take part and influence instrument design. Oriented scores (figure 3, left) is an example of adapting the score to the context of

“table music”, in this case enabling the musicians to read the score while they are sitting around a table. Similarly, screen-based DMIs can adapt their layout to the number of performers by presenting each of them a group of UI elements oriented toward them (figure 3, right).

Adapting to the experiment

Eventually, the process of designing music instruments contains a great deal of empirical work. The process of adjusting the settings of an instrument will often require direct feedback for hand-made fine tunings, until it sounds and feels good.

2. Graphical User Interfaces

Until the last decade, GUI were mostly operated with the mouse on square monitor screens. Software interfaces design was thus oriented toward offline processing, with sequential actions controlled by a small set of GUI components types which have become a de facto standard : buttons, knobs, sliders, and menus. To attain the fast parallel control that live music requires, performers would often use external devices such as MIDI interfaces.

On-screen parallel control came with multi-touch interfaces. Although first developed in the 1980s, notably by Lee, Buxton and Smith (1985), they came to a broader audience only after the turn of the century with works by Ishii and Ullmer (1997) or Paradiso (2002). Cheaper multitouch technologies (Han, 2005) and augmented reality techniques (Dietz and Leigh, 2001; Patten, Recht and Ishii, 2002; Costanza, Shelley and Robinson, 2003) contributed to spread interest for such systems, which eventually led to commercial products in the music market such as Jazzmutant’s Lemur, or the reacTable* (Jordà, Kaltenbrunner, Geiger and Bencina, 2005). Following this, tablets apps like TouchOSC, Control or later Mira¹ enabled end-user to compose their own GUI layouts on multitouch devices. However, the components remained mostly tied to a vertical/horizontal

scheme not particularly suited to forearm- or wrist-centered movements or any freer layout.²

Apart from the now-usual gestures such as swipe or pinch-zoom, multi-touch interfaces gave rise to a number of strategies to interpret touch data: the same gesture will yield a different response if performed with a single or multiple touch, or depending on the order in which fingers touch the screen. And, as for the temporal interactions specific to music performance, multi-touch screens allows for timed gestural combinations in a way the mouse could not offer.

3. The mp.TUI library

The mp.TUI library³ was born out of two previous works which will be presented briefly: the concept of “Dynamic Intermediate Model” and the “Modular Polyphony (MP)” framework.

Dynamic intermediate models

The idea of DIM (Goudard, Genevois, Ghomi and Doval, 2011) was an attempt at transposing the concept of intermediate models such as those found in the traditional instruments into the digital world. It was also an attempt to find a better term to qualify such systems which translate and transform gestures than the widespread name of “mapping”. This term lets the reader think of simple connections between a controller and a synth and does not reflect the real interaction design at work. With the help of computers, intermediate models become dynamic, both in the sense that the system can provide energy, but also in the sense that it can change on the fly and evolve during the performance itself.⁴

This study was concerned with connecting, arranging and composing such models into compounds and interactive scenarios. One of the issues was to find an efficient protocol to communicate between the models, that takes into account their asynchronous, polyphonic, heterogeneous and ephemeral nature. That is what led to the definition of the MP-framework.

¹ TouchOSC by Hexler : <https://hexler.net/software/touchosc>, Control by Charlie Roberts : <http://charlie-roberts.com/Control/>, Mira by Cycling’74: <https://cycling74.com/products/mira>

² A notable exception is the reacTable* (Jordà, 2005) whose design is mostly driven by circular components

allowing collective use around the device.

³ Sources available at <https://github.com/LAM-IJLRA/ModularPolyphony-TUI>.

⁴ A video presenting Dynamic Intermediate Models is available here : <https://vimeo.com/25740547/>

The MP framework

The MP framework (Goudard and Genevois, 2017) was born out of the need for polyphonic expressive control in a modular digital lutetrie environment such as Max. It allows to easily process incoming multi-touch data (TUIO and mouse) with usual Max objects, wrapped in *poly~* object. The MP framework is made of modules (“*mp-blocks*”) that process asynchronous events (“*mp-events*”). An *mp-event* is an abstract temporal object, somewhat similar to a MIDI note, that can travel several processing paths in parallel and be merged or associated with other *mp-events*. Each *mp-block* can process several *mp-events* in parallel.

An *mp-event* is defined by a set of *mp-messages*. These messages are made of control parameters tagged with a unique value identifying the *mp-event*. The message format is minimalist : a unique identifier, a parameter name followed by a list of values. Two parameter names are reserved. The “state” parameter, which can be set either to *on*, *off* or *update*, defines the way incoming mp-messages are to be interpreted. The “guest” parameter can be used to create

relations between events (e.g. parent/child) and combine them in a single process. This protocol allows to design full mapping paths from polyphonic controllers such as MPE or multi-touch interfaces down to “expressive”⁵ polyphonic synthesis, passing through several stages of control-transformation.

Overview of the mp.TUI library

The mp.TUI library is built on top of the MP protocol. Its provides a framework based on Max’s patching logics to create new multitouch UI components in an OpenGL context and overcome some limitations found in GUI available in the patching environment. For instance, GUI are usually oriented on a horizontal/vertical layout with a top-down reading orientation while one may like to have several orientations, like in the situation presented on figure 3. The layering of various components may require custom colours and transparencies, and one may want to include more complex visual interfaces than sliders and knobs, e.g. particles, video, 3d models, shaders (figure 5), etc.

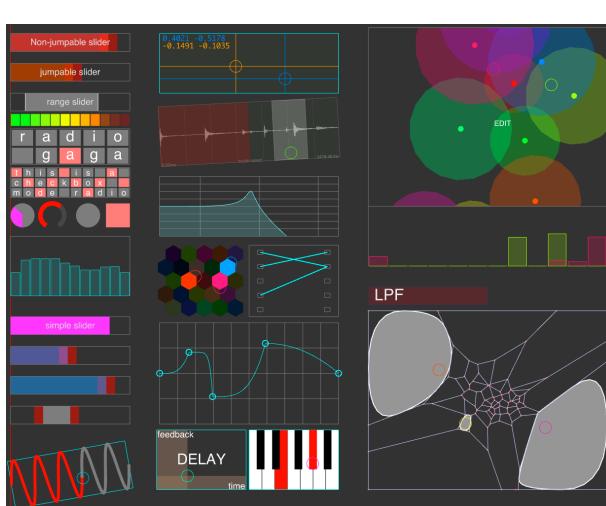


Figure 4. *Left:* overview of some mp.TUI components. *Right:* 5-fingers touching a dynamic Voronoï model.

⁵ “Expressive” meaning here that it allows the polyphonic modulation of previously triggered sound-events.

The possibility to design audiovisual objects in Max with a tight relation between gesture, audio and visuals allows to integrate them into custom dynamic scenarios: narrative stories for educational workshops with kids, reactive screen-scores, custom visualizations for visually impaired people, museum exhibitions with specific graphic charters, reactive adaptation to screen formats, experimental graphics for the aesthetic of live artistic performances, etc.

The underlying MP-protocol allows to activate GUI components on the fly in a way similar to the triggering of polyphonic notes. An example is shown on figure 4 (left) where the top-right “node” object dynamically instantiate multi-sliders objects below matching each active cursor on the node-object (two of them in this case).

The components of the library are of a set of abstractions of three types:

- 1. System components**, which implement the essential functions to wrap graphics into a pickable element. This includes the “mp.TUI.hub” which retrieves the data from the mouse interaction on the OpenGL window as well as TUIO messages received by UDP and send them to the picked GUI components.
- 2. GUI components**, which are ready-made instances of common and not-so-common widgets such as sliders, keyboards, breakpoint functions, etc.
- 3. Utilities**, a set of abstractions which make it possible to easily create new components by proposing useful functions for interaction design (viewing transforms, management of the polyphony on an element, pinch-zoom, computing deltas etc.)

The components make use of hierarchical geometry transform,⁶ which allows to get world-related or object-related coordinates regardless of the UI component’s position, scale and orientation. This also allows to create groups of components, like one would do in any

CAD software. Following the empirical nature of digital lutherie claimed above, an “edition mode” is also available to quickly manipulate UI components’ position, scale and orientation by hand (figure 6).

Performances

The mp.TUI library is fully developed with “vanilla” objects of Max’ distribution. This approach, although more CPU-expensive than compiled objects has the advantage of letting any Max user hack the components and adapt them to their needs. Besides, mp.TUI components are essentially relying on OpenGL so that most of the computation load is left to the GPU. UI picking is made with the help of the Bullet-Physic⁷ engine embedded in Max. While this may be more costly for some simple shapes, it allows us to design UI component of any shape and orientation, like bent sliders or hollow shapes, and to potentially animate them, like in the “bouncing balls” example where several 2D cursors can be moved around and launched in the bounding box.

As a library built on top of Max, mp.TUI is not the most optimized GUI system one can think of, especially in term of memory usage. Instantiating 50 sliders in Max take no time and has hardly any memory imprint while doing the same with mp.TUI will use some 250Mb and require several seconds on a recent laptop.

As far as its usage is concerned, since most parts of the mp.TUI components are running in an OpenGL context, the components responsiveness is tied to the OpenGL context scheduler, typically ranging between 20 and 60 FPS, yielding a latency from 15 to 40ms (in addition to the interface’s own latency). As experienced in several use-cases, the touch-to-display latency (Ng, 2012) was reasonable enough for polyphonic modulations in a live musical context, offering a responsiveness almost similar to existing apps like Mira or TouchOSC.

⁶ With the jit.anim.node object in Max.

⁷ <http://bulletphysics.org/>

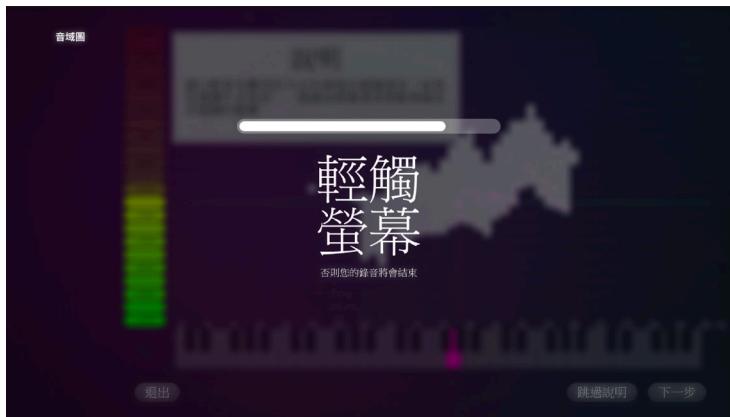


Figure 5. “The phonogram”, an app whose UI was designed with mp.TUI, showing a layered UI using shaders to blur the background.

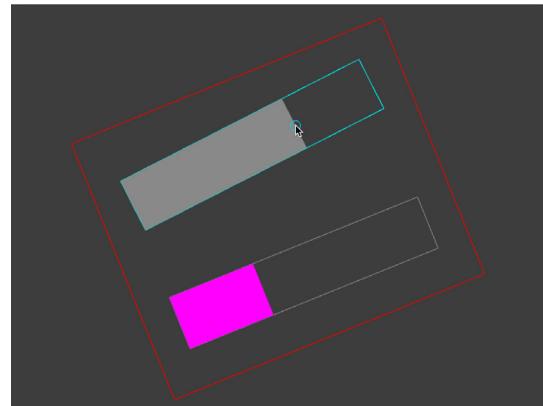


Figure 6. grouping objects and manipulation “by hand”.

4. Perspectives

The mp.TUI library aims at easing the design and development of original interactive GUI with strong interaction with sound. Components can be tailored for specific needs such as those encountered in the domain of digital lutheries with high-level Max patches, allowing non-expert programmers to build their own by reusing and modifying existing components. Components of the mp.TUI library can be mixed with and/or use advanced graphics, allowing for lively and aesthetic representation and control. Although the library is more memory- and CPU-costly than native Max GUI, it allows for experimenting with visual interaction design in a high-level visual programming environment. Much can be developed in this area open to creativity and it is hoped that this open library will help interface designer to come up with new exciting ways of representing and interacting with live music and sound.

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Penguin

Design of a Screen Score Interactive System

Raul Masu¹

raul.masu@m-iti.org

Nuno N. Correia²

nuno.correia@m-iti.org

¹ Madeira-ITI, Funchal, Portugal

² U. Greenwich, London, UK; Madeira-ITI, Funchal, Portugal

Abstract

In this paper, we present Penguin, a system for live scoring, and Studio I, a piece composed for the system and an accordion. The system is shaped in two modules, one that generates a musical stream in real-time and the other that manages a live scoring process. Penguin is designed to be used in interactive performances alongside traditional instruments. Studio I is a piece for Penguin and accordion. The interaction design of the system and the piece were fine-tuned involving the instrumentalist. We provide a general description of Penguin and present the design process that led to the development of the interactive performance. The design process led two main contributions. Firstly, we identify and frame a new performer role that mixes performing and conducting elements. Secondly, we discuss how the design process of the system affected the ownership of the aesthetic of music.

Keywords

HCI

Design

Scores

Screen Scores

Music Performance

Introduction

The emergence of Digital Musical Instruments (DMIs) and interactive musical systems in general, has blurred the distinctions between composers, designers and performers. Developing the instrument has become part of compositional processes. Schnell and Battier proposed the concept of composed instrument to describe those musical tools that incorporate the musical aesthetics in the technology itself (2002). These authors presented a number of interactive metaphors for composed instruments: playing, conducting, and playing together.

Screen score systems (Hope and Vickery 2011) can be considered as a particular typology of composed instruments, where an instrumentalist engages with the screen of a digital system by reading it. In this case, the composer and the performer are different actors. The instrumentalist is the actual end-user, involved in the interaction with the system. Still, the composer/developer uses the technology to express his/her compositions. Screen score systems have been used for musical pieces that provide the performer with some degree of freedom to improvise on the plotted score. Nevertheless, the authorship of the composer over the piece remains clear, since the composer encodes the aesthetic of the piece in the technology. Additionally, in western music tradition scores are responsible for determining the authorship of composers (Van Orden 2013).

In this paper, we present Penguin, a screen score composed instrument, and the piece Studio I for Penguin and accordion. The composer of the piece is also the first author of this paper. The final interaction design of the system and the piece were developed with the involvement of the end-user (the accordionist). This process consisted of a recursive iteration of rehearsal and evaluation, with consequent modification of the system and of the piece. We describe the interactive and musical modifications that occurred in the process, and how these modifications re-framed the role of the

performer due to the combination of performing and conducting elements. We also discuss how the process affected the aesthetic of the composition embedded in the instrument.

1. Related Work

Score, DMIs, and Screen

Scores are one of the fundamental elements in western musical practice, particularly in the classical tradition. Important relations between score and computer music were investigated with score-following algorithms (Orio, Lemouton, and Schwarz 2003). These tools aim at facilitating performances with classical instruments and electronics, synchronizing the timing of the electronic component with the instrumentalist. These tools are generally successful in the improvement of the expressiveness of the performances, but did not introduce any fundamental change to the relation between instrumentalist and traditional paper scores.

A novel conceptualization of scores is presented by Magnusson in the context of live coding (2011). He describes live coding as a new evolutionary and interactive branch of musical scores: the code is musical notation that is interpreted by a machine. More related to our study is the literature concerning screen score systems designed to be read by traditional instrumentalists. For instance, Kim-Boyle presents systems designed to control open-forms (flexible musical pieces) by the usage of the real-time generation of score (2006). The author describes how he adopted real-time generated score within the context of his composing practice for classical instruments. Relevant is also the Bach library for the visual programming environment for audio Max/MSP, designed for real-time computer-aided composition, generating scores according to algorithmically defined musical structures (Agostini and Ghisi 2013). A wide reflection about screen scores was provided by Hope and Vickery (2011), who classified four main screen scores categories: scrolling scores, permutative scores, transformative scores and generative

scores. According to this taxonomy, Penguin is a generative and transformative score system.

Involvement of End-Users in the Development of Music Technology

User-Centered Design (UCD) is “a term to describe design processes in which end-users influence how a design takes shape” (Abras, Maloney-Krichmar, and Preece 2004). In the context of music and HCI, UCD approaches have revealed to be successful in designing tools where the compositional element is not prominent. For instance, Wilkie et al. explored the usage of conceptual metaphors to involve non-musicians in participatory processes (2013). UCD has also been successfully applied to the design and development of music pedagogical tools (Core et al. 2017) or to explore audio-visual systems (Correia and Tanaka 2014). These related studies showed the benefits of adopting this approach to increase the user experience. However, applying UCD to composed instruments is a complex task, as the development of such systems is part of a compositional process. Indeed, with a participatory approach, the technology may no longer be designed and developed only according to the aesthetic needs of the composer. Our involvement of the end-user in the design of Penguin and the Studio I piece were informed by UCD.

2. Penguin

Penguin is a digital music system composed of two main modules: a module that manages a score in real-time – the Screen Score Module; and a module that generates a stream of synthesized audio – the Audio Module. The system is designed to be used in mixed performances with one instrument engaging in a musical dialogue with it. The system is implemented in SuperCollider, a platform for audio synthesis and algorithmic composition, and relies on LilyPond, a music engraving and file formatting program, for the generation of the score.

Penguin organizes the overall musical structure as a succession of “sections”. Each section is characterized by a specific chord/harmony and a set of possible rhythms. The sequence of the harmonies, the typology of rhythms, and the length of each section are predefined and stored in the system before the performance. The system generates the actual rhythms in real-time, according to the given descriptions. During the performance, Penguin automatically generates the score and plots it on a screen, while generating the audio stream (figure 1). The system also manages the sequencing of the sections. The instrumentalist is required to improvise on the given harmonies and the given rhythms, engaging in a musical dialogue with Penguin. During the participatory process emerged that the performer needed some control over the system leading the implementation of a controller.

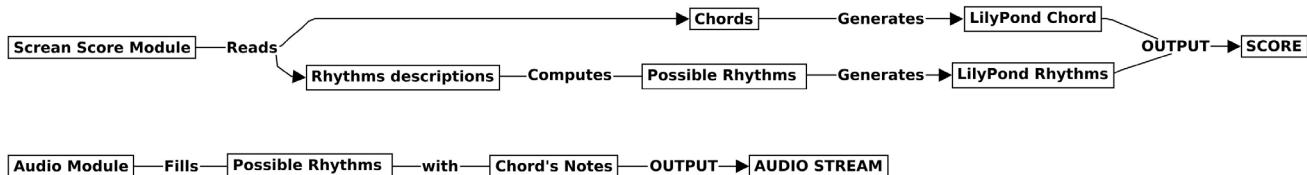


Figure 1. Overall structure of Penguin

Screen Score Module

The Screen Score Module uses almost standard musical notation (pentagram and notes), but harmony and rhythm are managed independently and plotted in different areas of the screen. The harmony is notated in the top part of the screen, and the rhythms are notated in the bottom part. Penguin generates the score relying on LilyPond, in three successive steps. In step one, it generates a .ly file that contains both the harmony and the rhythms. In step two, the .ly file is compiled, and in step three the resulting pdf is opened and plotted on the screen. Steps two and three are automatized using the unix-Cmd method provided by SuperCollider, which executes a Unix command using a standard shell. The harmony is notated on a two-pentagram staff. Penguin automatically translates the chords stored as MIDI values into LilyPond notation. The generation of the possible rhythms requires creating the patterns. Each pattern fits in one or two 4/4 bars. The system reads the allowed values (quarters, eighths, triplets etc.) and creates four patterns that randomly combine the different rhythmic figures. In this process, the allowed values can also be slightly modified to complete the 4/4 bar. For example, if the system combines a four-sixteenths pattern with 2 quarter notes, the 2-quarter is transformed into a 3-quarter note. Figure 2 shows a sample of the score.

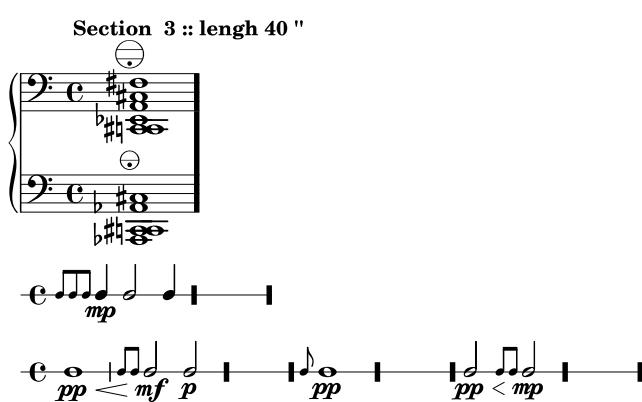


Figure 2. Sample of the generated score, with harmony in the upper part, and rhythms in the lower

Audio Module

The sound module generates a polyphonic stream of four lines combining the harmony with the patterns. For each line it recursively selects one of the possible patterns and fills the notes based on the chord. The system reiterates this operation up to the end of the section, then applies the same principle to the material of the new section.

Interaction Between Penguin and the Performer

The system is designed to be used alongside a classical instrument. The instrumentalist is the actual end-user involved in the musical performance. He/she has the freedom to interpret the notated harmony and patterns by improvising on this given material. The role of the instrumentalist in the musical performance was not completely defined before the final process. Consequently, the interaction between the system and the performer was undefined. As we detail in the next section, the role of the instrumentalist changed. Initially the instrumentalist was a soloist, who interacted with the technology only musically by reading the score in the screen. It emerged that the instrumentalist needed actual control over the system. Therefore, the performer was provided with a tool to manipulate the volume of Penguin.

3. Design with the Instrumentalist: Methods, and Results

The creation of the piece Studio I for accordion and Penguin relied on a recursive process with the end-user (the accordionist), having as an objective a public performance. In this process, the relation between the performer and the system was re-framed, and the system was fine-tuned according to the needs of the performer – leading to the change of the overall interactive musical metaphor. This process was structured in several steps, using observation and interviews: 1) rehearsal with the first prototype of Penguin, where observation was con-

ducted, followed by unstructured interview with the performer; 2) prototyping of a study score for personal study; 3) final rehearsal for a public concert, and the concert itself, each followed by an unstructured interview.

Rehearsal Stage

The objective of the first rehearsal was to test the musical interaction between the performer and Penguin. Initially, the accordionist was informed about the functioning of Penguin and her role. The piece was then rehearsed twice. The session concluded with an unstructured interview regarding strengths and weaknesses of the design of the system.

From the rehearsal observation, it emerged that the more the performer became confident with the harmonies, the more she was able to dialogue efficiently with the musical output of Penguin. This observation was also confirmed in the subsequent interview. In particular, she expressed the need to further study the piece, in order to find the right balance between her spontaneous creativity and the global form of the piece. To achieve this result, she explicitly required to have a printable version of the score with all the chords and some indication about the overall musical form. Overall the performer declared that performing alongside Penguin was stimulating, but also demanding.

Prototyping of a Study Score

According to the request of the performer, we created a printable study score. This score was composed of 13 pages (one for each section of Studio I) with an introduction that described how the rhythmic density evolves in the sequence of sections and how sections succeeded one another. In each page, the harmony and a sample of the possible rhythms were notated. After some private study, the performer required to have a more compact version of the score, with all the chords on one page, to have a better overview of the overall structure. We generated one

pattern for each section as an example of its rhythmical structure.



Figure 3. The performer during the final rehearsal

Final Rehearsal and Concert

In the interview following the final rehearsal (figure 3), the accordionist expressed the need for manipulating the volume during the performance. We then set up a physical controller with a knob that allowed her to modify the volume of Penguin. Thanks to this modification, she could perform more expressively and dynamically. With this setting, the performer not only dialogues with the system, but also plays the role of the conductor, controlling the overall dynamic.

In the final interview, following the public performance, the instrumentalist declared that she enjoyed the performance, both from a musical and from an interaction perspective. In spite of that, she expressed a difficulty in considering this a piece for accordion, performable by any musician, and that she felt that the piece was bound to her performance. The accordionist declared that she felt comfortable to perform the piece and that she liked the musical result. However, she did not think that another accordionist could feel the same confidence or achieve the same musical quality.

4. Discussion

We believe there are two main contributions from our study. Firstly, we identified and framed a new performing metaphor, that merges playing together and conducting elements. Secondly, we developed some reflections concerning the involvement of end-users/performers in the development of a composed instrument.

Performing Metaphor and Role of the Performer

The design process led two main modification to increase the expressiveness of the interaction with Penguin: 1) creation of a printable score for private study, and 2) control of the volume. Despite the fact that these modifications did not change the basic design of the score generation, they changed the overall performing metaphor. The need of a paper score can find a justification in the regular practice of classical musicians. Classical musicians are trained to study repertoire. In this process, musicians learn to articulate the phrasing of specific moments according to the global form of the piece. Given the fact the Studio I was initially proposed as a piece and not as an improvisation, it appears clear the instrumentalist wanted a similar understanding of the entire form of the piece.

Although control of the volume can be seen as a slightly different modification of the system, it changed the overall musical metaphor. As declared by Schnell and Battier (2002), composed instruments can have different interactive metaphors: playing, playing together, or conducting. Providing the instrumentalists with the possibility to manipulate the volume of Penguin shifts from the interactive metaphor of playing together to the metaphor of conducting and playing together at the same time. The accordionist switches from being a soloist to becoming a soloist and a conductor. The overall musical metaphor changed: from the a “Concerto” in the Romantic period, where the soloist is only a soloist and does not conduct the orchestra – playing together metaphor; to the idea of a “Concerto”

in Baroque time, where the soloist is also the maestro concertante (Taruskin 2006). For this role, we propose the name Soloist Concertante.

End-User and the Aesthetic of the Composed Instrument

In the introduction section we exposed how, within the context of DMIs, the compositional processes involves the development of interactive technology and the definition of interactive paradigms (Schnell and Battier 2002). Designing and developing a composed instrument is part of the compositional process. When the composer and the designer are same person, the authorship of the composer over the musical pieces is not affected. With Studio I, despite the fact the composer and the designer were the same actor, the composer is not the sole responsible for the interactive choices. The overall idea of the piece and the interaction, along with the harmonic and rhythmic choices, maintained the original shape, but other elements changed. The design process gradually shifted the musical scenario from the composition of a piece to the creation of a sonic art performance. The authorship is shared between the composer and the performer, and the final performance is bound to the idiosyncrasies of the performer. To redo the performance with a different performer, the same process will be required. Consequently, we argue that Penguin is a co-created composed instrument and that Studio I is a co-designed interactive performance, which relies on those specific actors to be performed.

Conclusion

The main contribution of this work is the involvement of an end-user in a design process of a screen score system, affecting the aesthetic of a musical piece. We rely on the concept of composed instrument by Schnell and Battier (2002) to describe those musical tools that incorporate aesthetics of the related pieces. During the design process we adapted the interaction design to the emerging requirements. These

modifications improved the user experience, but reduced the composer's control over the aesthetics of the piece. The outcome is therefore twofold: firstly, it identified a new musical role and interaction metaphor; secondly, it highlighted issues on to the involvement of end-users in the design of systems embedding a musical aesthetic. The main limitations of this study relate to only analyzing one case. Future work will involve more performers to more broadly investigate the relation between design process and control of the aesthetic.

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The Creative Mind – DRACLE II Further Development

Raffaella Folgieri¹

Raffaella.Folgieri@unimi.it

Maria Elide Vanutelli¹

Maria.Vanutelli@unimi.it

Paola Maria Sala¹

Salapaolamaria@gmail.com

Ludovico Dei Cas²

LudovicoDei@studenti.unimi.it

Dario Dei Cas³

DeiCas@museoscienza.it

Claudio Lucchiari¹

Claudio.Lucchiari@unimi.it

¹ Dipartimento di Filosofia, Università degli Studi di Milano, Milan, Italy

² Cdl Public Management, Università degli Studi di Milano, Milano, Italy

³ Museo Nazionale della Scienza e della Tecnologia “Leonardo da Vinci”, Milano, Italy

Abstract

The presented performance, using an EEG-BCI (Brain Computer Interface), is dedicated to artists, scholars and experts interested in the whole world of creativity and the related psychological and neuro-cognitive mechanisms. The aims of this work are: to identify possible biomarkers (EEG) related to the creative process in specific tasks, exploring it in a real-time ecological setting; to investigate the relation between explicit and implicit mechanisms, between creativity personality trait, and semantic memory; to validate a tool to study creativeness. In a previous pilot study, we revealed the presence of significant relations between personality components, EEG indices and creative processes, suggesting that the use of a self-echo setting may be applied also to boost creativity in people with specific thinking styles and personality traits, and to empower creativity in a tailored fashion. In this paper we extended the experimentation, consolidating the previous obtained results.

Keywords

Cognitive science

Creativity

BCI

Emotion

Consciousness

Introduction

We can define creativity as the process that gives rise to new items (ideas and artefacts) and then we can define three kinds of creativity. In fact, new ideas may derive by combination, exploration or transformation (Boden 2004). From a cognitive point of view, creativity is a complex cognitive process resulting from the search of a balance between conscious and unconscious processes. When a new idea arises to the consciousness, and then a balance is achieved, the mind turns back to a “creative-off” state. Then, divergent thinking is replaced by canonical thinking. This perspective allows scholars not only to analyze human’s productions, but also to investigate if computers may show some kind of creativity and the related mechanisms (Boden, 2009). Thus, it is possible to collect empirical data that could be potentially useful beyond entertaining and artistic applications. Indeed, it is conceivable the design of cognition-driven environments in which creativity-on and creativity-off states are interconnected in a way to create pathways for cognitive empowerment. Moreover, such environments could also be used to improve emotion regulation (Gyurak et al., 2012), thus creating virtuous interactions between the cognitive and the emotional compartments. In this last case, the environments proposed by the present prototype could be particularly useful and motivating.

The performance, presented and discussed in this paper, is dedicated to artists, scholars and experts interested in the whole world of creativity and the related psychological and neuro-cognitive mechanisms. The aims of this work are: to identify possible biomarkers (EEG) related to the creative process in specific tasks, exploring it in a real-time ecological setting; to investigate the relation between explicit and implicit mechanisms, between creativity personality trait, and semantic memory; to validate a tool to study creativeness. It is the second step of a previous research on creativity. Being a very wide and complex phenomenon, we will consider here the perspective of Cognitive Sci-

ence. In this field, human creativity is considered not just as the result of a cognitive encapsulated process, but as an online process linking together thoughts, emotions and sensory events in a complex fashion. Art and science are clear examples of the concrete enactment of this property, generally identified as “mental reflection”, allowing us to create a context in which we can give sense to the world.

The pilot study performed in our previous work revealed the presence of significant relations between personality components, EEG indices and creative processes, suggesting that the use of a self-echo setting may be applied also to boost creativity in people with specific thinking styles and personality traits, thus empowering creativity in a tailored fashion. In this paper we extended the experimentation, consolidating the previous obtained results.

The paper aims at explaining the possible benefits deriving from the contamination of Art and Science, in order to understand how mind and brain shape our experience through the dynamics of conscious and unconscious creativity mechanisms. We aim to contaminate the traditional academic thinking with the suggestions coming from the world of contemporary art and to introduce a discussion on the critical issue of the creativity mediated by technology and, as a counterpart, the creative mood of technology.

The acronym DRACLE comes from the names of the scholars and artists cooperating in this project (Dario, RAffaella, Claudio, Ludovico and Elide). Our group, born in the context of Neuro-aesthetic research and aimed at joining scientific research and Art, demonstrated that Art originates from our brain and is part of all the expression of our daily life. Eventually, we aim at reducing the distance between “Hard Sciences” and “Humanities”. The installation “The Creative Mind”, used for collecting data then analyzed in this paper, is focused on a real-time audio/visual representation of the creative process of our brain. Indeed, the installation allows analyze the individual creative process through a direct con-

nexion to the brain of a person, manipulating audio and video representation on a screen. The connection between the individuals' brains and the performance is realized by a B.C.I. (Brain Computer Interface) devices, described in the following paragraph "materials and methods".

The paper is organized as follows: a rationale of the experiment, the description of materials and adopted methods followed by the description of the performance, and then, in the final part, our conclusions and obtained results.

1. Rationale

Mind, environment and brain are historically connected concepts, intertwined and sometimes fused together. It is not possible to trace the trajectory of this conceptual path, but it is possible to think of its future that can be imagined as open, drawn on a background which, although variable, necessarily traces boundaries. Nonetheless, it is always possible to cross these boundaries by a process which includes all the three concepts, that is creativity.

Of course, we cannot give a unique definition of creativity, but we can state that, in general, it consists in the capacity of a system to draw new boundaries. The theoretical perspective proposed here refers to the application of an externalist model of the human mind to the construct of creativity, always immersed and depending on the environment. We could, indeed, compare the thoughts of our mind to a sort of software running on a biological hardware. In a complex system composed by mind, environment and brain, in which all the components overlap and define each other. We wish to recall the concept of "Complexification" introduced by John Casti (1995), who defines complexity as a hidden property of a system that shows up when an observing system (which could be called mind/brain), and an observed system (which could be called brain/environment) interact each other. When this happens, the effect is not only a form of complexity, but we obtain two different results: the first one is the "design

complexity" which is in relation to the observing system; the second one is the "control complexity" which underlines the active role of the observed system on the observing system. Casti suggests that the best interactive situation between the two systems occurs when they show a comparable level of complexity, thus leading an observing system to project towards a higher level of complexity. The environment is not only the external component of the system, but it is tightly connected with specific mental operations on which it is possible to build an inside/outside boundary. Despite the absence of a boundary, indeed, it is possible to contemplate the presence of a link between the inside and the outside in terms of matter, energy, and information. Each environment would thus be the product of the observation through which a system constitutes itself by tracing a boundary with the outside. Accordingly, an environment is the effect of a building operation based on the cognitive filters applied by the observing system. Subsequently, this relation is creative by nature, and the environment is continuously defined through actions and mental operations. It is also important to consider that the environment as an observed system, and the mind as the observing system, are not separated, but one includes the other, and vice versa.

Considering this point of view, our study aims to consider creativity from a complex perspective. For this reason, we implemented an active exchange between a biological organism and an electronic device, making the individuals' brain interacting with the performance through the BCI device. In this way, we have two systems (an observed and an observing one) simultaneously part of a more complex one. Neither the observing individual, nor the observed computer can define what is happening, where the specific information comes from, and what it is about to happen, but such information, from both sides, is continuously processed and generates new information (visual and auditory outputs, neural firing, electric signal transmission, etc.). This process produces an unstable system that nonetheless tends to stabil-

ity, since the human brain can implicitly learn how to predict the situation, and how to enjoy it emotionally. Through this simple, but powerful paradigm, it is possible to observe a creative process in relation to the shapes and sounds in a non-conscious way. Also, it is possible to analyze how this process dynamically modifies the cerebral functioning (implicit learning), and how this reflects into the individual-environment interaction. This way it is possible to collect empirical data that could be potentially useful beyond entertaining and artistic applications. This is possible because the dynamic, active, and functional cortical re-organization is associated with the cognitive processes underlying learning and cognitive empowerment.

The present paradigm provides some points of novelty: first, the participants will not be asked to perform any task, but only to set their mind free to “create” thanks to the enactment of continuing cross-modal loop. Also, the creative process will be analyzed step by step in real time by means of EEG. Finally, particular importance was given to the role of the creative process in shaping human experience, thus situating the mind within its environment. In fact, our paradigm will allow the self-revealing to the mind/environment dynamics through the brain-computer interface. Indeed, the disclosure of something implicit (as the process through one’s own mind connect with the world) can be considered a powerful phenomenon which could perturb both self-consciousness and the creative process. We may refer to this effect as “self-echo”. In other words, the present project is focused on the relationship between self-consciousness and creative enactment.

2. Materials and Methods

Studies on creativity take advantages especially from EEG. This is due to its low invasiveness and high time resolution, making this technique fundamental to measure the response in terms of time elapsed from the stimulation and cerebral response, in that it allows for a much more refined temporal analysis of brain activation and

can well capture the cognitive and emotional processes related to creativity within milliseconds. EEG provides, also, other useful information: the EEG power indicates the local activity of neuronal ensembles in a certain cortical area, whereas the EEG coherence in different frequency bands displays the degree of coordinated work of different brain regions (Bechtereva & Nagornova 2007). Neurofeedback, and more generally, BCIs, supply portable and easy-to-use solutions to explore such issues in a more ecological setting.

With the aim of collecting brain rhythms to show them interactively during the experiment, allowing the involved individuals to feel in comfort and free in movement, we chose to use a BCI device, a headset consisting in a simplification of the medical equipment for EEG (Allison et al. 2007), allowing to record cerebral rhythms and the direct brain-computer interaction. BCI devices are widely used in research, for the registration completely comparable to the medical EEG, but also for their low cost and high portability. Previous research with ecological meaning already explored the response to visual (Folgieri et al. 2012) and musical stimuli or creative acts (Folgieri & Zichella 2012) and recognize the emotions valence (LeDoux 2012; Folgieri & Zampolini 2014; Folgieri et al. 2014; Juslin & Sloboda 2012), and to reveal the mechanisms of the visual creativity (Folgieri et al. 2014). The objective of many researches, past and in fieri, is understanding which are the mechanisms triggering creativity or characterizing the creative process (the insight). In some experiments the objective is to evaluate the emotive and cognitive response to visual-perceptive stimuli based on the concept of priming (Banzi & Folgieri 2012). Other studies investigate the mechanisms of response to colors (Folgieri et al. 2013), or to stereoscopy and monoscopy (Calore et al. 2012). The obtained results show interesting correspondences among some cerebral rhythms and the creative activity. Here we decided to use the Neurosky Mindwave, a new version of Neurosky MindSet¹, which accuracy and reliability has already been studied by Gri-

¹ <http://www.neurosky.com>

erson and colleagues (Grierson & Kiefer 2011). The Mindwave is composed of a passive sensor positioned in Fp1 (left frontopolar) and from a reference sensor, positioned on the earlobe, used to subtract the common ambient noise through a process known as common mode rejection. This configuration is sufficient for our performance and research aims.

The chosen task is based on consideration revealed by Dietrich and Kanso (Dietrich and Kanso 2010), stating that existing work on the neuroscience of creativity fall into 3 categories: divergent thinking, artistic creativity, and insight. Nonetheless, except for a general recruitment of frontal areas, results are broadly inconsistent. In fact, according to the authors, creativity cannot be reduced "as a single, simple mental process or brain region" (p. 824). Also, research in the laboratory, under controlled conditions and with movement constriction, does not facilitate this ambitious aim.

Besides pure research, a few studies explored the topic of creativity by modulating, or reinforcing, some capacities that are thought to be related to creative processes. For example, neurofeedback has been used to teach participants how to self-regulate their neurophysiology; it has been used in groups of musicians (Egner & Gruzelier 2001, 2004) with significant improvement in music performance after the elevation of theta (4–7 Hz) over alpha (8–12 Hz) brain rhythms. In fact, EEG frequency bands reflect information processing, such as concentration, attention, as well as aspects of arousal, like tension, wakefulness, relaxation, or sleep, and neurofeedback technique makes individuals aware of these processes by feeding back a representation of their own electrical brain activity and allowing them to change it (Gruzelier & Egner 2004).

In the performance we used for our study, a BCI headset has been placed on the scalp of a performer, sending EEG rhythms to a computer which use it to modify bubbles and audio effects, varying dimensions, colors and the

intensity and sounds. In detail, the algorithm we developed takes the data coming from the headset and computes the real-time theta/beta ratio, an index commonly a marker of the ongoing balancing between limbic and cortical structures that driven motivational and automatic responses (Schutter & van Honk, 2005). The change of this ratio is then used to modify some parameters of a complex shape made by several bubbles rotating around a pivot. These parameters are: the scale of the graphics, so that it can appear smaller or greater; the rotation speed; the direction of the rotation (clockwise or counter clockwise); the vertical and horizontal position on the screen. The combination of these parameters creates a uniform rotating movement across the screen. Furthermore, the sound track is initially selected through the Alpha rhythm power. Higher or lower levels of the set threshold define which music will be run. Then, during the performance, the theta/beta ratio is used to regulate the value of the sound (high vs. low).

The graphical and sound interface was developed using the open source 3D graphics and animation software Blender². The next Figure 1 shows the user interface of the Blender development platform.

The graphical and audio objects were linked to the brain rhythm collected by the BCI in real time, using the interface library BrainWaveOSC³, BrainWaveOSC was designed to transfer EEG data from Neurosky ThinkGear-based bluetooth EEG sensors to other applications like Max-MSP and PureData via the OpenSoundControl networking protocol.

3. Procedure

Twenty volunteers took part in the study. All the participants in the experiment did not use drugs or narcotics or medicines of any kind. Half of them were familiar to Arts (music, paintings...), while half of them were naïve. Participants were asked to read and sign an informed written consent, then, they were required to com-

² <https://www.blender.org/>

³ <https://github.com/trentbrooks/BrainWaveOSC>

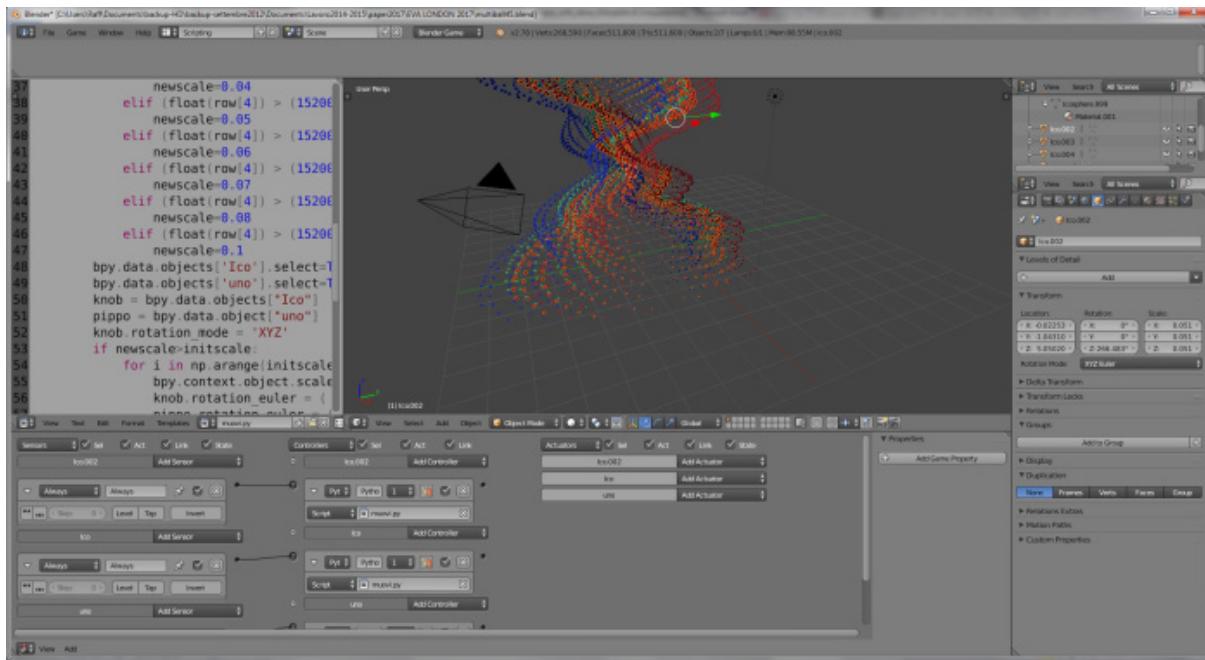


Figure 1. The Blender platform used to develop graphical and audio object of the performance.

plete the Behavioral Inhibition System/Behavioral Approach System Test (BIS/BAS) and the Big Five Questionnaire (BFQ).

We also wanted to measure the span of memory by repeating series of numbers, with two tasks. In the first, the experimenter read the numbers slowly, which the participant had to repeat in the same sequence. In the second, there was another list of numbers to be repeated in the reverse order to that used by the experimenter.

Therefore, participants were asked to read a brief study description: in the case of the members of a first group (aware: A), the sheet contained all the details about the content and purpose of the experiment; the members of the second group (unaware: UA) simply knew from the instructions that they would have taken part in a generic experiment on creativity, where they would be asked at some point to watch 3D animation on a screen.

Apart from the completeness of the information on the study, the experiment took place in the same identical way for both groups. Our

purpose was to see if there was a different involvement of alpha, theta and gamma waves between those who knew what they were doing and who was unaware of the situation. So, Group 1 was aware (A) of the fact that the BCI device would allow them to interact with the graphic interface, while subjects in Group 2 only known that the BCI would register their brain functioning (UnAware Group).

After the montage of EEG headband (Brain-Band XL) and the launch of BrainWaveOSC and Blender programs, a resting baseline was recorded (2 min eyes closed + 2 min eyes open;) with BrainWaveOSC. After these steps, participants received instructions by the experimenter to guide the different conditions during the creative task. The instructions were displayed on the screen and were referred to different experimental conditions. Before beginning with the 5 conditions, a 1-min free-run period was recorded. The instruction was: “Set your mind free to interact with the computer interface”. After this run, the other 5 conditions were presented randomly; each condition lasted 1 minute, and a 1-min pause was administered

between conditions. Together with the instructions, 3 words intruders (written in brackets in the examples below) have been presented to the participants. The intruders were 3 examples within the semantic category. The instructions were: "Concentrate and try to focus on...":

- Concrete task: "a concrete object" (like "shoes", "leaves"): Task Cn;
- Abstract task: "an abstract concept" (like "sympathy", "justice", "happiness"): Task A;
- Color task: "a color" (like "blue", "red", "green"): Task Cl;
- Place task: "a place you know" (like "home", "hospital", "university"): Task Pl;
- Person task: "an important person for you" (like a relative, a friend, a famous person): Task P.

During each task, participants watched the screen with Blender's DRACLE animation programmed with Python, accompanied by different music, like Yann Tiersen piano or other ambient songs. This animation consisted of round shapes of different colors that made movements uniformly in a three-dimensional space, usually turning around the 3 axes.

Finally, subjects were required to write a story down by using the 5 words and the related semantic fields previously imagined during the tasks. The instruction was: "Now we ask you to take some time to write down a story by using the concepts you experienced during the 5 experimental trials (color, concrete word, abstracts concept, place and person).

After a 2 minutes break from the story, participants were asked to compile some questionnaires to assess imaginative abilities, such as the Vividness of Visual Imagery Questionnaire (VVIQ) and the Test of Visual Imagery Control (TVIC).

Finally, the Torrance Test of Creative Thinking (TTCT) was administered.

4. Results

Correlations

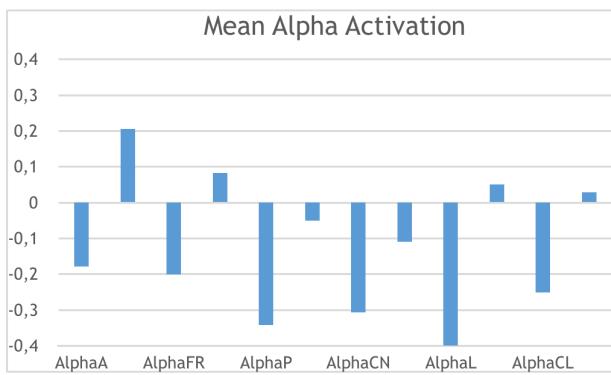
The strongest correlations of the Torrance creativity test were with the stories written immediately after the end of the BCI phase. The number of words, nouns, adjectives and, in part, adverbs, goes hand in hand with the ability in verbal fluidity, flexibility, processing and originality; more unexpected the correlation between the figurative elaboration and the use of words, above all names. Higher scores in fluidity, flexibility and verbal originality are negatively correlated with the use of intruders, the examples placed between brackets in the sheets with instructions. We can say for certain that greater knowledge of vocabulary and greater originality have made the individual less permeable to our intruders, given by the reduced effort made to look for an idea or a word that was outside the text they had in front of their eyes.

Analysis of Variance (Anova)

ANOVA revealed the difference in the activation of all the frontal waves between aware and unaware groups. The first group had a lower activation of alpha than the mean average of all EEG values. Group 2 participants, on the other hand, had almost always higher values than the mean average. In both groups, considering each frequency, almost all components have kept the constant of running less (Group1) or more (Group2) than the statistical mean. AlphaP ($M = -0,0495278$; $SD = 0,47$) and AlphaCN ($M = -0,10837388$; $SD = 0,29$), although the negative values, are still closer to 0 than Group1. Group1 has the lowest values in AlphaL ($M = -0,39$; $SD = 0,26$) and in AlphaP ($M = -0,34$; $SD = 0,35$). We found significant results in alpha t-Test ($t(17) = -1,61$; $p < 0,05$).

This is the most important result that underlines how aware and unaware participants reacted to the different conditions: in Group 1, general activation was almost always lower than in Group2. These parameters are also linked to the values

of attention and meditation, which were decisive in the final results. The first group, linked to the instruction to be creative, have more easily fallen into a meditative state; those in the second group were more intrigued by the animation of Blender and by trying to understand what was happening, therefore a higher attention.



We found similar values also in theta. In this case it was more relevant in the analysis of variance with thetaz (z to verify whether the average value of the distribution differs significantly from the reference value), especially in ThetazA and ThetazL .

Also, for what concerns TTCT, an analysis of variance on intruders was performed. A higher average number of intruders emerged in Group1 than Group2, which could be related to a greater permeability of the first group to examples with respect to the second sample.

Conclusion

Our study permitted to explore the correlation between physiological data, personality traits and levels of creativity. The EEG data confirm, in part, previous studies. Participants could have found a real or evocative figure in it, even if for many participants it was simply an animation to watch, letting their minds to be ‘transported’. Given the activation and deactivation of certain bands, the BCI could be used to stimulate creativity it-self. Understanding the response in frequencies to some stimuli starting from certain thoughts, whether concrete, abstract or emo-

tionally engaging, can lead us to understand how to stimulate those frequencies in terms of a greater interaction with a graphical interface, or improve the stimulation of creativity simply observing moving images. The fact that there have been more correlations and significance of results with the most creative people shows us precisely which frequencies are most used by them, and therefore those to work on so that even the least creative people can reach the same levels.

In fact, we found different associations between these elements, in first instance the relationship between BAS drive, BAS fun seeking, BFQ openness and levels of creativity. Often, very creative people are in fact considered to be open to the world and to new experiences, without setting too many limits when they want to do something; they are also considered a bit childish at times, in the constant search for fun and not inclined to respect the rigidity of the rules. The creative person wants to have fun and entertain, often coming out of schemes and boundaries. “I do something because I enjoy doing it”: there is pleasure from the task itself (intrinsic motivation) rather than from the benefit that comes once the work is completed. The latter is a motivation of an “extrinsic” nature and is more typical of “non-creative” people. Moreover, the “extrinsic” interests can interfere with creative thinking and thus jeopardize its “natural” development because the evaluation by an external subject could restrict the freedom of choice (Amabile, 1990). Openness is the most important trait of personality for creativity. Mental openness (or openness to experiences) is the best indicator of creativity according to the common academic consensus (Chamorro-Premuzic, 2015; Vohs et al, 2013): it is practically the synonym for creativity. This trait is characterized by imagination (vs. practicality), by curiosity, by the non-traditional. People who are mentally open and creative are aesthetically sensitive (attracted by various forms of art), intellectually curious and, in general, open to new experiences. We can therefore affirm that the level of creativity and the

personality traits are connected, so that one could interfere with the other.

A high level of creativity has also shown a lower permeability to the examples of the external world, confirmed by the negative correlation with the “intruders” in the final narrative. The creative has the world in his head, assimilates everything, but reworks it in his own way.

The reason why the second group has had a general greater activation than the first, especially in alpha and theta, remains uncertain. In part the difference could be given by a greater level of creativity and openness, on the other the condition of knowing or not knowing what they were actually doing during the experiment. This factor, although not fundamental, could be important in the development of new technologies and in their functioning.

Our results could also find usefulness for rehabilitation, improving cognitive performance. Just as they could be useful for entertainment, in order to create a new art form linked to technology and BCI. “In cognitive science, the functioning of the brain and the achievements of art are considered together to explain our aesthetic experience... For instance, it is possible to explicate why sometimes the reading of some images may depend on a subjective interpretation, based on the personal and sentimental response despite to perceptive cues, as colors and their contrasts.” (Lucchiari, 2017). During the interaction with Blender many participants, in fact, declared to have thought of many scenarios despite the focus on the initial image required, facilitated by what they had on the screen and the music they were hearing. We need to understand how much music has influenced EEG data; comparing people who had had experiences with music and those who had not, there were no significant differences in activation, except a slight increase in beta activation in musicians. It must be said that this study investigates only the frequencies emitted by the frontal lobe, while the differences

between artists and other categories are more evident in the temporal lobe.

Previous research in recent years conducted on brainwaves aimed at improving the functioning of BCI. Scientific and technological research tries to go hand in hand, walking together towards a single goal: the improvement of human life and the introduction of a new way of perceiving and developing reality. The field of use can range from medicine to gaming, from rehabilitation to new forms of art. In short, it could be the future. The various tools that allow brain-computer interaction are based on general electrical activity and on the activation of the different frequency bands; a better understanding the relationship between this and specific thoughts and activities can lead to an incredible improvement in this area. Although these studies are already well under way (see for example Banzi & Folgieri, 2012; Bechtereva & Nagornova, 2007; Folgieri & Zichella, 2012), there are still numerous steps to be taken. In this context, our paradigm provides some points of novelty: first, the participants are not asked to perform any task, but only to set their mind free to “create” thanks to the enactment of continuing cross-modal loop. Also, the creative process was analyzed step by step in real time by means of EEG. Finally, and more importantly, particular importance was given to the role of the creative process in shaping human experience, thus situating the mind within its environment. In fact, our paradigm allowed the self-revealing to the mind/environment dynamics through the brain-computer interface. Indeed, the disclosure of something implicit (as the process through one’s own mind connect with the world) can be considered a powerful phenomenon, which could perturb both self-consciousness and the creative process. We may refer to this effect as “self-echo”. In other words, the present project is focused on the relationship between self-consciousness and creative enactment. Such environments could also be used to improve emotion regulation (Gyurak et al. 2012), thus creating virtuous interactions between the cognitive and the emotional compartments.

In this last case, the environments proposed by the present prototype could be particularly useful and motivating.

To conclude, the present pilot study permitted to underline some preliminary data about the presence of significant relations between personality components, EEG indices and creative and imaginative processes. In particular, in future research, it will be possible to analyze if the use of a self-echo setting may be applied not only to investigate statistical correlations and/or the presence of neuropsychological correlates, but also to boost creativity in people with specific thinking styles and personality traits, in a way to empower creativity in a tailored fashion. Indeed, we argue that creativity is a personal feature that should be addressed in a complex setting able to take together several different components. In this way, we might substitute the “creativity-pill” approach with a more effective self-adaptive boosting process” (Lucchiari et al., 2017).

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HASGS

The Repertoire as an Approach to Prototype Augmentation

Henrique Portovedo¹
henriqueportovedo@gmail.com

Paulo Ferreira Lopes¹
pflopes@porto.ucp.pt

Ricardo Mendes²
ricardo.mendes@ua.pt

¹ CITAR, Portuguese Catholic University,
Oporto, Portugal

² Information Systems and Processing,
University of Aveiro, Aveiro, Portugal

Abstract

This paper discusses the development of HASGS regarding augmentation procedures applied to an acoustic instrument. This development has been driven by the compositional aspects of the original music created in specific for this instrumental electronic augmented system. Instruments are characterized not only by their sound and acoustical properties but also by their performative interface and repertoire. This last aspect has the potential to establish a practice among performers at the same time as creating the ideal of community contributing to the past, present and future of that instrument. Augmenting an acoustic instrument places some limitations on the designer's palette of feasible gestures because of those intrinsic performance gestures, and the existing mechanical interface, which have been developed over years, sometimes, centuries of acoustic practice. We conclude that acoustic instruments and digital technology, are able to influence and interact mutually creating Augmented Performance environments based on the aesthetics and intentions of repertoire being developed.

Keywords

Saxophone
Augmented Instruments
Gestural Interaction
Live electronics

Introduction

Augmenting an acoustic instrument places some limitations on the designer's palette of feasible gestures because of those intrinsic performance gestures, and the existing mechanical interface, which have been developed over years, sometimes, centuries of acoustic practice (Thibodeau and Wanderley 2013). A fundamental question when augmenting an instrument is whether it should be playable in the existing way: to what degree, if any, will augmentation modify traditional techniques? The goal here, according to our definition of "augmented", is to expand the gestural palette, at the same time as providing the performer with extra control of electronic parameters. From previous studies conducted by this research team we can say that the use of nonstandard performance gestures can also be exploited for augmentation and is, thus, a form of technique overloading.

It seems straightforward to define musical gesture as an action pattern that produces music, is encoded in music, or is made in response to music. The notion of gesture goes beyond this purely physical aspect in that it involves an action as a movement unit, or a chunk, which may be planned, goal directed, and perceived as a holistic entity (Buxton and Meyers 1986). Movements used to control sound in many multimedia settings differ from those used for acoustic instruments. For digital electronic instruments the link between gesture and sound is defined by the electronic design and the programming. This opens up many possible choices for the relationship between gesture and sound, usually referred to as mapping. The mapping from gesture to sound can be fairly straightforward so that, for example, a fast movement has a direct correspondence in the attack time or loudness of the sound. However, with electronically generated sounds it is also possible to make incongruent, "unrealistic" links between gesture and sound. The gestural control of electronic instruments encompasses a wide range of approaches and types of works, e.g. modifying acoustic instruments for mixed acoustic/electronics music, public interactive installations, and performances where a dancer

interacts with a sound environment. For these types of performances and interactions, the boundaries between, for instance, control and communicative gestures tend to get blurred. In the case of digital interactive performances, such as when a dancer is controlling the sound produced, there is very little distinction between sound-producing gestures, gestures made, or accompanying movements. To give enough freedom to the performers, the design of the interaction between sound and gesture is generally not as deterministic as in performances of acoustic music.

In our perspective, augmented instruments and systems should preserve, as much as possible, the technique that experienced musicians gain along several years of studying the acoustic instrument. The problem with augmented instruments is that they require, most of times, a new learning process of playing the instrument, some of them with a complex learning curve. Our system is prototyped in a perspective of retaining the quality of the performance practice gained over years of studying and practicing the acoustic instrument. Considering the electric guitar one of the most successful examples of instruments augmentations and, at the same time, one of the first instruments to be augmented, we consider that the preservation of the playing interface was a key factor of success, allied to the necessity of exploring new sonic possibilities for new genres of music aesthetics. The same principles are applied to the Buchla's Keyboard from the 70's, that stills influence new instruments, both physical instruments and digital applications. With HASGS is our intention to integrate the control of electronic parameters organically providing a degree of augmented playability within the acoustic instrument (Portovedo, Ferreira Lopes and Mendes 2017).

Recent Work

HASGS was initially developed within a DiY approach, justifiable by the repertoire that motivated the project. It is the repertoire that has been influencing the way this system has been developing. We consider the concept of Reduced Augmentation because, from the idea of having all the features of an EWI (Electronic

Wind Instrument) on an acoustic instrument, this could lead to performance technique overload, as well as making the acoustic instrument too much personal in terms of new hardware displacement. The proliferation regarding to the creation of augmented instruments in the NIME context is very big, but just a little number of them acquire recognition from the music market and players. As any musical instrument is a product of a technology of its time, augmented instruments are lacking the validation from composers and performers apart from their inventors. Due mostly to the novelty of the technology, few experimental hyper-instruments are built by artists. These artists mostly use the instruments themselves. There is no standardized hyperinstrument yet for which a composer could write. It is difficult to draw the line between the composer and the performer while using such systems. The majority of performers using such instruments are concerned with improvisation, as a way of making musical expression as free as possible (Palacio Quintin 2008).

In the first prototype of HASGS, we were using, attached to the saxophone one Arduino Nano board, processing and mapping the information from one ribbon sensor, one keypad, one trigger button and two pressure sensors. One of the pressure sensors was located on the saxophone mouthpiece, in order to sense the teeth pressure when blowing. Most of the sensors (ribbon, trigger, pressure) were distributed between the two thumb fingers. This proved to be very efficient once that the saxophonist doesn't use very much of these fingers in order to play the acoustic saxophone. This allowed, as well, very precise control of the parameters assigned to the sensors. The communication between the Arduino and the computer was programmed through Serial Port using USB protocol. This communication sent all the MIDI commands. The computer was running a Node.js program that simulated a MIDI port and every time it received data from the USB port, it sent that data to the virtual MIDI port.

A second prototype of HASGS was experienced having the features of the first prototype but adding a second device for augmentation. The MYO armband was considered an optional, or second layer, to the augmentation process.

The communication between the device and the computer was done using the bluetooth protocol. In this case, the mappings were based on Myo object for Max/MSP written by Jules Françoise. The creation of mappings using an application sold by Thalmic Labs were also possible, more precisely if using a DAW like Ableton Live. The MYO armband was used to collect data from its Accelerometer, Gyroscope, orientation of Quaternions and from eight Electromyograms. The analysis of MYO's behavior according to the normal position of different saxophones performance was possible to collect very different values. This showed to be an enormous potential to characterize involuntary gestures, as well as imprinting characteristics of bio feedback data to the pieces.

Present State

Taking in consideration that this system is still not a finalized interface, but an evolutionary prototype, our third version, presented here, started with the substitution of the Arduino Nano by an ESP8266 board. The communication between the sensors and the data received into the computer became wireless due to this fact. Both the computer and HASGS connect now to a Personal Hotspot created by a mobile phone API. This specification will allow much performance freedom to the performer, allowing now space for the integration of an accelerometer/gyroscope. To the previous sensors in the system were added two knobs allowing independent volume control for two parameters (Image 1). Regarding the use of the optional MYO Armband we started to use MYO Mapper developed by Balandino di Donato which proved to be more flexible, not only with Max/MSP but as well with other software.

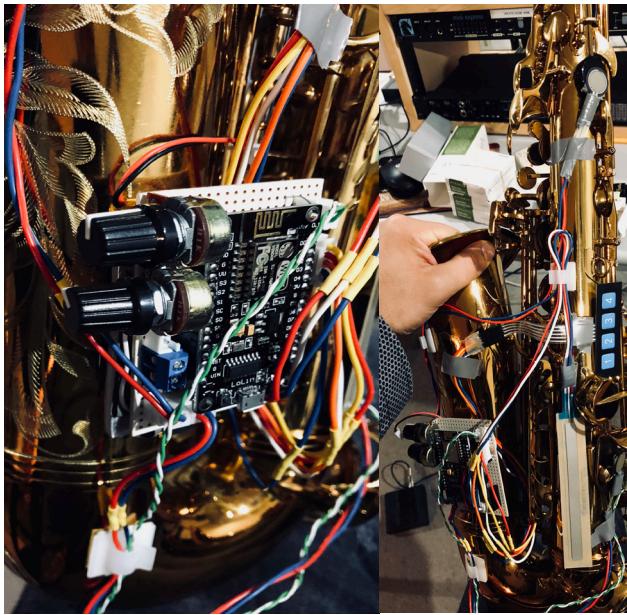


Figure 1. ESP8266 board and sensors of HASGS

In the process of developing the repertoire, a new table of instructions regarding communication between the sensors and the computer was sent to composers. We asked for a normalization on the software used, giving preference to Max/MSP. In that way, the table mentioned before showed the objects and attributes regarding the mapping of each sensor. An Max/MSP abstraction was produced for that purpose (Figure 2).

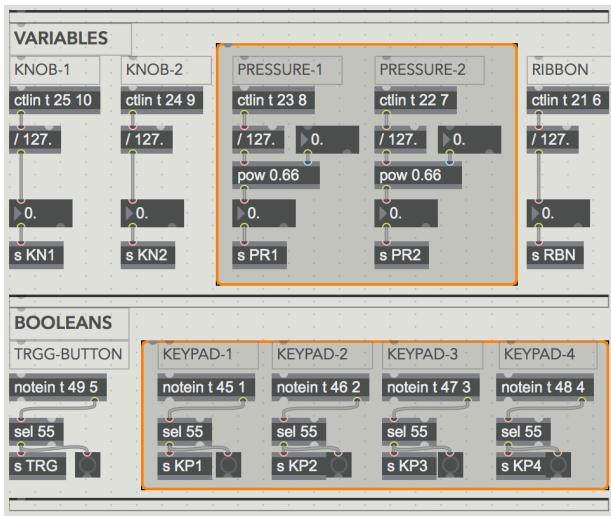


Figure 2. Max/MSP Abstraction for income data from HASGS sensors

Repertoire

While new repertoire is being created, notational development is very much dependent on the composer's preferences and how they decide to use devices and sensors. The new pieces being written show us that expressive notation will be represented with symbols and graphics, very much like the pieces composed for acoustic instruments these days. Expressive notation is nor dependent of technology nor of the device's control associated with new instruments for the producing of electronic music. Notation in music has been constantly evolve over time, according to the desire of producing new sounds or new sonic textures. This evolution has contributed largely for the development of extended techniques and instrumental virtuosity. Yet when acoustic instruments are played or combined in unconventional ways, the result can sometimes sound like electronic music (Roads 2015). One of the things to be considered, regarding to the new repertoire for augmented instruments, and more precisely, to this augmented saxophone system, is the presence of multiple layers of information, something that still not common when writing for a monophonic instrument (Figure 3).

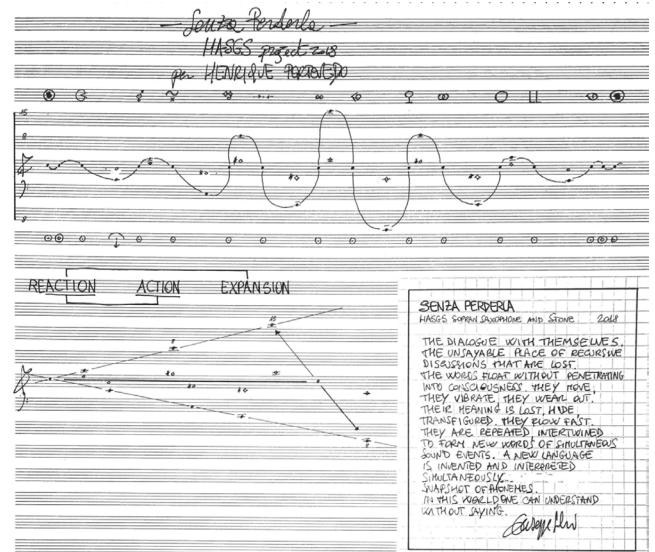


Figure 3. Example of Notation for HASGS

In the following examples of some pieces being written for HASGS, we describe the composer's approach as well as describing their musical intentionality allowed by the systems itself or its possible evolution. This is part of the corpus of study that is motivating the evolution of HASGS to acquire more or less sensors, more or less features.

Cicadas Memories

Composed by Nicolas Canot, Cicadas Memories is much more an improvisational process than a piece of written music. It was commissioned to be performed as a part of the HASGS (Hybrid Augmented Saxophone of Gestural Symbiosis) project. It explores a method that eventually introduces a non-standard musical way of thinking: the present of the live performed music is (at last partially) controlled, altered by the actualization of the past. In the case of CICADAS Memories, this means that the actual gesture of the player will alter (one minute later) the electronic sound-field used as the sonic background for the saxophone's rhythmic patterns (also created by the keypad's « 4 bits » layers of memory). Therefore, the performer has to develop two simultaneous ways of thinking (and acting) while performing: a part of his mind for the present (the patterns imposed by the software but created by the player's past action on the keypads), another one for the future (its gestural connection to the sensors). He has to deal with two temporalities usually separated in the act of live music performance: he writes the future score and improvises on his past gestures, in the present time. CICADAS MEMORIES could be defined as a *multi-temporal* sensitive feedback loop. Regarding the sonic / musical context, this explores the thinking of the piece as a process (maybe under the influence of Agostino di Scipio's thinking) rather than «written music».

Senza Perderla

Composed in collaboration between the programmer Balandino di Donato and the composer Giuseppe Silvi, Senza Perderla it's

a “Duo” for acoustic saxophonist and Virtual Saxophone in Physical Modeling Synthesis controlled by HASGS including MYO. The Synthesized Sax will be reproduced by S.T.ONE Loudspeaker so both physical (internal) than acoustical (perceived) characteristics of saxophone are reproduced. Using not only HASGS technology, the piece is structured with: a wire-piezo transducer fixed between ligature and embouchure; a disc-piezo transducer at the bell; an omnidirectional microphone inside the tube, under F plate; the two piezo are used to track pitch and amplitude of saxophone; the omnidirectional microphone is used to create controllable feedback between tube and loudspeaker, being used alone, with air, with tone. The notation system is organized with the following criteria: the first sinusoidal description of tones represents pitch expansion during the duration of the work; diamonds are soprano sax, normal heads are for esax; the ideograms above the system describe sound places, the toponomics of that sounds; the ideograms at the bottom of the system describe sound processing (Figure 3).

Verisimilitude

Composed by Tiago Ângelo, the setup for this piece, written for tenor saxophone and the HASGS system, uses a single speaker placed on front of the performer at the same height as the saxophone's bell. A play of acoustic sound source and electronic (processed and generated) sound using computer music techniques is driven in three sections - A, B and C (Figure 4) - each with its own specific processors and generators, implementing different mappings and control levels not only from the HASGS controller but also from real-time sound analysis.

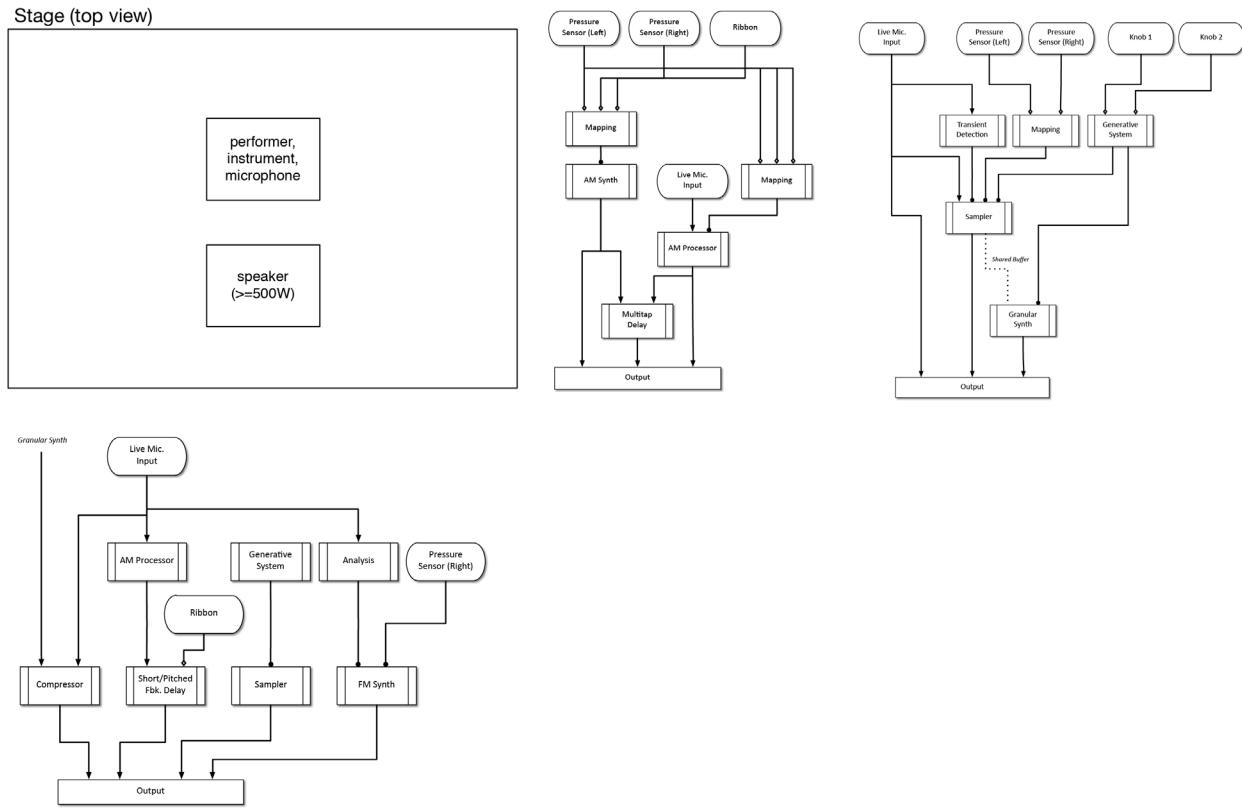


Figure 4. Verisimilitude's diagram of compositional sections

Comprovisador

Comprovisador is a system designed by Pedro Louzeiro to enable mediated soloist-ensemble interaction using machine listening, algorithmic compositional procedures and dynamic notation, in a networked environment. In real-time, as a soloist improvises, Comprovisador's algorithms produce a score that is immediately sight-read by an ensemble of musicians, creating a coordinated response to the improvisation. Interaction is mediated by a performance director through parameter manipulation. Implementation of this system requires a network of computers in order to display notation (separate parts) to each of the musicians playing in the ensemble. More so, wireless connectivity enables computers – and therefore musicians – to be far apart from each other, enabling space as a compositional element. Comprovisador consists of two applications – host and client. The adaptation for HASGS has been

done mapping its keypad to preset's selection, ribbon for phrase amplitude and instrumental density, as well as other sensors to control specialization and instrumentation.

Conclusions and Future Work

Starting as an artistic exploratory project, the conception and development of the HASGS (Hybrid Augmented Saxophone of Gestural Symbiosis) became, as well, a research project including a group of composers and engineers. The project has been developed at Portuguese Catholic University, University of California Santa Barbara, ZKM Karlsruhe and McGill University Montreal. The idea to benefit of this augmentation system was to recover and recast pieces written for other systems using electronics that are already outdated. The system intended as well to retain the focus on the performance keeping gestures centralized into the habitual practice of the acoustic instrument, reducing the potential use of ex-

ternal devices as foot pedals, faders or knobs. Taking a reduced approach, the technology chosen to prototype HASGS was developed in order to serve the aesthetic intention of some of the pieces being written for it, avoiding the overload of solutions that could bring artefacts and superficial use of the augmentation processes which sometimes occur on augmented instruments prototyped for improvisational intentionality. Traditional music instruments and digital technology, including new interfaces for music expression, are able to influence and interact mutually creating Augmented Performance environments. The new repertoire written by erudite composers and sound artists is contributing then for a system intended to survive in the proliferation of so much new instruments and interfaces for musical expression. The outcomes of the experience suggest as well that certain forms of continuous multi parametric mappings are beneficial to create new pieces of music, sound materials and performative environments.

Future work will include a profound reflection on the performative aspects of each piece, evaluating the mapping strategies of each new piece that is being written for HASGS. The notational aspect of the pieces being created will be, as well, a key aspect of this research, and how it could contribute to new interpretative paradigms. In the scope of this paper we decide to focus on the aesthetic of each piece and how HASGS could serve as the interface of their musical intention, how to influence them and how the prototype can evolve.

Acknowledgments

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Actuated Musical Instruments

A State of the Art

Tiago Ângelo¹

tiago.a.angelo@inesctec.pt

Rui Penha²

rui.penha@inesctec.pt

José Gomes³

jasgomes@gmail.com

Pedro Rebelo⁴

p.rebelo@qub.ac.uk

¹ INESC TEC and Faculty of Engineering,
University of Porto, Porto, Portugal

² INESC TEC and Faculty of Engineering,
University of Porto, Portugal

³ Digitópia-Casa da Música, Porto, Portugal

⁴ Sonic Arts Research Centre, Queen's
University, Belfast, Northern Ireland

Abstract

This article provides an overview of the state of the art in research driven towards the modification of the timbral properties of acoustic musical instruments through the use of electromechanical actuators (actuated instruments), allowing for synthetic sound generation to blend with the sound diffusion patterns of acoustic instruments. A selection of acoustic instruments and experimental research representing four Hornbostel-Sachs classes (idiophones, membranophones, chordophones and aerophones) is presented and their nouvelle characteristics and subsequent implementation is discussed, focusing on the techniques employed in the acoustical actuation.

Keywords

Acoustic-aggregate-synthesis

Actuated acoustic instruments

Actuators

Feedback control

Modal active control

Programmable

Prosthetic instruments

Sensors

Introduction

"(...) while most structural engineers seek to prevent structural vibrations, instrument builders seek to create sustained structural vibrations." (Berdahl 2009, 16)

Acoustic musical instruments have the ability to change their timbre namely through the excitation or attenuation of overtone frequencies of a fundamental, attained through different playing techniques. Paradigms such as extended techniques intend to take these a step further, allowing to reach a denser sound palette, but are nonetheless restricted to the acoustical properties of a given instrument as well as the physical constraints of a human performer. Recent technological advancements enabled finer modelling of the acoustical properties of musical instruments in real-time, leading to a new set of acoustical musical instruments whose synthesised sound components are actuated through electromechanical means in the instrument's resonant body. Actuated acoustic instruments,¹ also referred as prosthetic instruments (Walstijn & Rebelo 2005) or feedback controlled musical instruments (Berdahl, Niemeyer and Smith 2008), have the ability to 'escape' the constraints of the human body and the mechanics of acoustic instruments, much like a prosthetic exoskeleton has the potential to harvest an amount of force never attainable by a human being. Therefore this article provides a state of the art of actuated musical instruments by outlining a set of characteristics and techniques used to develop such instruments and subsequently referencing a group of instruments representing the Hornbostel-Sachs (H-S) top classification of acoustic instruments: idiophones, membranophones, chordophones and aerophones. The system developed for such instruments will be discussed in terms of its mechanical augmentation (sensors and actuators), the active technique applied to their modification and their sonic augmentations. A reasonably large set of instruments is provided so instead of providing in-depth analysis of each instrument, the rel-

atively simple analysis of each of these techniques serves as a comparison between actuated instruments as well as to inform and help building premises relative to different instruments of different H-S families.

The concept of actuated acoustic instrument provides a huge potential in electroacoustic music practice, bestowing both the performer and the composer with an augmented timbral palette for an instrument while being able to maintain at the same time its original acoustic properties. Although this is also true for augmented instruments,² actuated musical instruments possess the particularity of having similar sound radiation patterns as the acoustical counterpart, since the 'artificial' sound is actually radiated from the instrument's body via coupled actuators, in opposition to the augmented musical instruments which conventionally radiate the 'artificial' sound component through a generalised and non-idiomatic set of speakers that is physically detached from the acoustic counterpart.

1. Feedback Control

Through the perspective of systems control theory a musical instrument can be described and analysed as a *closed loop* system, depicted in Figure 1:

- r represents the excitation force applied to the instrument by a performer;
- $G(s)$ represents the system under control, in this case the musical instrument;
- v represents the system state, in this case sound radiation;
- and u represents the controller output which is added back to the system as negative feedback with a force F , a result of both the excitation applied by the performer and the controller output. (Berdahl, Niemeyer and Smith 2008)

¹ "We define actuated musical instruments as those which produce sound via vibrating element(s) that are co-manipulated by humans and electromechanical systems." (Overholt, Berdahl and Hamilton 2011, 155)

² Refer to Miranda & Wanderley (2006) for a comprehensive literary revision of augmented musical instruments.

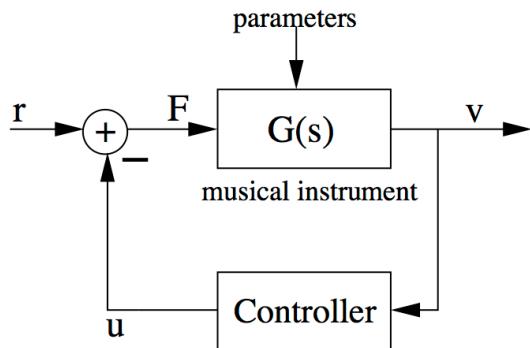


Figure 1. Simple block diagram for feedback control of an acoustic musical instrument. (Berdahl, Niemeyer and Smith 2008)

Regarding musical instruments one can think of the controller unit as the instrument's body resonance and vibration modes, providing haptic feedback to the performer as well as continuously interacting with sound radiation. E.g. a performer playing a trombone would create an excitation force through the mouthpiece, which sets an air column to interact with the instrument's body, resonating it and radiating sound through the bell, which is then perceived by the performer not only by the sound emanating through it but also as small vibrations that reach to the performer's hands and lips. Although the complex intricacies of the acoustics of musical instruments as well as systems control theory is out of the scope of this article, the reader can find valuable information in Chaigne & Kergomard (2016) and Warwick (1996), respectively.

Going beyond this closed-loop control mechanisms of acoustic instruments, it is possible to augment such instruments using feedback control techniques recurring to mechanical, electronic or digital components. A common application of feedback control has been used extensively by electric guitar players, using acoustic feedback between power amplifiers and the guitar's strings to produce self-oscillations or continuous tones. (Berdahl, Niemeyer and Smith 2008)

Another example is the *EMdrum*, an electromagnetically actuated concert bass drum that uses two coil drivers: one acting as an actuator

responsible to induce vibrations on the membrane, and the other, in reverse polarity, acting as a sensor picking up the electromagnetic field of a metal rod attached to the membrane traveling both through the actuator and sensor coils (Fig. 2). This is a good technique to avoid parasitic feedbacks from sound travelling through air, like it would happen with common microphones, ensuring that the feedback comes solely from vibrations in the membrane. Which can be intentionally achieved when, for example, playing a bass clarinet near the membrane, as exemplified by Rector and Topel. (Rector & Topel 2014)

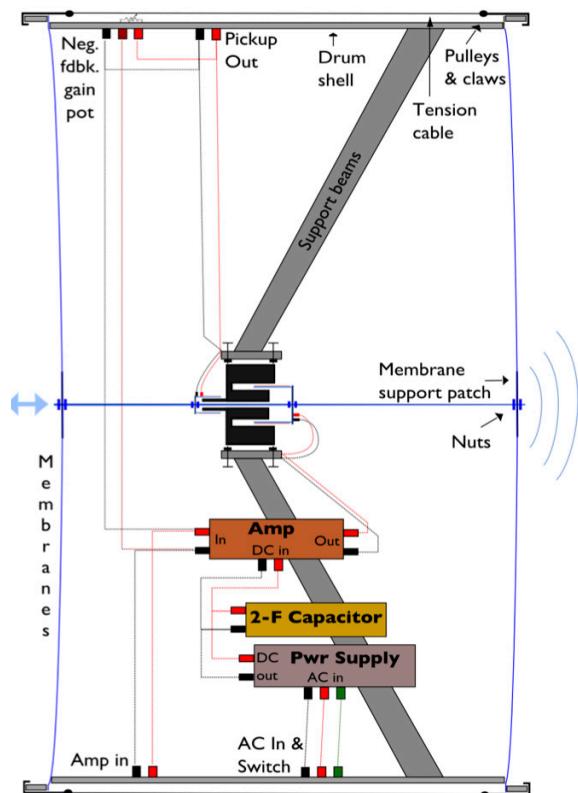


Figure 2. Moving-coil implementation, complete. (Rector & Topel 2014)

The acoustic applications of feedback controllers are obviously not constrained to musical instruments and there has been a significant surge of interest in the development of public address (PA) systems, hearing aids, and speech applications. (Troyer 2014)

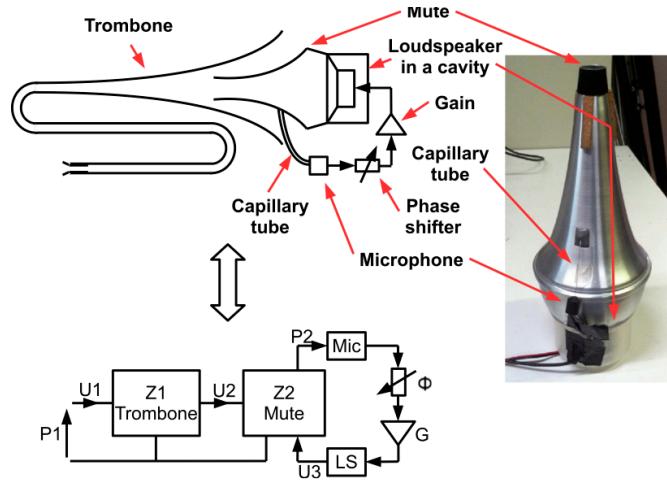


Figure 3. (Color online) (Top left) Schematic diagram of a straight mute with embedded microphone and speaker, and control system. (Right) Photograph of the active straight mute. (Bottom left) Equivalent electric circuit of the trombone coupled to the mute with control system. (Meurisse et. al 2015b)



Figure 4. Top: Simplified bass clarinet (a cylindrical tube with a bass clarinet mouthpiece and a reed) with embedded control setup with co-located microphone and speaker. Top right corner: control setup removed from the instrument. (Meurisse et. al 2015a)

2. Modal Active Control

Modal active control is the modification of a system's damping and resonant frequencies. (Meurisse et. al 2014) The majority of applications in musical instruments make use of audio feedback control systems, but not entirely. (One good example is the actuated clarinet mouthpiece presented by René Caussé (2014, 12'25'') in a lecture at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT, Montreal, Canada), where a water-actuated contraption inside the clarinet's mouthpiece acts as a mute, providing continuous control as opposed to traditional mutes, which exhibit a static behaviour.)

Most common modal active control applications on musical instruments also include the use of sensors, usually capturing the sound through mid-air (e.g. the active trombone mute (Meurisse et. al 2015b) or the simplified bass clarinet shown in Figure 4), coupled to the instrument's resonant body (e.g. Chinese gong (Jossic et. al 2017), monochord (Benacchio et. al 2016), decoupled guitar (Lee 2014) and xylophone bar (Boutin, Besnainou and Polack 2015), or through electromagnetic fields generated by parts of the instrument such as the magnetic resonator piano by McPherson and Kim (2010) which also applies optical sensors in order to determine which keys of the piano are being pressed.

A necessary component for modal active control is the actuator, which is responsible for physical actuation of the system's extended damping and resonance. These can induce vibrations in the instrument through electro-magnetic fields as seen in McPherson and Kim's piano (2010), through air using loudspeakers with a membrane cone (e.g. Meurisse and colleagues' simplified bass clarinet (2015a) or the active trombone mute in Figure 3) or coupled to the instrument's resonant body, using surface-borne drivers (e.g. Jossic and colleagues' actuated gong (2017) and etc.).

The system controller unit then receives data from the sensor(s), transforming and sending it to the actuator(s), either using simple Phase Inversion techniques (e.g. Meurisse et. al, see Figure 3), or more elaborate techniques³ such as Phase Locked Loops (McPherson and Kim 2010), Transfer Functions (Lee 2014, Meurisse et. al 2015a and 2015b), Luenberger observers (Benacchio et. al 2016 or Jossic et. al 2017), Proportional Derivatives and Proportional Integral Derivatives (Boutin, Besnainou and Polack 2015).

3. Acoustic-Aggregate-Synthesis

Acoustic-aggregate-synthesis is a technique used in actuated acoustic instruments which intends to fuse synthetic and acoustic sources in order to achieve a semi-acoustic re-synthesis of a predefined acoustic model, often aiming to maintain the original amplitude envelope and diffusion patterns while overriding the acoustic instrument's timbral identity. To achieve such phenomena acoustic-aggregate-synthesis makes use of similar setups found in modal active control (sensor-controller-actuator) although in this case the controller unit deals with more parameters than just signal phase in order to achieve its goals. (Clift 2012)

The resulting transformations are, to a certain extent, similar to a digital technique known as convolution, although in acoustic-aggregate-synthesis one part of the convoluted signal is actually acoustic, while the other, despite

coming from a digital source, collides with the original signal in the acoustic medium resulting in a new identifiable timbre. This technique has an enormous compositional potential, portraying the sensation, or illusion, of morphing two different instruments.

An example of this technique can be found in the work of Paul Clift and colleagues (2015) on a bass clarinet and on a trombone, experimenting with the 'convolution' of these instruments with other acoustic instruments such as flutes or oboes, equipping both instruments with specific microphones and speakers designed specifically for their acoustic specifications (Fig. 5, 6 and 7). (Clift et. al 2015)



Figure 5. Trombone mouthpiece with an integrated piezo microphone. (Clift et. al 2015)



Figure 6. Loudspeaker which has been permanently integrated into a trombone tuning-slide. (Clift et. al 2015)

³ The mathematical foundations of such techniques is out of the scope of this article, where the reader should refer to the mentioned references for more information or to (Havelock, Sonoko and Vorländer 2008) for a general understanding of signal processing techniques in applied acoustics.

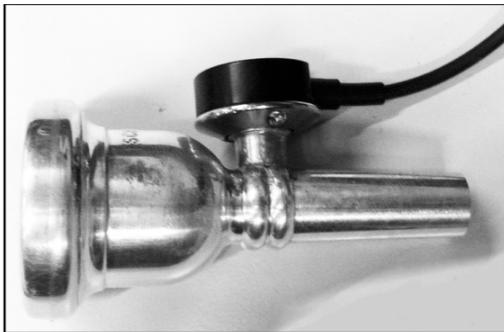


Figure 7. An ad-hoc device fashioned to suit the bell of a bass-clarinet. (Clift et. al 2015)

4. Prosthesis and programmable extensions

The concept of prosthetic instrument or instrument prosthesis, introduced by Rebelo and colleagues, is a practical metaphor to refer to some actuated instruments, since it implies a relationship between an artificial or foreigner component — the prosthesis — and a body — the instrument. Furthermore, it introduces the notions of potential, extension, mimicry and rejection. (Rebelo and Walstijn 2004)

Other metaphors can nonetheless be applied to actuated musical instruments, especially those with a digital controller unit. Thus taking advantage of the intrinsic programmable nature of digital systems, which can go beyond the notions of mimicry or extension of a natural or preconceived instrument morphology and resonant behaviour. Providing on one hand a wide range of active acoustic augmentations and on the other the use of an acoustic instrument's resonant body as a mere resonator for the diffusion of arbitrary sounds, going beyond the mimicry metaphor into, hypothetically, a question and answer or time-lapse metaphor, where sounds appear from the instrument's body without being attached to the performer-excited amplitude envelopes (e.g. *Overtone Fiddle* by Daniel Overholt (2011) or Neal Farrell's *eMute* (2006), see Fig. 8 and 9).



Figure 8. eMute in use. (Farwell 2006)



Figure 9. The Overtone Fiddle - first prototype. (Overholt 2011)

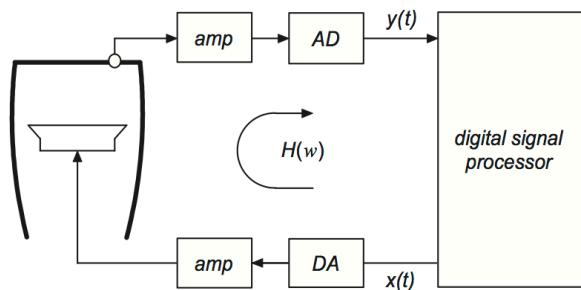


Figure 10. Prosthetic Conga sound reinforcement and membrane vibration monitoring. (Walstijn & Rebelo 2005)

The notions of prosthesis and programmable extensions is in the same chapter because the distinction between the two is not quite binary, although it can be assumed that prosthetic instruments exert some sort of feedback control system (see Fig. 10), containing at least one sensor, where a programmable actuated instrument may or may not apply these techniques and may or may not have any sensor (e.g. eMute). Additionally, an actuated instrument with a programmable extension might be capable of applying a feedback control algorithm or not according to a given musical composition or section.



Figure 11. Haptic drum v1. (Berdahl 2009)

Prosthetic synthesis can thus be seen as a form of dynamic modal actuation, where the instruments' damping and resonance behaviours can be dynamically modified during a course of a composition or from different compositions or musical sections. (e.g. prosthetic conga (Walstijn and Rebelo 2005), prosthetic mbira (Vriezenga and Rebelo 2011), Lähdeoja (2016) acoustic guitars, Berdahl's feedback resonance guitar (Overholt, Berdahl and Hamilton 2011) or bistable resonator cymbal (Piepenbrink and Wright 2015)) Also, a good example of a prosthetic actuated instrument is the haptic drum developed by Berdahl (2009), which uses a woofer as a drum membrane with a set of sensors attached to it (see Fig. 11), triggering

impulses to the voice coil whenever the sensors are activated, resulting in a quasi-automatic drum roll able to reach speeds that would be otherwise impossible to achieve.

On the other hand of the spectrum is the *EMvibe* (Britt, Snyder and McPherson, 2012) and Bloland's electromagnetically-prepared piano (2007), which do not make use of any acoustic sensor technology, recurring only on actuators to excite a vibraphone's bars and the strings of a concert piano respectively (see Fig. 12 and 13) using arbitrary computer generated sounds that follow a musical score.

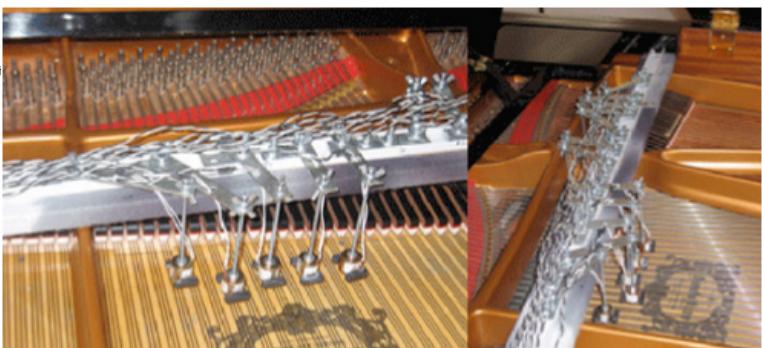
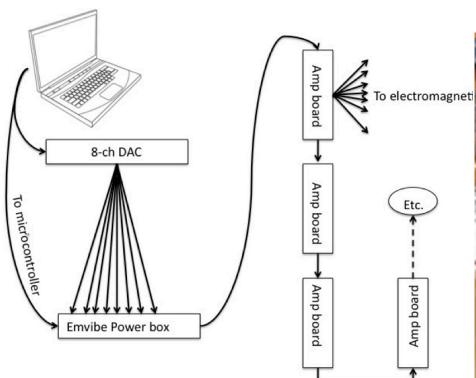


Figure 12. Electromagnets in a grand piano. (Bloland 2007)

Figure 13. EMvibe signal flow (McPherson & Kim 2010)

Conclusions

This article provided a comprehensive overview of the state of the art of actuated musical instruments. Several actuated instruments belonging to the four H-S classes of acoustic instruments – idiophones, membranophones, chordophones and aerophones— were presented and their characteristics were discussed whenever possible in the viewpoint of hardware/software and control systems. From this overview it is possible to condense and reach the following abstractions:

- Activated wind instruments pose some difficulties in the choice and implementation of transducers, although some new commercially available products start to emerge;⁴
- The idiosyncrasy observed in the instruments here discussed will most certainly prove to be an obstacle when attempting to develop a generalised system that may apply to several instruments. Although grouping the instruments by classes and hence their properties might cause this task to become slightly more manageable;
- The development of highly efficient feed-back control systems are highly dependent on timing (very short delay times) and hence computational speed. Luckily there has been quite some progress in the past years with smaller and more powerful platforms for embedded systems capable of low-latency audio, such as Bela;⁵

- Despite several technical issues, actuated musical instruments seem to excel where digital musical instruments have struggled, namely the notions of embodiment and engagement with the performer, since their ‘synthetic’ component is applied in the acoustic medium it is automatically captured by the performer’s haptic apparatus. With some exceptions, namely idiophones that are not played with bare hands.

In general active control of musical instruments, damping or attenuation proved to be a lot more difficult than excitation, which might hypothetically lead towards finer developments of the programmable paradigm and, although both paradigms can coexist, from the viewpoint of composition the latter, at least for the time being, seems more promising.

⁴ PiezoBarrel® Wind Instrument Pickups (<http://www.piezobarrel.com>)

⁵ <https://bela.io>

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Collaborative Design Methods towards the Evaluation of a Tangible Interface

Visda Goudarzi¹

vgoudarzi@colum.edu

Enrique Tomás²

enrique.tomas@ufg.at

Artemi-Maria Gioti¹

gioti@iem.at

¹ Institute of Electronic Music and Acoustics,
Graz, Austria

² University of Art and Industrial Design,
Linz, Austria

Abstract

This paper is a reflection on our experience of design of an interactive instrument and its evaluation and redesign using a collaborative creativity process. This paper examines the interface from three different perspectives; designer, performer, and expert audience. The designer describes and evaluates the chain of decisions taken to release an experimental tangible interface for professional use by a duo of electronic musicians. The performers examine the usability aspects, and a group of composers participate in a creative workshop to explore different aspects of the interface in a collaborative creativity process.

Keywords

Participatory Design

Collaborative Creativity

Evaluation Methods

Tangible Interfaces

Sonic Interaction Design

Introduction

Creativity and arts are deeply interrelated and creativity stems from a collaborative context, rather than from the reasoning of an isolated individual. Collaborative artwork has been investigated to explore the improvisational nature of it in both art and human-computer interaction. Other artistic research practice methods such as performance-based and collective making have extended the vocabulary of interdisciplinary and experimental approaches in HCI. We explore such methods and demonstrate how we expand them to an open-ended learning and design process. Art-based creative processes and outcomes can help designers to see and imagine opportunities and dimensions of technology and design that they wouldn't have seen otherwise. Design of musical instruments and composing electronic music are very isolated tasks. By asking such composers and designers to work together in a collaborative process, we aim to expand their vocabulary in design and ours in collaborative compositional ideation as a valid generative research activity. HCI researchers state that collaborative sound creation in form of improvisation is a form of active learning that enables emerging creativity through tension between structure and freedom. Contemporary experimental musicians and composers such as John Cage also had the same idea. They explored the "situational" nature of aesthetics and creativity through a range of novel exploratory works. E.g. Cage's idea of the "indeterminate score" (Feisst 2009) emphasized the interaction of musical creativity with uncertain situations. Driven by the desire to "let things be themselves", the role of the composer in this type of music is no longer to determine the musical outcome through a traditional notation system with a precise relation between notation and sound; instead, the composer determines a set of rules which performers and audience members interpret to regulate and produce situated sound experiences.

Similarly in HCI, human activities are not perceived as goal-directed and linear as in the first wave HCI (Harrison et al. 2007) anymore. A generative and inductive research approach necessitates open-endedness which is actively employed as a resource for discovery and surprise. Furthermore, digital ensembles, collaborative instruments (Hattwick and Wanderley 2012), and other frameworks (Weinberg 2005) (Blaine and Fels 2003) have evolved the notion of collaborative creativity in electronic music creation. Nevertheless, the design and idea creation process of the interactive instruments are left to isolated design processes by the designer or composer. We propose an array of collaborative work in form of designer-designer, designer-performer, designer-composer collaboration (Goudarzi and Gioti 2016). How this open-ended collaborative process continues and evolves is still unknown. The goal is to use these collaborative interactions as stepping stones towards idea creation in design practice and composition.

1. Case Study: A Tangible Interfaces Concert

A collaborative design workshop requires detailed briefing of at least one real case study. This is usually the topic provoking collaborative observation, ideation and prototyping. Instead of providing recorded documentation, we invited the participants of our workshop to attend a concert given by the electronic duo *Intra-sonic*, consisting of Visda Goudarzi and Artemi-Maria Gioti. The duo performed three different sound works at a concert at IEM (Graz) in May 2017. The first sound piece would be used as the case study for the collaborative design workshop. It was "Tangible Scores", an improvisation for two performers with four tangible interfaces. We found this work interesting because we could maintain direct communication with the builder and because it is a critical tangible interface affording discussion about musical intention. A tangible user interface (TUI) is a device for human-computer interaction in which a person interacts with digital information through the physical environment. In other words, a tangible

interface is an electronic artifact whose physical form embeds digital information (Ullmer and Ishii 2010). These interfaces take advantage of tacit human abilities to grasp and manipulate physical objects and materials to suggest interaction. TUIs were envisioned as an alternative to graphical user interfaces that would bring the richness of interaction with physical artifacts back into human computer interaction. As Hornecker and Buur have described (2006), tangible interaction “tends to emphasize materiality, physical embodiment of data, bodily interaction and embeddedness in real spaces and contexts”.

More into detail, “Tangible Scores” consists of a musical improvisation following the tactile and sonic affordances of a tangible interface. The author (Tomás and Kaltenbrunner 2014) defines the tangible score of an interface as the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements (Figure 1). The physical profile of these artifacts suggests specific gestural behaviors to their performers while they are also the medium to control the sound produced. For this reason the tangible part of the interface is also called a score. The materials used for composing tangible scores can be various: wood, paper, silicones, clay, etc. Technically, each “Tangible Score” interface can incorporate different sensor tech-

nologies for detecting tactile activity. For the concert studied, the interfaces featured contact microphones. The physical contact of a performer’s hands with the interface produces sounds which are used to drive a polyphonic concatenative synthesizer (Schwarz 2006) based on a real-time analysis and classification of input signal spectra. Each of these interfaces was composed defining the physical profile and the specific sound corpus which defines its sonic identity.

The four “Tangible Scores” interfaces performed by the duo of performers (figure 1) were built from casted paper and laser-engraved wooden panels. The graphic patterns were designed using the library *Generative Gestaltung* for Processing. The profiles on wood were engraved using a standard laser cutter. The molds for casting paper where created with an automatic milling machine.

The duo’s first proposal for performing “Tangible Scores” was received two months before the concert. At that moment, the instruments were highly dependant on their builder who had carried the project in a continuous state of development during his artistic PhD. This concert would suppose the first appearance of “Tangible Scores” without their builder. This is a crucial fact for evaluating the concert.



Figure 1. Tangible Scores used at the concert



Figure 2. Arrangement of the interfaces for the improvisation and capture of the performance

Preparation Phase and Performance

The performers duo and the instruments builder arranged a first meeting thirteen days before the concert. It served as an introductory session for setting up the instruments and running the computer systems. This session can be resumed as follows:

- Performers were introduced to the instruments, the routines to start and stop the computer system and the temporal structure of the piece.
- The builder took the decision of not giving many conceptual and organological details of the instruments. The intention was affording personal exploration of the instruments.

The first tryouts with the interfaces resulted into interesting findings and discussions. After this first meeting, the duo established a schedule of rehearsals where they could prepare the concert without the support of the builder. For the concert, the interfaces were arranged in the concert space as it can be observed at figure 2. The concert hall (CUBE, IEM) is a mixed space for concerts and acoustics research featuring 120 square meters. The audience, including the workshop participants and the designer of Tangible Scores, were seated in front of the performers. The sound work was played through

two main speakers in the corners of the hall. The improvisation had a duration of ten minutes approximately.

2. Evaluation of the Concert from the Designer's Perspective

After the concert, the builder of the instruments provided the performers with the following feedback:

- Technical Release: the duo was able to prepare the performance without the supervision of the builder. Some technical issues appeared but they were solved through online communication with the builder. However, further work has to be done for a real final release (i.e documentation, friendly configuration menus, examples of use, etc).
- Engagement with the interfaces: performers understood how to play and control Tangible Scores. They invested great effort and interest in exploring the instruments during the learning phase. However they couldn't develop an idiosyncratic or personal way to play them. As the performers were not especially trained on techniques to control Tangible Interfaces, a certain lack of mastery was noticeable. We can conclude that the period of time employed for preparing the concert was too short.

- Development of the performance: the improvisation was divided into four sections of around two and a half minutes. These sections were programmed in the system by the instruments builder. From a designer's view that was a strategy to conduct the improvisation but it resulted in a bad idea. Performers had to change sound material too often. As a consequence the musical improvisation lacked of sound exploration. A better strategy would have enhanced a more minimal performer's connection with the tangible nuances of the surfaces and their sonic outcome.

3. Evaluation Process throughout a Collaborative Design Workshop

Collaborative creativity approach

For the evaluation process, we adopted a User-Centered Design (UCD) approach consisting of two steps. We first asked the volunteers to attend the concert, listen and observe. We then conducted a one day workshop for brainstorming, creating imaginary scenarios, and sketching possible future tools for performance inspired by Tangible Scores. This study follows a UCD approach. UCD is "a broad term to describe design processes in which end-users influence how a design takes shape" (Abras et al., 2004). In this case, the end-users are electronic and computer music composers and performers. We adopted a UCD approach to better understand current practices of the composers/performers and to conceptualize a tool that addresses their needs. Collaborative workshops are defined as "collaborative design events providing a participatory and equal arena for sharing perspectives, forming visions and creating new solutions" (Soini et al. 2005). Due to the collaborative and participatory nature of workshops, they were chosen as a key element of the adopted methodology. A one-day, 6-hour workshop was conducted, aiming to produce sketches of novel ideas for Tangible Scores. The first part of the workshop focused

on the analysis and brainstorming about the Tangible Score interface and performance at the concert. The second half of the workshop was focused on creative ideation and generating new interaction ideas for Tangible Scores. During the workshop, participants went through a cycle of design process: analysis, prototype development and evaluation. Tangible Scores were analysed in terms of: ergonomics, interaction, expressiveness, mapping, and aesthetics.

During the workshop sessions, participants shared experiences through practical exercises. Several practical exercises were conducted such as "speed dating" (Davidoff et al. 2007), generating ideas in pairs in a very short time, regularly changing partners to stimulate ideas. During this exercise, the participants were given two minutes each to answer the following questions:

- Rate the interface in terms of ergonomics, interaction, expressiveness, mapping, and aesthetics (rating from 0:negative ... 7:excellent
- Imagine new scenarios using tangible scores and act as if you are using them. Which types of movements and gestures would you prefer to use?

first by talking in speed dating (two by two and then switching discussion partners as soon as the timer rang). Then they were given some quiet time to think and write down their answers and sketch their ideas.

Furthermore, we used "bodystorming" (Oulasvirta et al. 2003), i.e. play active situations with objects to test scenarios, or "sound drama" (Hug 2010), i.e. the scenarios are staged with objects using audio post production. During bodystorming, one in each pair acted and the other observed and took notes. The notes and sketches were later shared during a short discussion by all workshop participants. These exercises were complemented by sonic prototyping using sound processing in SuperCol-



Figure 2. Collaborative creativity workshop session: a group came up with moving the tangible interface (left) and another group suggested a transparent and standing tangible interface to make it more visible to the audience (right)

lider. The workshop participants created sound textures using granular synthesis to emulate the sounds created by the composer, but having their own control structures over the modulations in the synthesis.

Participants and Reflections

The intention of the workshop was to engage in the details of compositional and design process, therefore, an expert group of participants was preferred over a random group of volunteers. Six composers/music technologists were asked to participate in the concert and the follow up workshop.

Gathering the qualitative data from the questionnaires, interviews, workshop discussions, and videos; the participants rated the ergonomics and aesthetics of the interface as very high, but the mapping and expressiveness got the lowest ratings. We can not conclude a statistically significant result because of the small number of participants but we would like to discuss their viewpoints. By clustering the information gathered from the workshop, we could summarize the suggestions of the participants into three categories:

Interaction: The participants found the interface physically very appealing and easy to use and interact with. The hand movement on the scores seemed very intuitive and scratching the scores very organic. Additionally they suggested to use the hands in more ways than just scratching. E.g. by using the whole surface of flat hands, or by using the bones of the hand's fist. Another suggestion by multiple groups was to use physical objects, in addition to the hands, in order to add a variety of frictions between the surface of the scores and different objects. Furthermore, one group suggested to have destructive objects to reshape the score during the performance.

Visibility: All participants had difficulty seeing the performance during the concert. After the concert they all came closer to the tangible interfaces to thoroughly observe and inspect. They suggested variations of the interfaces in order to make them more visible and engaging for the audience. E.g. one group suggested a transparent interface made of glass that is vertically on the wall so that the performer faces the audience while the score is visible to the audience. Another group suggested the performers to be on a stage located lower than the audience, or a video projection of the interface that the audience manage to observe the score and the interactions with it. The third sugges-

tion was a tangible interface that is moving instead of the hand of the performer moving. This allows the interaction of an object with a hanging tangible score that is visible to the audience and very engaging. (Fig.3)

Controllability of sound: Participants found the aesthetics of the objects very intriguing but not the aesthetics of the sounds. All participants of the workshop found the controllability of sound very low. They found that only changes in dynamics were perceivable and suggested more variability of sound parameters with a richer vocabulary of gestures. They found such a small variation of sound makes the purpose of the score ambivalent. One group stated that for such a variation of sound they would just rather use a pair of microphones without any score. They couldn't find an evolving mapping structure in the sound or any fades between the microphones. One group suggested using granular synthesis on real time recorded sound which creates a lot more variability in the sound.

4. Evaluation of the Interface from a Performer's Perspective

For the evaluation of the interfaces from a performer's perspective we examined different parameters than the ones used in the workshop, focusing primarily on usability. In particular, we examined four features: *learnability*, *explorability*, *feature controllability* and *timing controllability* (Wanderley and Orio 2002). The communication of compositional instructions to the performer was also evaluated, an addition that was considered necessary due to the premise of the composition (i.e. the integration of score and musical interface).

Learnability. The design of the interfaces was rather straightforward, allowing for a high degree of learnability. While mastering the instruments might take some time, interaction with them is intuitive and effortless already in the first session.

Explorability. Due to the combination of tactile interaction with a variety of engraved graphical designs, the interfaces also demonstrated a high degree of explorability. Each interface showcased a different graphical design, consisting of several engraved areas that enabled a plethora of gestural and sonic interactions.

Feature controllability. In contrast to learnability and explorability, the degree of feature controllability – or, more accurately, *perceived controllability* – was evaluated as rather low. The intention of imitating the input signal through the use of Corpus Based Concatenative Synthesis (CBCS) (Tomás and Kaltenbrunner 2014) was not directly observable from a performer's perspective. This may be attributed to the fact that the composition in hand was based on a fixed time structure, each section of which used different sound samples as an input to the synthesis engine. As a result, no direct relationship could be established between the performative gestures and the sound samples chosen by the algorithm. The sound synthesis parameter with the highest degree of observable controllability was that of amplitude, which was in a direct – yet non-linear – relation to the amplitude of the input signal.

Timing controllability. Due to the absence of a score that requires strict timing this parameter was omitted from our evaluation.

Communication of compositional instructions. It is important to note that the performance that this evaluation is based on was the first performance of *Tangible Scores* by someone other than the composer himself. Because of this, and due to the lack of a score, the first rehearsals were both challenging and engaging. After a short demonstration of the instruments by the composer and a discussion on technical and design aspects, the performers participated in a “naïve rehearsal” (Hsu and Sosnick 2009), without receiving any prior information on either the sounds or the mapping strategies employed in the piece. This had the purpose of allowing the performers to explore and experiment with the instruments without feeling restricted by com-

positional instructions. However, after several “naïve rehearsals” it became clear that a performance/demonstration by the composer would be necessary in order for the performers to gain a better understanding of the expressive capacities of the instruments. During this demonstration, the performers were able to identify a “vocabulary” of gestures developed by the composer over his long-term engagement with the instruments, and subsequently integrate these gestures in their own performance. While this form of communication proved to be quite efficient, the existence of some form of documentation – verbal, graphical or otherwise – of these gestures could have made the composition more accessible to the performers, while providing an alternative for the composer’s physical presence at the rehearsals.

5. Discussion and Reflections

In this paper, we explored the design of a tangible musical interface by assessing it from three different perspectives. First, the designer and developer of the interface discussed his design decisions and compositional goals. Subsequently, performers of an electronic music duo, who performed with the interface, described their experience with it, examining the interface from a usability standpoint. Finally, in a collaborative creativity process, a group of composers gathered ideas on how to evolve such an interface physically and aesthetically. The use of different parameters for the evaluation by each group/stakeholder (performers, expert audience, designer-composer) was necessitated by the different roles that these stakeholders undertake in the creative process and served the purpose of integrating different perspectives in the evaluation process. The parameters examined by performers were essential in the process of interaction with the instrument to deliver the performative and sonic ideas that were designed by the composer/developer of the interface whereas the parameters established by the workshop participants were rather developed iteratively based on the creative perspective of the workshop participants.

The design of musical interfaces is a highly idiosyncratic task. Designers always have their favourite understanding about musical interaction and composition. Collaborative and participative approaches can help designers to examine the validity of many aesthetic and conceptual assumptions which usually cannot be evaluated through other methods (e.g., a usability test).

A collaboration with performers other than the designer/composer themselves can also be beneficial for the design process. The composer-designer-performer paradigm has established a bidirectional and dynamic relationship between the traditionally separated tasks of instrument-building, composing and performing. However, the lack of a thorough documentation of technical and aesthetic components of compositions/performances created through this process often limits their reproducibility. Working in collaboration with other performers could help assess design practices and communicate musical ideas, enabling their reproducibility.

From the collaborative workshop, we learned that the process of creating musical interactions could be an iterative process with different stakeholders who communicate their results in further iterations. The way other composers work and interact with one’s interactive instrument, could generate a lot of ideas for the designer to explore. A deeper assessment of such ideas could be challenging due to the short length of the collaboration. The workshop participants created a great collection of ideas for further assessments. Their contributions could be more valuable if there was more time for prototyping the ideas physically as well. Our participants’ background is in electronic music composition. For future research directions, we would like to recommend adding multidisciplinarity to the creativity workshop by combining a group of composers with technologists or interaction designers to compare and establish the relationship between the three different sets of parameters and perspectives.

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Digital Art

A Long History

Alex McLean¹

a.mclean@deutsches-museum.de

Ellen Harlizius-Klück¹

e.harlizius-klueck@deutsches-museum.de

David Griffiths²

dave@fo.am

¹ Deutsches Museum Research Institute,
Munich, Germany

² FoAM Kernow, Penryn, United Kingdom

Abstract

A *digital* representation is one based on countable, discrete values, but definitions of Digital Art do not always take account of this. We examine the nature of digital and analogue representations, and draw from a rich pre-industrial and ancient history of their presence in the arts, with emphasis on textile weaves. We reflect on how this approach opens up a long, rich history, arguing that our understanding of digital art should be based on discrete pattern, rather than technological fashion.

Keywords

Digital art
Representation
Digital art history
Weaving
Pattern

Introduction

A digital representation is one based on countable, discrete values, whereas an analogue representation is based on uncountable, continuous values. This is a core distinction in the design and use of Live Interfaces in the performing arts, the topic of the present conference. For example, does an interface capture digital gestures such as the flick of a switch or press of a button, or analogue ones such as the particular arc of movement taken by a hand? Or indeed, both?

When the word digital is used in a technology context, its use drifts from the standard dictionary definition expressed above. Instead of referring to discrete representation, digital is used to refer to contemporary technology in general; computers, databases, the internet, blockchain, and so on. In an online survey advertised on the eu-gene discussion forum for generative art, as well as social media, 98 respondents were asked to define the word digital and phrase digital art. Of these, 53 defined digital as referring to a discrete (or binary) representation, whereas 32 defined it more generally in terms of technology, algorithms or computers. This changed with the phrase digital art; 27 defined it in terms of discrete representation, and 52 gave a more general answer around computers or technology.¹ In wider culture, the word digital is increasingly used as a noun, apparently referring to ‘digital industries’ reliant on such technology. This vague notion of the digital is present also in digital art; practitioners know that the digital in digital art relates to discrete representations, but nonetheless treat digital art as a category or genre broadly engaged with contemporary technology. As a result it can be difficult to know what digital art is really about, particularly with technology becoming pervasive.

In the following, we clarify the nature of analogue and digital representations, and to some extent, how they relate to human perception and cognition in the making and experience of art, music and craft. In doing so we take a long view,

tracing the use of discrete representations in art back millennia, in order to untether the notion of digital art from recent technology. Taking this longer view, we are able to more fully appreciate the fundamental human fascination with discrete structures, carried on through art history.

1. Analogue and Digital: layers of representation

Digital is defined in relation to analogue, and vice-versa, so in order to continue on firm ground, we must first understand how they fit together. The analogue-digital relation runs through everything, and accordingly goes by many names: real/integral, smooth/striated, amorphous/pulsating, plane/grid, articulation/sequence, wave/particle, and so on. We cannot, however, divide the world into things which are digital and things which are analogue. For example, a tape measure is a continuous strip, but has discrete markings along it; whether we consider it a digital or analogue device simply depends on which aspect we are attending to. This is true also of the electronic transistor at the heart of modern technology; the very same transistor may be used as a digital switch or an analogue amplifier.

The psychologist Allan Paivio (1990) dedicated much of his study to digital and analogue phenomena in human cognition, conducting a great deal of experimental work to refine his Dual Coding theory. This theory holds that we experience phenomena along separate channels, where continuous images (including continuous forms in aural and other senses as well as visual) are processed separately from (and so do not contend with) discrete symbols. These analogue and digital ‘codes’ are experienced in parallel, and integrated into a whole experience. The human voice is a fine example of this, where discrete words are perceived alongside the continuous gesture of prosody, and integrated into a whole experience of speech. The work of Paivio and others in this area makes clear that although analogue and digital are distinct, they

¹ For the raw survey results and our coding of them, see <http://goo.gl/2gyNDR>

do not necessarily contend with one another in cognition.

So there is not an analogue world and a digital world. Rather, layers of interoperating analogue and digital representations. If we take the commonly held view that our physical reality is analogue, then the job of a electronic computer hardware is to create a digital reality inside it, by imposing thresholds on continuously varying signals, in order to create discrete states. These states are usually binary (base 2) states, following from high/low thresholds, but other bases are possible, for example the early ENIAC and Decatron computers work in base 10; a digital computer is simply one that works with discrete values.²

Digital computers have a somewhat fragile existence within an analogue world, battling against analogue interference and corruption, by using digital checksums and error correction. Despite this, we rightly call them digital in nature, rather than analogue. Digital computers create a layer of digital representation within an analogue one. But the layering does not stop there. Much of what digital computers do is the simulation of analogue systems, for example applying computational geometry to manipulate photographs, simulating three-dimensional worlds, or synthesising audio signals. Of course an analogue representation inside a digital one may itself host a digital representation in turn, a simulation within a simulation; digital and analogue turtles on each other's back, all the way down. If everything involves layers of both digital and analogue representation, where does this leave digital art?

2.The Digital in Art and Craft

A good place to look for the digital in art, music and craft, is in notation. Here notation involves discrete symbols, whether source code for notating software run by computers, punched cards for notating weave structures run by powerlooms, or staff notation for musical pitches. Musical notation is the 'odd one out' in these

examples, since it is used by humans to instruct other humans, and is incomplete, in that the discrete notes are specified in detail, but the articulatory movements are not. By contrast in the oral ('vocalable') transmission of instrumental sounds, for example the Canntaireachd (chanting) of Scottish highland pipers, and the Bol syllables of Indian Classical tabla players, the continuous gesture is foregrounded. Digital representation tends towards the general, and analogue towards the specific, and it is easier to notate music as discrete notes, than the continuous articulation of sound. In this shift from oral to written tradition in music culture, we see a shift from analogue to digital communication, and therefore a shift of emphasis from the specific to the general.

Discrete musical notation is hardly a problem for instrumental musicians, because they are happy to contribute continuous articulation themselves, informed by written prompts in the sheet music. It can become more of a problem when the notation is intended for a computer; where music is translated from sheet music to computer MIDI files for playback, the lack of continuous articulation can be sorely felt. Of course in a different context this mechanistic feel can become highly desirable, for example it is core to the aesthetic of industrial techno.

As well as feeding early electronic digital computers, punched tape is also used to feed music machines, such as the music box. On close examination, it becomes clear that musical punched tape is half digital, and half analogue. In one dimension we specify the discrete notes - at any one position the hole is either punched, or it is not. However in the other dimension we specify when the note plays, and this can be in any position. Here the relation between digital and analogue is as clear as X and Y, literally orthogonal.

Whereas the historical development of written notation has imposed discrete scores on oral traditions (Chambers, 1980), some traditions have always been based on digital representa-

² Analogue computers of course also exist, for example early flight computers using analogue gear ratios.

tions, one of the clearest examples being Quipu (or Khipu) once in common use in the Andean region of South America, for example used by the Inca people to record bureaucratic data (e.g. agricultural and tax records). Each Quipu consists of textile cords and yarns, hitched together into a non-cyclic branching structure, using a base-10 system of knots to represent numerical data. Quipus are not fully decoded and understood, but in modern terms, we can say that Quipu is analogous to a database, perhaps storing numerical calculations done with a yupana system of pebbles. Gary Urton's Quipu database (Urton, 2003) identifies several discrete channels of information; the structure of the Quipus and the arrangement of knots, but also less well-understood parameters such as spin direction, colour, material and the orientation of the hitch used. Rohrhuber and Griffiths (2017) have explored these parameters by translating them into digital pixel art and sound, emphasising the less well understood aspects.

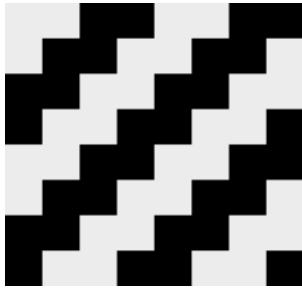
3. Weaving digital interference patterns

Where the relation between textiles and computation is discussed, the Jacquard Loom is almost always raised. However, we argue that if we are to progress discussion of digital art, we should cast all thoughts of the Jacquard loom to one side. In fact there is no such thing as a Jacquard loom, but a Jacquard device, placed upon a traditional loom to replace the human drawboy. The Jacquard device did not make an analogue loom digital, but provided one way (among others already established) to make an already digital loom programmable. Before then, a program of discrete movements was executed by a person, without the need for electricity. Once we look beyond the Jacquard device, we see that all weaving is digital, with its own complex, binary logic (Harlizius-Klück, 2017).

Weaving has a distinct structure, indeed it is true to say that the structure of weaving is as different from other textiles, e.g. knitting, crochet, braids, as it is from the structure of com-

puter source code. We could almost consider these five structures as equidistant. The logic of weaving is formed by the interactions between warp, under tension while on a loom, and weft, running perpendicular to the warp. Each time a weft thread meets a warp thread, it may either go over, or under it, giving weave its binary nature. In general, a weave is to a large extent 'programmed' not in the weaving itself but in the particular setting up of a loom, which sets the possibilities for what may later be woven. Warp threads may be grouped together into a number of shafts for instance, so that patterns are formed not by one-by-one selection of up and downs, but by combining groups of warp threads. The warp is lifted in these additive combinations, creating a gap or shed for the weft to pass through, but the weaver must stay aware of the structure that results, ensuring that the weave holds together, avoiding lengths of thread which 'float' above or below the weave. There are many constraints at play, which the weaver must work with and against, in order to feel their way to creating a fabric.

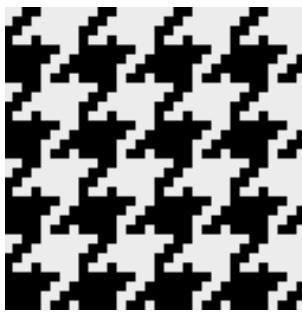
Colour-weave effect patterns (Takatera and Akira, 1998; Sutton, 1984; Harlizius-Klück, 2012) are of particular interest when considering the binary logic of weaving. This is where the colours of warp and weft follow their own respective patterns, which interfere through the up-down structure of the weave, to create an often surprising end result. Colour-weave effects can be strikingly complex, but Figure 1 illustrates a simple example, showing a houndstooth pattern. In this example the warp and weft are striped, both alternating between groups of four black and grey threads, but then interact with each other through the diagonal twill structure of the weave seen in Figure 1a. The resulting weave is the jagged star pattern seen in Figure 1c. This houndstooth pattern is in common use, but what we see in it is not the colour pattern of warp or of weft, or the structure of the weave alone, but an interference pattern between all three. Furthermore this is not a design dreamt up by a textile designer, but rather a visual outcome of the process of weaving.



a) A 2:2 twill weave, where warp (vertical) threads are black, and weft (horizontal) threads are grey. Each weft alternates between going over and under two warps at a time, with the pattern shifting one thread to the left each row.



b) The same 2:2 twill weave structure as in a), but where warp and weft threads change colour. The first four warp (left) and first four weft (top) threads are black, and the others are grey.



c) The same weave as b), but repeated four times (and scaled down in size accordingly). This reveals the traditional houndstooth weave.

Figure 1. The colour-weave effect of the Houndstooth weave.

Digital information has specific properties making it robust to transmission over long distances in space or through time. These properties are the reason for the gradual changeover from analogue to digital signals in the recent past, as the same information can be broadcast at lower energies. One example of this property in weaving is the ability for an archaeologist to discover a woven artefact (Barber, 1991) preserved in a burial site for thousands of years, and ‘read’ it to recreate the weavers actions exactly, step by step, including mistakes. It is then possible to replicate the fabric by weaving a new textile, essentially as a digital copy (a process involving various layers of notation and interpretation). Regardless of the complexity of the weave, the crossings of thread are discrete (over or under) making the information legible even in decayed samples.

In the same way it is possible to demonstrate the physical limitations of digital information using weaves. A pattern can be woven in a textile via manipulation of *tablets*, an ancient form of weaving which incorporates a discrete sequence of tablet rotations to select sets of warp threads. The specific sequence of rotations used to weave the pattern can itself be encoded as a binary string, and therefore woven in turn. This second pattern can theoretically be ‘read’ and interpreted in order to recreate the first one. This is a form of lossless digital compression, as the second pattern is shorter than the first, exhibiting Shannon’s physical laws of information (Shannon, 1948). The compressed pattern contains higher entropy than the first, with more disorder and less visually pleasing repetition or redundancy even though the same information is represented.

4. Taking the long view of Digital Art

Taking digital for its fundamental definition as discrete representation, we’ve reviewed historical examples of digital art, including the ancient craft of weaving and tablet weaving.

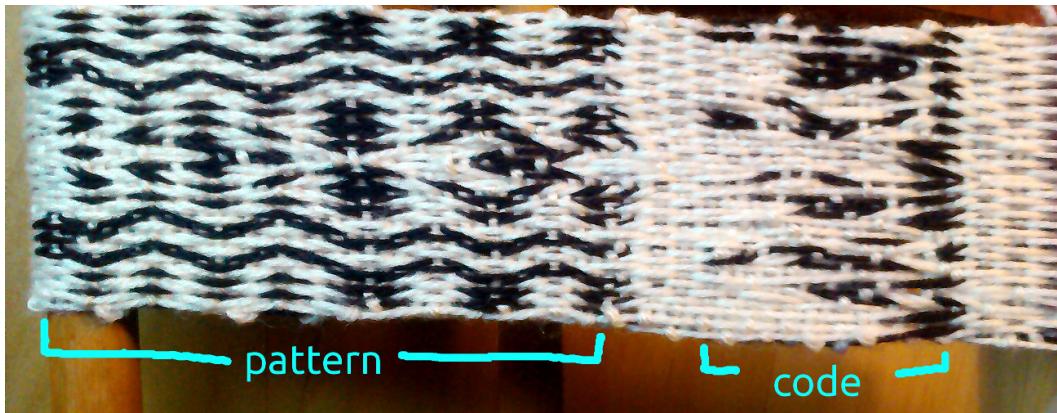


Figure 2. A pattern and its losslessly compressed digital representation

A fair question is, what is gained by taking this approach? Why not simply accept the pervasive view of digital art, as involving modern computing technology?

Our argument is that taking this longer view opens up an alternative historical narrative, which is culturally richer than the one we have. As generally held, the history of computing begins in the mid 20th century, with some reference to 19th century mechanical computers. This is an industrial and post-industrial history, with its development stemming from the military motivations of ballistics calculation and code-breaking. Despite efforts to recognise the early key contributions from figures such as Ada Lovelace and Grace Hopper, this historical view of digital technology is overwhelmingly dominated by men, a tendency which is only recently begun to be widely challenged. From this viewpoint, digital art is the repurposing of military equipment for the arts (Usselmann, 2003), an association that the field still struggles to shake off.

By focussing on the affordances of discrete representation that are visible in digital art, we open up a field that runs across human history. The emphasis moves from a digital defined by whatever is in vogue (computer vision one day, augmented reality the next), to one which

centres instead by discrete patterns, including patterns of imagery (e.g. cave paintings, mosaics), of textile craft (weaving, knitting, tablet weaving, embroidery), of dance (morris dancing, maypole dance), and of sound (rounds, arpeggios, inversions). These patterns breathe meaning into our lives, and connect the pattern-based digital machinations of contemporary technology, such as the shifting and combination of bitwise operations, with the pattern manipulations of the ancients. We argue that the human desire to engage with the discrete symbols of pattern is what makes us truly digital, allowing us to make generalisations and metaphorical inferences across domains.

Acknowledgments

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Ergomimesis

Towards a Language Describing Instrumental Transductions

Thor Magnusson
t.magnusson@sussex.ac.uk

Experimental Music Technologies Lab /
Department of Music, University of
Sussex, Brighton, UK

Abstract

This speculative paper proposes a terminology of ergomimesis for engaging with the way new musical instruments derive their design from previous music technologies. What new instruments translate from earlier technologies are not simply the simulation of an interface, but a whole constellation of embodied contexts, where trained movements, musical actions, human-instrument relationships and other processes are transduced or moved over to a technology of a different material substratum (from organic to digital material). The concept of ergodynamics in a musical instrument is subsequently contextualised in relation to the semiotics of mapping, from the background of the Peircian analysis of the sign.

Keywords

Ergomimesis
HCI
NIME
Ergodynamics
Instrument Design
Affordances
Constraints

Introduction

"To treat sound as a musical medium skirts musical technologies; better put, it stands in for the technologies that have been bypassed. Yet it would make just as much sense to talk about the media of music as consisting of the wood, metal, wires, reeds, pipes, valves, speakers, magnetic tape, vinyl, and circuits that we use to produce and record sounds. After all, sound is the effect produced by the battery of physical media." (Dolan 2012, 3)

Musical instruments are peculiar objects. They serve as media for musical expression, but in that, they concurrently reject their medium-ness and become objects that we are set in a dialogue with, through their oscillatory shifting of modes from what Heidegger famously called "being-at-hand" to "present-at-hand" (Heidegger 1962). In music, instruments are not the channel but the source of that communication: they are the message, as McLuhan would have said, collapsing a complex communicative scenario into a neat phrase (McLuhan 1964). Instruments are actors: they teach, adapt, explain, direct, suggest, entice. Instruments are impregnated with knowledge expressed as music theory, they adapt to our tunings, playing, manipulations; they explain the world, they demonstrate our theories of harmony, tunings and mathematical relationships; they direct our playing, suggest music, styles, behaviours. Musical instruments are objects of mystery and they can entice us into their world or be used to probe into our imaginary worlds, all through methods that go beyond conceptual language. These instruments are antennae into the unknown, into where rationality cannot take us, yet bringing back knowledge of the world and insight into the human condition.

The art of making musical instruments has diversified with our increasingly reticulated technological infrastructure. New materials have appeared, such as electric oscillators, filters, sensors, and interfaces, or digital chips,

compilers and languages that enable us to define the body of our instruments through computational means, ever flexible, adaptive, evolutionary or learning.

1.Traditional and Digital Lutherie

We might quickly explore this diversity of technical material. Here we encounter the traditional luthier, say a violin maker, who is a person whose education involves an initiation of a long tradition reaching hundreds of years of technological progress. The knowledge of wood (e.g., spruce, maple, and ebony), glue (protein colloid glue made of animal connective tissues), strings (first made of sheep's intestines, now wound metal strings), horse hair, rosin, and other materials is transmitted from the master to the apprentice in the workshop through actual practice. The process is mimetic not theoretical, where the apprentice copies and receives advice from the master through the mediative object of the instrument. The use of manuals or textbooks in these practices, if available at all, are only secondary to the real passing of knowledge in this form of apprenticeship. The evolution of the instrument has focused on timbre and sound projection in combination with developments in composition and performance.



Figure 1. From the workshop of luthier Hans Johannsson

The luthier understands the role of tradition in musical culture. Performers learn instruments from other experienced instrumentalists; they need instruments of the same type in order to be able to learn. The fact that there are types of instruments makes it possible for composers to write for them. And interpreters perform the pieces. Thus, we get conservatories maintaining the lineage of canonical works, training instrumentalists in the tradition, as well as composers to continue and further that tradition. All with a shared common reference: the musical instruments themselves!

Tradition versus innovation is a delicate equation for the luthier. When producing instruments that are a fixed entity in the minds of thousands of composers, performers, and listeners, innovations and change in the build and sonic timbre of the instrument will have to be carefully implemented. There are issues with the ergonomics (violinists often have problems in the neck or repetitive strain injuries in their left hand, as well as some hearing damage in the left ear due to the proximity to the strings) of the instrument, and the shape of the instrument itself is not a necessary evolution resulting in the best sound. The f-shaped holes are not necessarily the ideal shape, although there are discussions about that (Nia et al. 2015).

The luthier is not concerned so much with current popular ideas of usability and smooth learning curves. For the luthier, the instrument is a locus for reaching spiritual depth via music, via mind-body virtuosity and control. And that takes time. The luthier has spent 10k hours learning to make a masterful instrument: they have no problem expecting the musician to dedicate the same amount of time to their vocation.

The *digital* luthier (Jordà 2004), on the other hand, perhaps better termed as computational luthier, is interested in the web, in connections, mapping, ergonomics, and the rhizomatic structures of control messages. The focus here is on an object that incorporates a particular vision of what music is and how it can be composed or played. The digital luthier understands musi-

cal ensembles differently from the composer. The composer provides a script for performers to play alongside each other. The digital luthier is more focussed on the musical instrument as a model of musical theory: and here a problem emerges in that this theoretical construct might not be compatible with other digital instruments, preventing deep collaboration or ensemble playing. This can be evidenced if we seek to find out how many digital instruments are designed for solo performance versus ensemble playing?

Since the digital luthier writes the music theory into the instrument itself, it shakes up ancient structures of composer-performer relationships. Improvisation becomes more relevant than notated music, and performing the instrument is often a process of exploration and a dialogue, not a transparent channelling of intention. The digital luthier is skilled in musical theory, acoustics, signal processing and performance. For him musical brilliance emerges if the right conditions have been established. The art is therefore to set up the network of technological nodes in a manner such that a relatively novice performer can get good music out of the system. For the digital luthier, intelligence and creativity is distributed. It does not have an origin in one place. Musical creativity is therefore contextual, not something that beams down into a composer's head via the muses.

2. Imitative Origins of New Digital Instruments

There is not much point in seriously maintaining a rigid distinction between acoustic, electronic, and digital instruments. Firstly, because the digital is analogue at diverse layers (e.g., the top interface layer and the electronics layer), and the acoustic is often discrete, with a good example in piano keys. In actual practice, we constantly move beyond these distinctions, but for the sake of analysis they can be useful, as, if prompted, musicians report on common perceptions that are too often latent and not explored. It might actually be equally relevant to talk about old and new instruments, as

this distinction does not contain references to information-material properties, such as acoustics, electronics, or digital. Using the old/new distinction we apply an acoustic versus digital dichotomy in practice as there are clearly no electronics in old instruments, and most new ones introduced to the market will involve computer chips and electronics. We therefore need to consider our instruments as hybrid objects, pulling in technologies from different application domains, cultures, or embodied practices. Another way musical instruments are hybrid are their production models: they range from commercial businesses (Steinway, Fender, Ableton) to individuals creating their own technologies (instruments and interfaces, DIY, open source).

A phenomenological description of the difference between an acoustic (old) and digital instrument (new) might be due: We can begin by looking at the materiality of the instruments. Here the acoustic instrument's body is a resonator (either through a string instrument body's cavity or a wind instrument's tube) and we feel its vibration during playing. The body resonates due to human energy exerted through some excitation source, for example a skin membrane, a string, a reed, or a brass mouthpiece. The type of material matters and the physical shape is an important factor in how the instrument sounds and feels. The instrumentalist forges a strong bond with the individual instrument, one that becomes part of the performer's body. For the audience, it is very clear how the human effort, often one of intense continuous focus, results in the shaping of the sounds coming out of the instrument. The instrument becomes a central focus, it occupies a location in space from where we hear the sounds.

With the digital instrument, on the other hand, the sounds are not of its body, which is typically of plastic or metal, with glass screens, and it does not resonate with the complexity of the sound coming out of the speakers, even if the interface includes a tactile or haptic feedback system. The speakers are often located on either side of the stage, splitting

the instrument's sound source into two distant locations. In the digital instrument there is no necessary mapping between the human and the sonic energy: the performer might trigger a sound that prolongs until it is actively stopped. However, sensors on the interface might change the sound, through gestural movements, but those might not be isomorphic to the physics of the sound (a strong gestural movement could be mapped to softer sound, or any such disparity between hard/soft, fast/slow, up/down, wide/narrow, and so on) as all mappings are arbitrary. It is rare that a performer forges a strong bond with a controller or a digital instrument in the same way we find with acoustic and electric instruments.



Figure 2. The Seaboard, as an example of a typical new instrument, leveraging tradition in design, mapped to software

Yet, considering the material differences in these musical technologies, the instrument and the interface, it is quite remarkable how new instruments are designed through a process of imitating existing music technologies. This is, of course, a natural process as it leverages people's knowledge, imagination, and skill. Importantly for business, it also enables a marketing where the new is contextualised in the terms of the past, with narratives such as "the professional recording studio in your bedroom" (for DAW software). But this is a real question for software developers: if we can implement everything in the software and hardware that we are developing, where do we set the constraints? Where do we create the bottleneck

(Jack, Stockman and McPherson 2017) that defines the instrument as it is? This is often done through an imitation not simply of the functionality, sound, look of a musical instrument, but more importantly about the actions that make that object possible. Because before the snare drum there was stick beating on a tree trunk, or a more recent example: before the typewriter, there were pianos (and, according to Kittler (1999), women becoming secretaries as they could reapply the finger dexterity from their piano practice on the type writer).

3. Ergomimesis

What conceptual tools do we have when we analyse the change or transduction that happens when ideas, techniques, methods and technologies from established instruments and music technologies are implemented in our new digital instruments? I use the word “transduction” in the general sense that it involves converting systems of energy flow from one form to another. To freeze water is a process of transduction, but so is the function of the analogue-digital converter (ADC). More nuanced sense of the transduction process in media studies can be found in the work of Simondon (2017) and Mackenzie (2002), both of whom analyse transduction as a process of transforming constitutive structures. It involves the study of “how things become what they are rather than what they are.” (Mackenzie 2002, 16). From a media theoretical perspective, we are borrowing as well as remediating (Bolter and Grusin 1999), but what name should we give to this transduction of musical instruments? Objects so complex that they involve physics, materials, ergonomics, aesthetics, community, expression, performance, ideation, art.

Stiegler’s concepts of *epiphylogenetics* and *tertiary memory* (technological memory) are useful in explaining how technology constitutes the human our thinking (Stiegler 1998), but they are less useful in explaining the transmission process and the mechanics of design. For our analysis we need to emphasise the socio-technical

appropriation and continuation (passing on) of ideas, techniques, methods, and technologies. Instead of technology as our tertiary memory (the first being genetic and second epigenetic memory) storing our culture, I’m interested in a concept that focuses on action; our movements or kinetic memory. The Greek word for work is *ergon*, and we might as well call this *ergogenetic* memory for now; that is, the affiliated memory of how to use an object. A bone with holes in it is not a flute if the Divje Babe cave dweller has never heard (of) a flute. The actions affiliated with technological objects are of the objects, but they can be borrowed and used in other technological contexts.

Therefore, if we copy work processes from one domain to another we can call this *ergomimesis*. We mime and imitate actions and processes of one area and we implement the same in a different one. Intrinsic to the concept of ergomimesis is the fact that any repetition, copying, or translation is a new event in itself, involving noise, errors, misunderstandings, abstractions, and new affordances. This noise in the translation is clearly the source of much creative solutions and adaptations. The field of *ergography* would study how technological things emerge from previous actions and processes, translated into a new domain; this involves classifying key musical gestures (plucking, hitting, fingering, stroking, blowing, etc.) and trace how a particular behaviour, movement, or design trope, carries over to new instruments (the Greek *organon*, for instrument, is etymologically related to *ergon*). This product of transduction or “carrying over” might therefore be called an *ergophore* (like a metaphor), as it “contains” the trope, the embodied inscribed pattern of motoric memory over to a new physical object, a new instrument. Finally, in a musical instrument we have infinite dimensions for expression. The instrument has a latent potential, some directly perceivable as affordances, others more hidden and discovered as constraints (Magnusson 2010). This discovery of an instrument is a dynamic process, it happens through time, and through it we find the object’s power and potential (*potens*, *dyna-*

mis). In Greek, the power of a word can be called dynamis, as well as ability, skill, value. I do think that we can benefit from the concept of *ergodynamics* when analysing musical instruments. This concept expresses the instrument's potential for expression, what lies in it, not directly perceivable (like affordances) and not simply its limits (like the constraints), but an acknowledgement that the instrument is an object that never rests, every time we pick it up there are new things to discover, new patterns our fingers know (from another instrument? From typing on an ascii keyboard? From cooking?)

To take a concrete example of such an ergography, we could take the *swipe* ergophore as an example. This movement is familiar to us as we turn the pages of a book or a newspaper, or operate with other layered objects, such as a deck of cards. For the HCI designer who wanted to represent stacked information, the swipe is therefore an ergomimetic implementation of a well-known human action. We could then talk about the ergodynamics of a PDF reader mobile app, as it supports well known actions from book reading books, but it also supports things such as zooming into the text, copying it, highlighting, and so on.

4. The Semiotics of Ergomimetic Design

Translation, implantation of metaphors in design, derived from actions in a source domain (the flicking of a book page becoming a swipe design in a screen-based device), thus *ergophores*, is a striking character of new musical instruments. They are novel and alien objects in our new world, but they pretend they drag with them the culture of the past. They want to be something they are not, but through that, they become what they are. This refers to electric as well as digital instruments. Like Ihde's dentist, who with a metal probe is able to find irregularities in the tooth, experiences an extension to the body, and amplification of sense, yet losing experience

too, for example the warmth and wetness of the mouth (Ihde 1979, p. 21.)

Mapping is therefore a key difference in the way new musical instruments work. From a semiotic perspective, we could apply the Peircian trichotomy (Peirce 1955) that divides signs into the types of *icon*, *index* and *symbol*. Briefly explained, the *iconic* sign is one where the represented thing resembles, imitates or reflects the qualities of the signified object. A statue, a gendered toilet sign, or onomatopoetic words are iconic. They physically resemble (visually, sonically, etc.) the signified. The *indexical* sign does not have to resemble what it stands for. However, it is directly connected to it, for example foot prints in the snow are indexical signs, or a phone ring tone. These are learned signs, but they contiguous with the origin. Finally, *symbolic* signs are arbitrarily assigned structures where the signifier and the signified might have no relation at all. This is based on convention, and a population of users. Peirce notes that these signs often overlap, and, for example, that a symbolic sign might contain an iconic element.

This semiotic model can be applied to the manner in which musical instruments work, in order to understand and try make explicit a certain unease of qualitative differences between acoustic, electronic, and digital instruments. Here we note that acoustic instruments are of *iconic* nature: the string on the guitar is at the same time the sign, the interface, and the sound source. There is a direct and necessary relationship between interface and sound, one based on acoustics or physical laws. Electronic instruments can be seen as *indexical*. There is a link between the sign and the signified (e.g., between the filter knob and the filter behaviour) and this link is contiguous. A voltage controlled low-pass filter works a certain way, and its behaviour is clear. We might however wire the knob such that it increases the cut-off frequency when we turn it to the left, and decreases the frequency when turned right. That is a convention, an index, but it is not arbitrary, as the

behaviour is still based on the principles of electronics. Digital instruments are *symbolic* (and I have used the words “epistemic,” “theoretical” and “ergomimetic,” to signify from different perspectives that open yet machinic mapping between input and output). The mapping between the interface element, whether screen-based or physical, is arbitrary: there are no natural laws that limit our design options. A soft touch could result in a loud sound, and vice versa. A lively acrobatic gesture might result in a timbrally simple sound, where no movement could yield a sound of rich sonic spectra.

It is therefore relatively uncomplicated to notate for iconic instruments, a blob on staff represents a pitch (or even an action), but it has a location on the fingerboard, and an expected setup on the instrument. It is not so easy to create symbols for the behaviour of electronic instruments. The instruments are unstable, they are never the same (it is well known that you can never get exactly the same sonic structure on a modular synthesizer), so the symbolic notation can hardly refer directly to a defined outcome. Thus, we might apply more imprecise notation for imprecise instruments. The trouble triples with digital instruments. They change like the wind, a parameter in the code could result in a

very different instrument, the sound engines change as well as the mapping engines. For the composer, it is not clear then what kind of object is being notated for. Here the notation has to be not of pitch or tempo, but of general design: the notation becomes the structure of the instrument itself, for example in a Max, Kyma, Pd or SuperCollider patch. That becomes the notational piece, just like a graphic score or the Greek music theory, and the performer improvises out of that platform.

This “problem of notation” ceases to be a problem when we consider how musical practices change with the advent of the new instruments. The former roles of composer, performer, instrument maker, sound engineer, audience member, etc. begin to unite, in different ways for every new piece of instrument, work, or installation, transforming our concepts of notation, musical work, and performance.

Conclusion

This paper has articulated the problems we are experiencing today with all the new instruments invented, typically through an ergomimetic process, yet they cannot infiltrate the established culture of traditional musics, from classical and

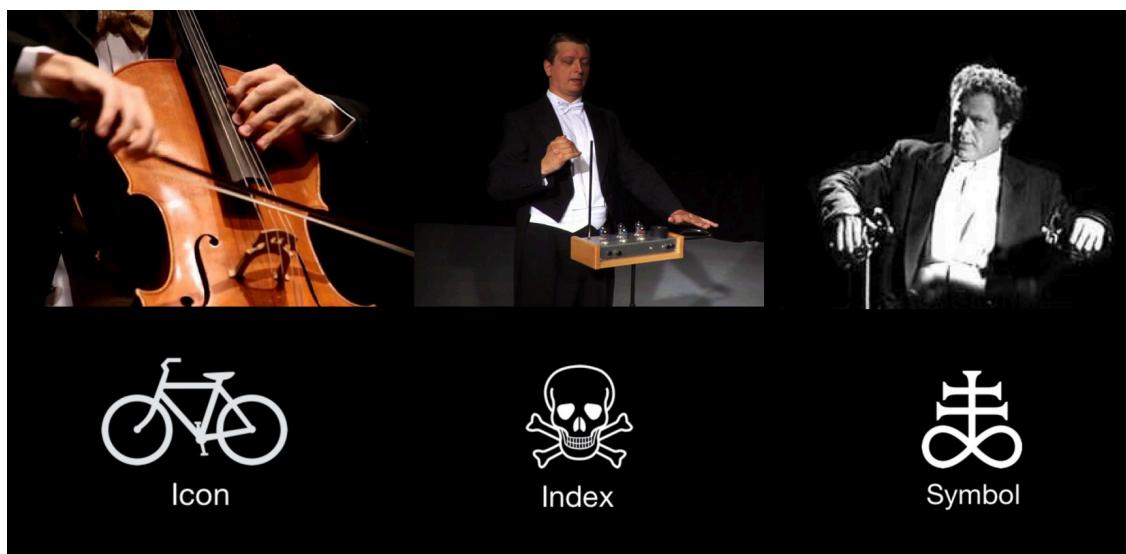


Figure 3. The different semiotic mapping modes in musical instruments (Steven Bradley - www.vanseodesign.com)

jazz to popular music. The new instruments are in a particular solipsistic void where they work on their own, as a theory of music that fits their designers musical purpose, but they are often poor for ensemble or orchestral contexts where they form part of an improvisatory or notated musical performance.

This speculative paper has introduced preliminary thoughts regarding the semiotics of mapping in new instruments and how they relate to the ergomimetic translation process of moving actions, ideas, techniques, and physical design from one domain to another – the physical, the electronic, and the digital are distinct, albeit at

times overlapping, platforms that share proprioceptive or kinaesthetic action, musical ideas, design, yet on a material substrata so completely different. The paper proposed ergonomics, with affiliated cluster of words, as an HCI, NIME, and musicological terminology for defining the processual potential of an instrument, what it offers in terms of musical potential, how one plays it, and what it brings from other musical contexts (traces of other musical contexts). Just like the game critic expresses that a particular video game has a good gameplay, we want to be able to say that an instrument has an interesting ergodynamic.

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Instrumentality, Perception and Listening in Crossadaptive Performance

Marije Baalman¹

marije@nescivi.nl

Simon Emmerson²

s.emmerson@dmu.ac.uk

Øyvind Brandtsegg³

oyvind.brandtsegg@ntnu.no

¹ Nescivi, Amsterdam, The Netherlands

² De Montfort University, Leicester, UK

³ Norwegian University of Science and

Technology, Trondheim, Norway

Abstract

Crossadaptive processing describes situations where one performer's output effects the audio processing of another, thus imposing direct modulation on the sound of another performer's instrument. This is done by analysis of the acoustic signal, extracting expressive features and creating modulation vectors that can be mapped to audio processing parameters. Crossadaptive performance can be situated between the performance practices of the audio processing musician, augmented (acoustic) instruments, live algorithms, group improvisation and interconnected musical networks. The addition of crossadaptive processing to these musical practices brings up questions of agency and instrumentality. Performance with crossadaptive techniques produces complex behaviours that are difficult to describe by the performer or the listener. This paper covers issues of transparency & technical language, instrument and ensemble learning. For the performer a shared ensemble identity may emerge. And for the listener we discuss the role of intention and emergent musical behaviour.

Keywords

Feature extraction

Modulation

Live processing

Crossadaptive performance

Instrumentality

Agency

Improvisation

Introduction

The current paper explores issues encountered in the project “Cross-adaptive audio processing as musical intervention”. Digital audio analysis methods are used to let features of one sound modulate the electronic processing of another, allowing one performer’s musical expression on her instrument to influence quite radical changes to another performer’s sound. This action deeply intervenes with the performance environment for the other musician. The continuous timbral modulations imposed on one’s own instrumental sound enables new forms of creative interplay, and at the same time inhibits some learned and habituary modes of performance. Listening, anticipation, preconception, and thus motivation to exert said modulations are closely linked to expectation and familiarity. The project method is thus based on iterative practical experimentation done in studio sessions. Sessions are documented by multitrack audio and video recording, and reflections supported by short personal video interviews with the participants. Documentation is an integral part of the reflection process in the research project. The documentation is also made publicly available in a research blog.¹ Development of processing tools and composition of interaction mappings are refined on each iteration, and different performative strategies explored.

1. Crossadaptive processing and signal interaction

Interaction between two or more audio signals has been used for creative sound design purposes in a number of contexts. Stockhausen’s use of *Ring modulation*, Laurie Anderson’s use of *Vocoder*, and the *Auto-wah* effect on Stevie Wonder’s clavinet are examples of adaptive and crossadaptive treatments. Similarly, the pumping effects of *sidechain compression* is ubiquitous in pop music of the last 20 years, an example is Eric Prydz’ *Call On Me* from 2004. In the same period, we have also seen extensive research into adaptive (e.g. Verfaille, Zolzer and Arfib 2006) and intelligent (e.g. Reiss 2011)

effects for music production, and more recently these techniques have been put to use for live performance (e.g. Fasciani 2014, Brandtsegg 2015). The activities in this field use signal analysis to extract control vectors for use of parametric control of effects processing. Many of the feature extraction methods come from the field of music information retrieval, but the utilization of these features to form control signals for processing lies within crossadaptive processing. *Crossadaptive performance* relates to the use of crossadaptive processing for live performance, where the musicians are enabled to modulate the sound of each other’s instruments. Assuming that a musician relates intimately to the sound of her instrument, allowing another musician to change the sound on the fly will enable radically new forms of interaction, between performer and instrument as well as between performers.

In addition to the feature extraction and modulator mapping described above, our exploration of crossadaptive performance has also included processes of more direct signal interaction between two sources, for example with convolution, where we have adapted the technique for live interaction by devising a method of continuous update of the filter (see Brandtsegg, Saué and Lazzarini 2018). *Convolution* has some interesting implications for signal interaction, as the temporal characteristics as well as the spectral profile of one signal are imposed on the other.

2. Situating crossadaptive processing in other performance practices

Crossadaptive performance can be situated between the performance practices of the audio processing musician, augmented (acoustic) instruments, interactive music machines or live algorithms, group improvisation and interconnected musical networks, but also has distinct differences from these practices. An audio processing musician’s role is to process the sound of another musician (or multiple musicians). Most often the instrument pro-

¹ <http://crossadaptive.hf.ntnu.no/>. In the footnotes in this paper linking to particular entries of the blog we use shortlinks.

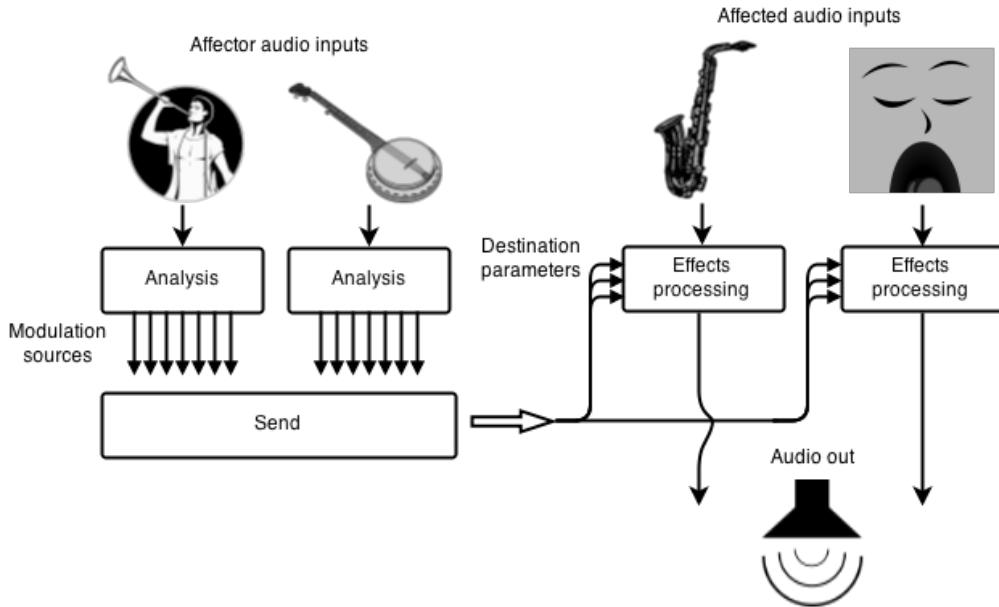


Figure 1. Analysis of expressive features generates modulator signals (Brandtsegg 2015)

cessed is an acoustic instrument. The artists Dafna Naphtali and Joel Ryan are examples. They have developed a set of realtime audio processing units and control interfaces for live performance. During the performance they use these tools as they make decisions on which to use while responding to the acoustic and the combined sound they create. The decisions they make are as much based on experience gained through building their tools as performing them in different situations with different kinds of musicians (Naphtali 2016). While playing, a dialogue unfolds between the musician whose sound is processed (who will adapt his playing based on the effects on his sound) and the processing musician.

Various musicians have augmented their acoustic instrument to process the sound. The acoustic sound is captured, analysed and processed during performance, controlled by sensors mounted onto the instrument. Examples of augmented instruments are Gibson's modified cello (Andersen and Gibson 2017) and Leeuw's electrumpet (Leeuw 2009). The latter also makes use of auto-adaptive processing of the sound.

Interactive music machines or *live algorithms* usually consist of a set of analysis methods to determine what a musician is playing and some sort of system to create a sonic response to what the musician is playing. Besides live processing, often these algorithms operate on a longer timescale, giving musical phrases back in response to phrases that were played by the human performer. A live algorithm can: 1) collaborate actively with human performers in real-time performance without a human operator; 2) make apt and creative contributions to the musical dimensions of sound, time and structure; and 3) contain a parametric representation of the aural environment which changes to reflect interaction between machine and environment (Lewis 2007).

Group improvisation is a practice where a group of musicians plays together to improvise together: that is, they do not have a pre-conceived score that they play, rather each musician draws on their own skill in playing their instrument and by playing together and listening to each other, a joint sonic experience is created. Often there is a notion that the sound created together is more than the sum of its parts and

by improvising together the musicians inspire and challenge each other allowing each to find new ways of playing their instruments. Weinberg (2005) discusses interconnected musical networks. His examples involve completely electronic or digital networks, but the crossadaptive performance setup also fits well into his description, and the theoretical framework he presents can be used to further analyse and understand crossadaptive performance situations.

With crossadaptive processing the sound of an acoustic instrument is augmented through processing, similar to the audio processing musician in that one musician is processing the sound of another musician. However, there is a distinct difference in that the control over this processing is indirect: it depends on the acoustic features or musical qualities of the sound another acoustic musician is playing, rather than explicit control using sensors and controllers. The setups for crossadaptive processing are similar to live algorithms in that the algorithms are decided upon and fixed before the performance. The choices for which analysis features to use to control certain processing parameters, and the choices for which processing algorithms to use and which parameters to control are made before the musicians start to play. Of course, these design choices can be and often are informed by previous playing sessions. Also there may be a choice to play with different sets of crossadaptive entanglements, thereby dividing the live performance into different sections. In the connections that are made, usually the effect is taking place *in the moment*, that is the algorithms do not perform by themselves on higher level time structures of the music.

A crossadaptive performance is a special case of a group improvisation with the added entanglement of the instruments through the crossadaptive connections that are made between the acoustic instruments. For the performer being modulated then, there is a filter into which one's expression on the instrument must pass. Cobussen (2017) in his theory of *Field of Musical Improvisation* understands musical improv-

isation as a nonlinear, dynamic and complex system in which various actants are at work: not only the musicians, but also "space, acoustics, instruments, audience, technicians, musical and socio-cultural backgrounds, technology, and the like all play a significant role". He also stresses the singularity: "each improvisation thus yields a different network of actants and interactions, a unique configuration or assembly." When we look at the performances that were done during this project, this insight helps us to understand the crossadaptive interaction.

3. Notions of instrumentality

Looking closer at what happens during a crossadaptive performance, questions of agency of the musician and the musical instrument arise. In the discussions following the crossadaptive playing sessions, one musician remarked: "It is like giving away some part of what you've played, and it must be capable of being transformed out of your own control"². This remark hints that the single musician is giving some of their sound to another agency within the performing context. In the discussion around the *live convolver*³ that was developed the musicians noted that they could be either in control of the timing of the musical events or of the sonic texture.⁴ Notably also different musicians found one form of control more comfortable than another, presumably based on different modes of music making (e.g. more biased towards the timbral image, the temporal phrasing, the gestural energy flow, etc.). Other concepts that arose from the discussion of the playing within a crossadaptive setting were the notion of *control intimacy*: how close the physical gesture is to the sound that is created and *reactive inertia*:⁵ how fast the player can change the sound she is playing.

A pianist remarked "It felt like there was a 3rd musician present."⁶ And this points to the notion of the crossadaptive processing having its own agency, similar to Peters (2016) observation when playing in a physically interconnected assemblage of instruments: "We understood that we were dealing with an unfamiliar other,

² <http://wp.me/p7UOyo-ci>

³ In the live convolver the sound of one musician is captured in a buffer. This buffer is then used as an 'impulse response' with which the sound of the other musician is convolved. For a more in-depth description, see (Brandtsegg, Saue and Lazzarini 2018).

⁴ <http://wp.me/p7UOyo-e0>

⁵ Described in blog post <http://wp.me/p7UOyo-e0#reactive>

⁶ <http://wp.me/p7UOyo-cE>

and we kept the shared imaginative connection we had immediately made between the natural agencies (...) and that voice's agency intact".

Alperson (2008) argues that "ontologically, musical instruments need to be understood as musically, conceptually, and culturally situated" and as "an amalgam of material object, the performer's body, and bodily dispositions as habituated by the developments of various musically related skills" (including not only those of performers but also of instrument builders, composers and the audience). He argues that "musical instruments must be understood as instrumentalities in the context of human affairs". He writes "what the performer does is perform a work with an instrument that is at once both *recalcitrant* – insofar that it must be 'mastered' so that the instrument can be utilized in the service of the production of musical works – and *intimate* – insofar as musical instruments are inevitably connected with the bodies and bodily actions of performers" (our emphasis). He recognises the performance as a 'work-in-performance' that is "doubly bound in consciousness" in that it can be appreciated aesthetically in terms of its instrumental accomplishment: appreciating both "the performance of the work, as the performance *in* the work." (our emphasis).

Peters (2016) extends Alperson's concept with the notion of *shared instrumentality*, which can vary over time. He uses the term *distributed instrumentality* for the idea that many instruments join up to form a single instrument (e.g. in an orchestra) and then describes how over the course of a performance instrumentality can shift between its *individual* (monadic) and *distributed* (shared) forms as *individual* sonic territories are negotiated with the *interdependence* of decision-making and the creation of *shared* gestures. In the example of his assemblage performance with his ensemble he describes how the environmental agency (that comes out of the physical interconnection between the instruments the performers are playing) can enter and contribute its intrumen-

tality, "the interconnectedness of the instruments creates a new instrument". The listener to the ensemble can then at the same time appreciate the "*technical* accomplishment and the virtuosity; she can also appreciate the performers' interpersonal accomplishment and virtuosity" (his emphasis).

In view of Alperson's discussion (2008), the instrumentality of crossadaptive processing encompasses both the creation and building of the crossadaptive connections between the instruments before they are performed, and the performance with these connections. The instrumentality of the performers that they can build up then encompasses (similar to the 2nd order instrumental skills of Marques Lopes, Hoelzl and De Campo (2016)):

- familiarity/knowledge/implementations of feature extraction for their (acoustic) instrument,
- familiarity/knowledge/implementations of processing for their (acoustic) instrument,
- experience in playing in different constellations (with different musicians playing different instruments),
- and in the moment of performing in a particular setup: the accomplishments within that performance.

Similar to Peters's (2016) physical interconnectedness of instruments, in the crossadaptive setting (where the interconnections are made by algorithms), the musician has to balance her own individual sonic territory (the direct sound of her instrument) with the shared sonic territory (emerging out of the processing of her instrument's sound controlled by the other musicians sound, and the processing of the other musicians' sound based on analysis of her own direct sound). Meanwhile the other musicians are also navigating between this individual and shared territory. Depending on how the interconnections have been set up, it may be that there is almost no possibility to create an individual gesture as it is always (also) a shared gesture.

Equivalent to Peters's (2016) ensemble setup, the crossadaptive interconnectedness of instruments can be seen as an environmental agency, although we can also argue, especially in the case of multiple musicians being interconnected in different pairwise ways with other musicians (e.g. between saxophone and guitar, guitar and percussion, and percussion and saxophone.) that a multiple of such agencies emerge out of the performing together. Lewis (2018) writes "Through improvisation, with and without machines, and within or outside the purview of the arts, we learn to celebrate our vulnerability, add part of a continuous transformation of both Other and Self." In improvisation with crossadaptive processing, this vulnerability is mutual and interdependent.

4. Discourse and communication – How we talk

In analysing how we perceive and talk about performance, there is a tension between the viewpoint of the performer and the listener, and also between the experiential (phenomenological) and the technical approach. On the technical level, the performer has an understanding of her own acoustic instrument, the methods used for feature extraction on the sound of her instrument, and the effects this will have in modulating the instrument sound of other performers in the ensemble. Also she knows what features from the other instruments will control the processing of her own sound. During the performance, the performer has an embodied experience, where she has an active influence on the process. At this moment there may be a tension with the desire to forget about the technical implementation while performing. Borgo (2005) describes this desire in Evan Parker's music as a shift from left-brain to right-brain activity and "although (Parker) had worked diligently to establish these extended techniques, he believes the best parts of his playing to be beyond his conscious control and his rational ability to understand." Thus being able to forget about the techniques may improve the experience of performing. However,

to be able to adjust and improve the experience, an understanding needs to be gained on what aspects of the technical implementation worked and which did not, so they can be adjusted.

During the performance the listener has an experience of listening to the music, the music affecting his mind and body in a non-analytical, non-verbalised way – the experience of being there in the moment in the same space with the performers. At the same time, the listener is curious about what is happening and may attempt to analyse what is going on: Who is creating which sound, who is doing what? What are the interactions between performers? The socio-cultural, musical and technical background of the listener as well as the information provided by the performers and the event organisers will affect this analysis and how the listener can subsequently verbalise her understanding of what happened during the performance. For the performer and listener to discuss the performance, awareness of these different levels of understanding and making translations between these levels is important: a listener may have observed important interactions between the musicians, but verbalise these in a way that is not directly understandable to the performer. And vice versa.

5. The crossadaptive instrument

Musicians generally learn (in any style or genre) through a variable mix of two approaches. On the one hand small increment demonstrations⁷ – more atomistic, from which larger ideas are built up – and, on the other, the practice of learning through creative play – more holistic, which may be broken into smaller chunks on reflection.⁸ In crossadaptive performance the challenge is that there must be at least two mutually interactive performers who must learn their instrument together. A specific aim – a desired change or end – may not be feasible; indeed a rational choice may only be possible in the most general terms.⁹ We might wish to have a binary 'we do' or 'we do not' know the outcome of an experiment. In practice, however, while learning

⁷ For example Trond Engum's documented sessions are excellent examples of small increment learning.

⁸ For example the session at UCSD Studio A, June 2017, complex mappings were used with a more holistic explorative approach.

⁹ NTNU meeting discussion June 2016.

a new system such as this, performers become aware of a range of more general possibilities. It may be we need to shift from control intimacy to much more *fuzzy causality* – this type of action will have this *range* of possible results. The mapping of action to result is no longer simple.

The recursive interaction of crossadaptive processing creates a potentially unstable mapping. There is (probably) no longer a direct linear causal relationship to any result. While we might expect the possibility of a kind of ‘chaotic anarchy’, many of the learning and practice sessions¹⁰ show that rehearsal acts as a ‘control filter’. A criteria that emerges in discussion and observation appears to focus on making ‘ecological’ sense (or not) of the possible results. This strongly suggests that the mapping need not be conceptualized in detail but that metaphoric and more general descriptors emerge as more useful. Contributors to one discussion likened this to learning to balance on a high wire or to ride a bicycle. So we see developing an ‘immanent’ or ‘emergent’ description of the results – holistic and not detailed. Our language makes a transition from a local to a global description. This shifts issues of control or influence over what is performable. A holistic approach allows other modes of control: “... not to intellectually focus on controlling specific dimensions but to allow the adaptive process to naturally follow whatever happens to the music”¹¹

6. Perception, imagination, intentionality, emergent qualities

The question of sound monitoring in such a complex performance situation needs to be addressed and this effects how we can “play by ear”. Several of the performers on the cross-adaptive project also commented on this. For example Kyle Motl and Steven Leffue in session reflections.¹² This also raises the question of “is it important enough to the performer to effect this change in another musician’s sound, so that she will switch from what she was otherwise about to play?” As open an issue as this may be, one can imagine it has to do with the degree of

preconception. If the musician can preconceive the effect, then there might be an urgency and a will to do what is required to effectuate that change. Then again, we see some particular areas of conflict, where the desire to play (or not play) something might conflict with the desire to control some parameter. The roles of “playing as a controller” or “playing as an independent instrument” can be used to indicate some of this conflict.

So is this music interesting in itself as music or is it interesting merely by means of its production methods? Indeed some of the musically interesting features of the music are connected to the modulation interaction patterns. One could object that this makes it merely intellectually or technically interesting. Then again, just as a random example, say, when Thelonius Monk attempts to play microtonally by means of using clusters of semitones, there is an interesting musical negotiation between intent and instrument. The manner in which the characteristics of the instrument are explored to express the initial creative impulse makes this music have an additional layer of fascination available.

Finally and most importantly there is the issue of intentionality – not a new discussion but very important here. The traditional form of the question might be ‘Does what the creator intends matter?’. But we have confused this issue here – above, we suggested that with crossadaptive processing scenarios we may have only very vague (fuzzy) notions of what might happen next – so our intentions likewise cannot be specified exactly *a priori*. This may have no bearing on whether this makes the music ‘good’ or ‘better’. ‘Did you hear what was happening?’ could be asked by a listener. What does it mean: ‘To hear a process’ – this is not the aim (we suggest). Too often this implies a kind of technological listening – do you hear the technical processes? Do you ‘decode’ how these operate? Let us ask instead ‘Do you hear what is happening *musically*? For that we hear the *results of the process* – the sense of an *emergent* quality that comes about through a procedure the listener may not

¹⁰ For example the seminar of 16 December 2016.

¹¹ <http://wp.me/p7UOyo-e0>

¹² <http://wp.me/p7UOyo-fw#playbyear>

be able to identify or describe. Thus, as we have already remarked, the listener may have no need of knowing, or any means to know, the details of a crossadaptive interaction. Other overall characteristics may emerge – in performativity: senses of play, exploration, interaction, or in the musical material: timbral, textural. The sense of fluid flow in its many manifestations is one such common emergent property.

So we have an interesting additional duality here – can the performer hear the emergent property to which they contribute? Well, maybe. There are some issues here that are technical, philosophical and ethical at once. Treating the individual performer as a ‘cog in a machine’ – only aware of the immediate cogs surrounding – is a continuation of a long tradition within western art music. If, however, we wish to empower the performer to take performative decisions (however fuzzy) then this question becomes immediately more complex.

7. Evaluation and reflection on potential

As we have seen in practical experiments, the issue that one performer’s actions modifies another performer’s sound has some profound musical consequences and implications. Since the performer cannot necessarily expect to follow up her statements, the opportunity to build form on various levels has been punctured. Then, with these clearly limiting factors, what makes it worthwhile? The musical action of crossadaptive processing has some potentially attractive features that we could say belong to the compositional: allowing one character/gesture/motif to reappear somewhere else and thus create connections in the compositional whole. With crossadaptive performance, these connections would most often be synchronous. Something changes in a particular manner in one part of the sound world, while something else changes in perfect synchrony somewhere else. Still, it is not simple mimesis, the connection will most often be blurred because it also depends on a complex set of factors.

The potential for co-creation and interconnected timbral modulation gives birth to a new set of affordances. Overcoming the flip side elements may well be a question of mastering the new, collective instrument. One could argue that we, after more than two years of exploration, should have gotten some sort of control over this. Then again, part of these two years have been spent identifying (and getting to know intimately by performance) the problems, and also actively seeking to discover potential unknown problems by working with diverse groups of performers. Perhaps the mastering of the collective instrumentality, and the environmental agency is one of the biggest challenges.

One could also argue that the instrument design to a very high degree determines the musical potential and the modes of exploration. In this we include the selection of effects to apply to process the sound, the features to extract, and how exactly to map them. The mapping from features to control parameters can be characterized along a dimension from simple to complex, direct or indirect. A simple mapping can be easy to understand for performers and listener with a perceptually direct connection between action and modulation. More complex mappings can enable intricate relationships and rich environments. Some parts of the mapping may only be enabled under certain conditions. Such complexity can enable the construction of a rich potential for intricate expression or it can result in obfuscation and lack of control intimacy. If this seems exaggerated or contrived, in terms of the number of active control parameters and their mappings, think of the situation with a traditional acoustic instrument like the violin or the human voice. There are literally dozens of control parameters of varying influence on the sound, and some of them are only active on the condition of the activation of other control parameters. The most radical aspect of crossadaptive modulation is thus that the conditions of activation may lie in the hands of another performer.

Control intimacy as coined by Moore (1988) allows an open interpretation, but is commonly used to signify an instrument's facilitation to minimize the distance between the performer's intent and the musical outcome. In such an interpretation, crossadaptive methods will in many cases lessen the control intimacy. However, we might argue that the control intimacy of cross adaptive performance is greater than elsewhere, because it is symbiotic and dependant on conditions. The actions of the other performer enables certain nuances within my expression. Control intimacy is not a static feature of the instrument but is dependent on skill, and in this context also on interaction with the other performer.

8. Conclusions and future directions

We have looked at the relatively recent practice of crossadaptive performance, and situated it in the light of other electroacoustic and improvisational performance practices of the last few decades. As part of the investigation, we have also looked at the instrumental agency and the shared instrumentality that naturally arise in the context of crossadaptivity. To discuss the process we found that we needed to balance the phenomenological (holistic) and the technical (atomistic) approaches, as well as consider the viewpoints of the performer and the listener. This somewhat phenomenological approach is also suffused by an evaluation and a reflection on the yet-to-be-tapped source of intimately tuned musical expression enabled by these techniques.

After two years of intense exploration, it seems the field has more the character of an explosion of potential directions than a condensation and stabilization. It is clear that the crossadaptive mode of performance requires specialized skill and that further experimentation with a select few performers may be fruitful. Simultaneously, we see a huge variety of approaches, even

within our relatively small group. Perhaps 50 performers have been in direct contact with these techniques within our research project, and with the variety seen here, one could expect other groups of performers to come up with wildly differing perspectives and vantage points. As such, one important part of future work is to make the work methods more easily accessible for performers and researchers outside of our group. We also see that others are already picking up alternate modes of utilization.¹³ Other use cases might involve expressive control of technology in a wider context, say, like voice control of devices and environments. Crossadaptive techniques involves methods of expressive analysis that might enable nonverbal emotive control of such responsive environments. These are but a few of the yet unexplored directions.

¹³ For example in the project "Goodbye intuition" currently being conducted at the Norwegian Academy of Music.

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Before Ink Starts to Blink

Scripts and Diagrams on Paper as Interfaces for Machines and Humans (in Creative Processes)

Michael Rottmann
michael.rottmann@fhnw.ch

Academy of Art and Design Basel /
University of Applied Sciences
Northwestern Switzerland

Abstract

Creative processes, which can be treated as live performative acts, are seen nowadays as an interplay of humans, materials, media and machines. Interfaces are a part of this and often understood as technical devices, which bridge between humans and machines – Ivan Sutherland's *Sketchpad* counts as a prime example for it. Picking up this historical case this media-theoretical paper wants to introduce scripts and diagrams on paper as interfaces for machines and humans. Coming from historical case studies it will be shown that both media with regard to their operativity have to be considered even as "auto-interfaces", which allow for example to influence someone's self. Therefore scripts and diagrams as well as the interface-concept will be reflected media-theoretically. Thus, the paper expands the interface-discourse and links it to media theory, especially to diagrammatics and notational iconicity and provides a better understanding of creative processes based on handwriting or -drawing.

Keywords

Interface
Interactivity
Script
Diagram
Media
Machine
Computer
Creative Process
Art & Science

Introduction

On January 7th, 1963 the electrical engineer Ivan Sutherland submitted his doctoral thesis at Massachusetts Institute of Technology about a computer system, which he developed in the field of computer-aided design-research. He wrote: "The Sketchpad system makes it possible for a man and a computer to converse rapidly through the medium of line drawings." (Sutherland 1963, 8) His graphical user interface (Figure 1), is nowadays seen as ground-breaking (Pias 2002, 60ff), because it marks the change of the computer from a machine of experts to one of everyman (Pratschke 2008, 68). Since this time an interface is understood foremost as a so-called human-machine-interface (HMI). Thus, the term "user interface" describes today these components, which provide a place like a surface,¹ where humans can act, to interact with a machine and control it (Pias 2003). The interface serves as a "bridge"² (Hellige 2008a, 7). Instead of only pressing buttons on a keyboard,³ in *Sketchpad* one can point at something and operate (in combinations with buttons) on a screen. For our purpose, it is important to notice that the term "interface" does not mean necessarily a human-machine-configuration. *Merriam Webster's Collegiate Dictionary* characterized an "interface" in 2003 as "the place at which independent and often unrelated systems meet and act on or communicate with each other" and further "a surface forming a common boundary of two bodies, spaces or phases".⁴ The description "two phases" refers to the origin in the fields of chemistry at the end of the 19th century and electrical engineering, where it denotes the boundary layer or surface of two liquids or the transition between technical components of a system. At latest in the 1950s it was widened out onto the interaction between man and machine (Hellige 2008b, 13). Hence hardware-interfaces, hardware-software-interfaces, software-interfaces, network-interfaces and last but not least human-machine-interfaces

have been distinguished.⁵ But the article in *Merriam Webster's Collegiate Dictionary* makes aware of two important aspects: First, it is not spoken of machines at all, but in a general, unspecified meaning of "unrelated systems" and explicitly of "bodies". Actually, the term "interface" is related also to "human-human-interfaces" which is even illustrated with a pictogram in the dictionary for computer science *Duden Informatik* in 2001.⁶ And it is explicitly not meant a human-human-configuration based on a machine, especially when the distribution-property of the internet is used for chat, e-mail, etc. (Goertz 2004, 99). On the contrary, in literature the human-human-interface (HHI) is described as independent and antecedent to the technical sphere (Balasis 2003, 246f).⁷ It is even indicated that HMI-design profits by the analysis of human-human-interfaces.⁸ The second aspect is that communication is distinguished by interaction. This is important, because interfaces can serve for both. A precise differentiation of the terms, which have become in our daily use fuzzy and often synonymous, is not easy, because their relationship is described in disciplines like communication theory, sociology or computer science in different manners, sometimes as subsets of each other, sometimes as independent from each other and sometimes as only appearing together (Neuberger 2007, 36ff). For a better understanding, a short reconstruction shall be provided:⁹ Originated in sociology, "interaction" means (according to the German term "Wechselwirkung") an active, consciously two-way or reciprocal influencing of persons on each other to coordinate actions or behaviour (Neuberger 2007, 36; Goertz 2004, 98). Because successful interaction requires an adequate interpretation by all participants concerning the actions, motivations and purposes of the counterparts, some authors argue that social interaction has to be considered always as communication, which can be understood as an exchange of information via language for an understanding among humans (Neuberger 2007, 36f.; Jäckel 1995). This sociological

¹ Also three-dimensional spaces (equipped with sensors) can function as interfaces.

² All translations from German to English language are done by the author.

³ Whirlwind-MIT-team was talking in the 1950s about "keyboard interactions" (Hellige 2008b, 32).

⁴ *Merriam Webster's Collegiate Dictionary*, 11th ed., s.v. "Interface."

⁵ Duden Informatik, Ein Fachlexikon für Studium und Prax-

is, 3d ed., s.v. "Schnittstelle."

⁶ Ibid.

⁷ French phenomenology argues, that there is always an interaction between our bodies and the surrounding world (Halbach 1994, 140ff.).

⁸ Ibid.

⁹ See also *Grundbegriffe der Medientheorie*, ed. Alexander Roesler and Bernd Stiegler (Paderborn: Wilhelm Fink Verlag, 2005), s.v., "Interaktivität." and GamesCoop 2012, 80ff.

notion of interaction was transferred onto the processes between human beings and computers, to indicate the leap in quality from a serial batch-program to a dialogue mode (Pias 2002, 60).¹⁰ Although it is accepted that “communication in a language is the most important form of human interaction”,¹¹ interaction can also happen without it (Luhmann 1993, 81). For example, when two tightly entwined organisms react to the movements of each other, neither using a spoken language nor with exchanging or interpreting information consciously. Or how Ivan Sutherland puts it: “Boxers interact, but don’t communicate. Poets communicate but don’t interact.”¹² In other cases communication does not allow interaction, because it happens in a one-way or so called unidirectional mode, so there is no possibility of influencing each other (Jäckel 1995, 36).¹³



Figure 1. Ivan Sutherland's *Sketchpad* (1961-63).
Source: Evan Yares. 2013. 50 Years of CAD. *Design World*. 13.02.2013. <https://www.designworldonline.com/50-years-of-cad/> (22.02.2018).

Seizing on Sutherland's *Sketchpad*, which was linked to conventional drawing, I want to apply the concept of an interface to analogue graphical media script and diagram and make it productive for them, assuming, that not only “technical images” (Pratschke 2008) can serve

as graphical interfaces. The central question is: How can scripts and diagrams do so? To answer this, they will be characterized with more details. Because they are understood like the computer as a “medium of communication and information” (Hellige 2008a, 7), it must be shown, that they serve also for interaction. This will happen in three parts: In the first one, I want to show with historical case studies that scripts and diagrams on paper have a certain tradition to serve as interfaces in human-machine-configurations. Secondly, I want to demonstrate, that both function as human-human-interfaces with the example of a didactic situation. Finally, it will be explained, why scripts and diagrams could be understood as “auto-interfaces,” how I want to describe them. Therefore, interfaces here are not only diagnosed concerning their ontological properties, but also the practices and functionalities they offer. This happens on the basis of such interface-theories, which consider an interface more as a process combined with practices and not only as a product like a technical system (Drucker 2011; Galloway 2012).¹⁴ By introducing scripts and diagrams as interfaces this paper wants to illuminate and expand the interface-concept. To do this the interface-discourse will be linked up to diagrammatics and media theory and an interdisciplinary bridge build. Picking up thoughts of mediaphilosopher Sybille Krämer, especially the idea of operative media, this approach – media as interfaces – wants to fill at the same time a diagnosed gap in her media theory (GamesCoop 2012, 41), although she was describing script as an “operating room” (Krämer 2005, 23) and was bringing “interaction with symbols” and “computer user’s interfaces” close together (Krämer 2008b, 38). This approach can be also interesting for artists, because interfaces and interactive art are two sides of a coin. Finally, a better understanding of paper-based (artistic) creative processes will be enabled.

¹⁰ Although machines are not (yet) consciously acting (Fuchs 1991, 45). Mertens suggested to speak instead of “navigation” and possibilities of “intervention” and “control” (Mertens 2004, 273).

¹¹ Duden Rechtschreibung Online, „Interaktion,“ <https://www.duden.de/rechtschreibung/Interaktion> (accessed October 14, 2014).

¹² Ivan Sutherland, e-mail conversation with the author,

November 21, 2014.

¹³ For some authors a one-way communication is not a communication and only a multi-channel face-to-face-communication (with mimics and gestures) is accepted as interactive.

¹⁴ Similar to the concept “media” in media theory it was argued in a poststructural manner, that interfaces are made in a certain historical and cultural situation.

1. Scripts and Diagrams as Human-Machine-Interfaces

When Jack I. Raffel, employee at MIT informed Ivan Sutherland at the end of the summer of 1960 about the research interest of Lincoln Laboratories, to make the computer “more approachable” (Sutherland 1963, 24) using its display, it was a declared goal to improve the interaction between the user and the machine. This was a widespread thought and wish at this time (Brooks 1965; Hellige 2008b, 12ff.). To realize it, two strategies exist: Either the computer becomes more human-like or people must get engaged in the specifications of the machine. This is because computers work with invisible data and humans work sensually with visible, tactile and audible media, as mediaphilosopher Claus Pias explicated (Pias 2003). *Sketchpad* allowed a more user-friendly interaction with a kind of electronical drawing by pointing on the screen, assisted by a “light pen” and buttons, as Sutherland described it in his dissertation, and he points out: “The sketchpad system uses drawing as a novel communication medium for a computer.” (Sutherland 1963, 2) The crucial advantage was: “Except for legends, no written language is used”. Instead of programming the user handles geometric objects on the screen (with a light pen). Drawing on paper has become a showing on the screen, because the machine is working with signs of a prepared written program – an “auto-operative script” (Grube 2005, 97) – in the background, how computer scientist and computer art pioneer Frieder Nake argued (Nake 2008, 146ff.). In a MIT-documentation-video about *Sketchpad* from 1964, in which co-worker Timothy Johnson demonstrates the operating, Steven Coons, co-director of Lincoln Labs, explained: “In the old days to solve a problem, it was necessary to [...] write out in detail on a typewriter or in punchcard-form all the steps, all the regulations [...]” (MIT-Video 1964, Min. 2:36). With regard to punch cards Sutherland wrote in his dissertation: “[...] in the past, we have been writing letters to rather than confering with our computers.” (Sutherland 1963, 8) In the middle of the 19th century mathematician

and philosopher Charles Babbage used such coded ‘letters’, punch cards (or punched paper tapes), which were invented for Jacquard-looms, for its calculating machine *Analytical Engine*. The “orders to the machine” happened by “arrangements” of different “sets of cards”, each representing data, working steps and operations (Babbage 1989, S. 45f.; Hellige 2008b, 23). They gained a bigger prominence in the context of the American census in 1890, when engineer Herman Hollerith developed it further, to use it as a data storage for calculating machines (Figure 2). The punch card can be understood as a script¹⁵ on paper for a machine, which can be decoded only by an especially trained and experienced human. But different to other common and haptic scripts for humans like Braille, which was developed in 1825 and discussed as an example for the importance of spatiality in writing (Grube and Kogge 2005, 14.), the form and relative location of a single marking to another is not relevant, but the absolute location on the paper. Like in a Cartesian coordinate system the meaning is determined by the concrete position of an element in the field of a system. It is a symptom of a diagrammatic representation, when places, fields or areas are predefined semantically (Bogen and Thürlemann 2003, 7f.).¹⁶ So punch cards must be understood more as diagrammatic than written representations – diagrams for a machine.

The developers of *Sketchpad* wanted to replace such traditional paper-interfaces at least because of two reasons: They were machine-coded media, thus difficult to comprehend and communicate. And for problem-solving “all the steps” of a solution needed to be described in advance. Concerning this matter *Sketchpad* could be applied easier and more understandable (Nake 2008, 143f.) Solutions could especially be found interactively by trial and error in a creative process – (programming could also be experimented with, but in the 1960s the process was much more lengthily). But even more efficient and ergonomic would have been a human-machine-interaction, which is similar to the most basic human communication: natural,

¹⁵ Here meant in the sense of a notation and not a computer-script as a small program.

¹⁶ Space is also regarded as an essential ingredient of scripts, which are ‘living’ on the two-dimensional surface of the support, but it is the sheet of paper that – culturally determined – defines the surface in a topological manner (top, bottom, center, left, right) and its meaning (Schapiro 2006).

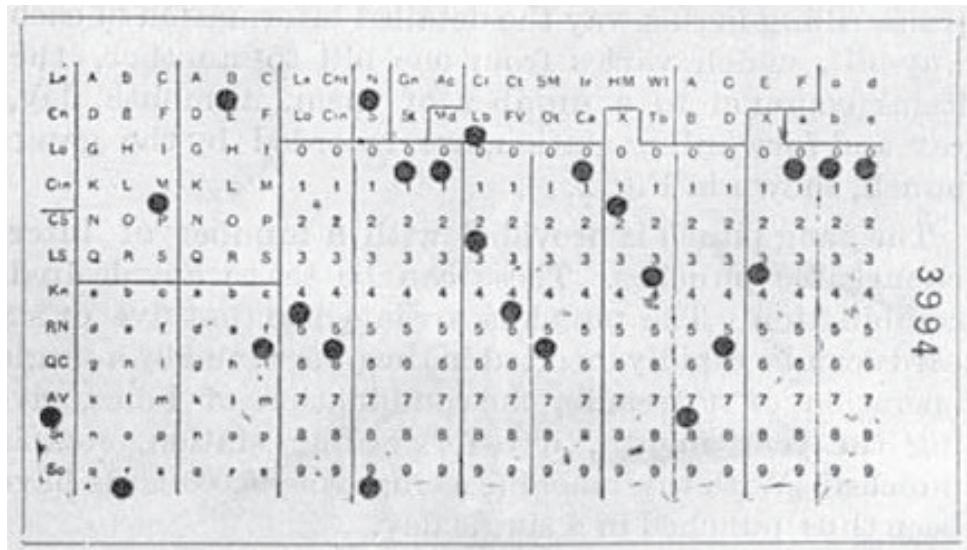


Figure 2. Hollerith-punch card in Railroad Gazette (1895). Source: https://en.wikipedia.org/wiki/Punched_card#/media/File:Hollerith_punched_card.jpg [03.10.2014]

spoken language. In this way *Sketchpad* was announced metaphorically in the MIT-demonstration-film as a “graphical language”,¹⁷ which could be used for “talking graphically”.



Figure 3. Still of the TV-show *I've got a secret*, CBS Television (18. November 1959) (Min. 6:50). Source: <https://www.youtube.com/watch?v=v2HM1DvQUdk> (03.10.2014).

The idea to communicate with computers via spoken or written words was in circulation at the latest since the 1930s. After initial positive results by analyzing spoken language, it became clear in the 1960s that voice recognition was not as easy to realize; stimulated by

pattern recognition, which was already used with punch cards, the idea of character recognition of text as a more human-like procedure was pursued (Hellige 2008b, 30ff). A computer like this, named *Analyzing Reader*, which could recognize text done by typewriter and print it as a punched paper tape, was invented in the 1950s by David Shepard and presented in the popular TV-show *I've got a secret* (1959) (Figure 3).

Even if the text does not serve explicitly to control the machine, it does it implicitly, because otherwise the text would not have become translated. In any case the information to control the machine could be saved in a natural language on a simple storage medium, again a sheet of paper. It can be read easily by humans, without technical equipment. Like the punch card, this example shows, that paper-based storage media were invented and applied as interfaces – (still today the machine-readable lottery ticket exists as a popular one). Optical character recognition (OCR) of handwritten text, which mathematician and computer scientist Alan Turing thought to be realized already in the 1950s, worked not faultlessly before the 1970s (Hellige 2008b, 30f.).

¹⁷ Steven Coons: “Now, he is going to be talking graphically, he is going to be drawing and the computer is going to understand these drawings. And the man will be using a language, a graphical language, that we call Sketchpad, that started with Ivan Sutherland some years ago, when he was busy with his doctoral degree.” (MIT-Video 1964, Min. 0:58)

In a historical review *Sketchpad* appeared at the right time, to satisfy the need for an easy human-computer-interaction. The system offered a third way: not speaking, not writing, but drawing as a familiar means of communication. We remember, Sutherland was talking about “[through] the medium of line drawings”, although he points out, that it is different to traditional drawing, namely “an active process which leaves a trail of carbon on the paper” (Sutherland 1963, 102). *Sketchpad*, that at the same time realizes and overcomes drawing on paper, shows the great importance of traditional graphical practices like drawing and writing. *Sketchpad* imitates the sketch and the geometrical and engineering drawing to a certain kind. A media-archaeology uncovers that Timothy Johnson refers in the MIT-demonstration-film to the tradition of graphical practices: He compares *Sketchpad* with a “pencil-paper-drawing” and explains the delete-function with “you have several pieces of paper” (MIT-Video 1964, Min. 6:08; Min. 8:45). He does it, to make clear that the electronic drawing would – different to paper drawing – understand what has been drawn. Last but not least, Johnson points with a gesture to the characters “INK” (MIT-Video 1964, Min. 4:29), which as an electronic script are blinking on the screen, being like a reminiscence to traditional writing and drawing done by hand (Figure 4). One can only speculate, if Ivan Sutherland was influenced by the popular animation series *Out of the Inkwell*. Its animator Max Fleischer reactivated it around 1960 and had invented the Rotoscope before as a device for creating it: a glass plane served both for projecting film on and as a drawing surface (Pointer 2017, 23ff.). In any case, *Sketchpad* itself gives reason to examine the potentiality of traditional graphical practices as interfaces, especially in times *before ink starts to blink*.



Figure 4. Still of the Sketchpad MIT-Demo (1964) (Min. 4:30).

Source: https://www.youtube.com/watch?v=USyoT_Ha_bA (03.10.2014)

2. Scripts and Diagrams as Human-Human-Interfaces (HHI)

It is well known, that media play an essential role in interpersonal communication. It is, so to say, their constitutive property to mediate. In particular with scripts and diagrams on paper ephemeral knowledge can be permanently fixed on a support, thus transported in space and time.¹⁸ Hence such graphical media are understood, according to Niklas Luhmann’s media theory, as “media of distribution” (Luhmann 2001, 81f.). Luhmann, for whom communication is *the basis for social systems*, categorizes media depending on their potential to transform improbable communication, which is with regard to “understanding”, “reachability” and “success” a premise for him, into a (more) probable one (Luhmann 2001, 78ff.); and media of distribution could do so when exceeding the “communication between attenders” in a spatial or temporal manner when attention and response could no more be guaranteed – (it seems that Luhmann in 1981 still had the idea that a face-to-face-communication could only be imitated insufficiently with technical media).

Using the example of a learning situation in a school or university, where the participants discuss a common problem or topic at a board, shall now be argued, that scripts and diagrams

¹⁸ Bruno Latour speaks of an “immutable mobile.” In oral cultures knowledge can be passed (from one to another generation) with a chain-communication.

play in this process an important role and how they serve as interfaces between humans or function as human-human-interfaces – (it does not matter, if the writing happens with chalk on a board or with ink on a flipchart). In such a face-to-face communication plays the spoken word an essential role along with facial expressions and gestures. Media science is talking about “primary media” (Pross 1972, 127ff.), which are linked to the body and do not need any use of technology. It is important here, that Luhman describes the get-together of attenders, who are close, as a “system of interaction” (Luhmann 2001, 78) and actually face-to-face communication is also mentioned as a model for “interactive media” (Goertz 2004, 100), because “sender and receiver use all their senses, the reply is immediate, the communication is generally closed circuit, and the content is primarily informal or ‘ad lib’” (Durlak 1987, 744). As an aside, the “list” has been suggested by Jack Goody as an “interface between the written and the oral” (Deicher 2014, 14). What about our learning situation? People met to learn, which means in general to acquire mental and/or physical knowledge, skills and abilities with and from each other. Here speech, gestures, script and diagrams are playing together. Scripts and diagrams allow not only to visualize abstract thoughts, they make them visible and bring them home to the participants. Under discussion these representations of certain issues on the board can also be pointed and referred to (Meynen 2007), so they can be retraced inter-subjectively. Thus, a kind of symbol based or symbolic interaction happens (Goertz 2004). Especially physics and mathematics make aware about the practise of showing in a double meaning, when the participants argue and prove with reference to the board. Didactics knows that (visual) media can function as a corrective to language in group-communications (Lorenz 2005, 163). Like every medium the script as an immaterial concept is only thinkable with a material support, and the materiality offers specific properties for the interaction. The writing can be edited while having a conversation, that means something could be added

or erased by wiping away. The same goes for diagrams. Especially the duplication or parallel use of media allows a better interactive, instant comparison of a content, when spoken and written language correspond and must be translated in one another. It is well known in didactics that such processes increase the success of communication. (Lorenz 2005, 156ff.) Our case example shows, that Luhman’s categorization of single media makes sense to explain the probability of a successful communication in general, but does not in special, mixed-media settings; Graphical media need not necessarily serve as media of distribution. On the contrary, writing and drawing can be a social practice, a kind of acting as part of a group-communication-process. In fact linguist Karl Bühler used writing on a board as an example within his organon-model, in which he distinguished the “representation”, the “appeal” and the “expression” as three functions of language, to describe that the way someone writes on a board, can be diagnosed as an expression of his personality (Bühler 1999, 32). Since graphical media here are bound with social interaction in a system of interaction, they rather must be regarded as media of interaction. That is why scripts and diagrams are interfaces, which offer both a surface and a place, where actors can communicate with and influence each other.

If we take into account that Ivan Sutherland used scripts and diagrams in his research and teaching – he liked especially flow diagrams¹⁹ – and was aware of the advantages of media for creative processes (Sutherland 1963, 130ff.), then we can conclude that he had brought in consequently the properties of manual graphical interfaces in his technical graphical interface *Sketchpad*.

3. Scripts and Diagrams as Auto-Interfaces

In the last part scripts and diagrams shall be introduced as “auto-interfaces”. That means they enable the interaction of an individual with him/herself. This can be understood as a special

¹⁹ Ivan Sutherland, e-mail conversation with the author, November 21, 2014.

case of a human-human-interface, in which two participants are united in one person. Moreover, scripts and diagrams can be described as auto-interfaces, because they are also “symbolic machines” (Krämer 1988, 3), thus interfaces to themselves.

With scripts and diagrams, I want to claim, we can influence and control our thinking and thus the creative process. Referring to this, the consideration of three practices are of significance: First, the production of new artefacts with writing or drawing. While doing so a necessary “transcription” (Krämer 2005, 43) happens, to externalize inner thoughts; secondly the “reception” of existing artefacts when reading or viewing them. It enables the repeated internalization of represented, especially own issues. Thirdly, the operative use of existing artefacts. Scripts and diagrams can be operated in a symbolic manner, for example by adding or modifying elements (as already mentioned).

Let us go now more in detail: Externalizing thoughts means to sort and to bring them into the specific order of a medium. With a view to diagrams it has been said that in the production procedure happens a “synthetic condensation or compression” of knowledge (Bogen and Thürlemann 2003, 8). We can understand this better looking at two historical examples: While Luca Pacioli’s *Tree of Proportions* shows the connections between objects of mathematics, the *mundus-annus-homo*-diagram stimulated by Isidore of Seville offers a cosmological scheme for the interplay of world, man and time (Figure 5; 6). It becomes clear that a hierachic tree diagram has a different order than an egalitarian circle diagram; in a tree diagram dichotomy and logical dependence predominate (Schmidt-Burkhardt 2009, 174ff; Lüthy and Smets 2009, 402)

With regard to speech and text and their chronological sequence it is – although it can be criticized – mostly spoken about a linear order (Harris 2005, 76; Raible 2004). It is a well-known phenomenon, that our thoughts will be

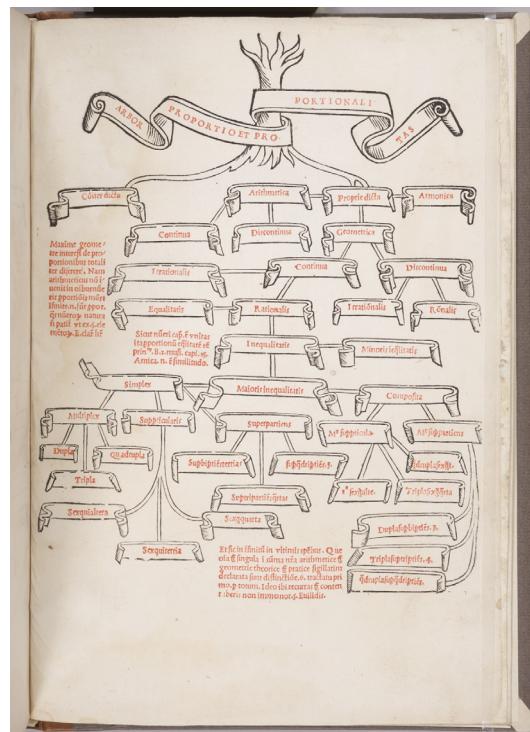


Figure 5. Tree of Proportions, in: Luca Pacioli *De Divina Proportione* (1509). Source: <http://www.maa.org/publications/periodicals/convergence/mathematical-treasures-de-divina-proportione-by-luca-pacioli> (13.10.2014).

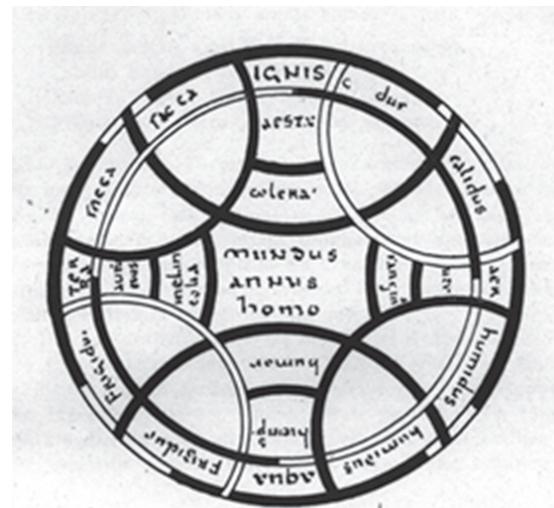


Figure 6. Mundus-Annus-Homo-diagram with 4 elements, 4 seasons and 4 temperatures after Isidore of Seville, remake of *De natura rerum* (kritische Edition). Source: Jacques Fontaine, Isidore de Sevilla. *Traité de la nature*, Bordeaux 1960, S. 216. Accessed: <http://www.uni-koeln.de/~ahz26/edition/ofon5gr2.htm> (13.10.2014).

concentrated, clarified and ordered by writing. When we formulate them, they become more precise. Existing thoughts will be modified or neglected and new ones appear. At the same time, it is possible to surprise oneself (Raible 2004, 200). Sybille Krämer makes a good note on this point: "Writing becomes a place of insights, a workshop and laboratory of our thinking, it becomes a forge for our thoughts" (Krämer 2005, 42) – (this also happened while preparing this paper). The fact that our "writing utensils" ("Schreibzeug") (Nietzsche 2002, 18) work on our thoughts, said no other than Friedrich Nietzsche, using 1882 an early sort of a typewriter. To say it simply, a pen allows another flow of writing and thinking than a typewriter.
²⁰In such a material-based perspective, scripts and diagrams on paper are *tangible interfaces*, which own haptic surfaces, resisting when writing and drawing. One could say, depending on their support, they offer "touching-zones" (Hellige 2008a, 13), which let us interact with our own selves.²¹ That media could be described by their "user interfaces" or their "human interface" has been mentioned in media theory.²² Nevertheless, these graphical interfaces work not (totally) automated, humans are not machines. Once represented as a script or a diagram our thoughts can be *looked at* from outside. Similar to an inner monologue they allow (like in a diary) a kind of *talking to oneself* to check our thoughts, but they face us – after a while – more like statements of an alter ego or somebody else. It is not only meant, that thoughts leave the inner and enter it again after being transformed by a medium. We have to remember, media do not work neutrally when mediating, but create or at least transform the message due to their specific properties (Krämer 2008a, 67).²³ Moreover it happens, because the producer himself becomes the receiver. Even programmers forget over the years the meaning of written code. That way the producer gains a certain, critical distance and can reflect on his own thoughts

(Krämer 2005, 42). With Michel Foucault one could describe these practices of writing combined with self-monitoring and control intended to change the mind as "technologies of the self" ("Technologien des Selbst") interlaced with "technologies of symbol systems" ("Technologien von Zeichensystemen") (Foucault 2007, 289). Therefore the *producer* is entering a feedback-process. A popular effect is the self-correction when we talk and hear our own voice and recognize errors (Krämer 2005, 42f). The same happens when we read our own writings, when we do proof-reading. This can be seen in a manuscript from writer Fritz Hochwälder, in which the two procedures can be retraced very well, because of their splitting into manu- and typescript (Figure 7). It becomes clear, that a literary text like *Der Himbeerpfücker* comes into being not only in a process of writing down thoughts, but also by its intensive revision on the paper. Theory of literature is speaking of brain workers and paper workers. It has been shown in detail with the example of Hubert Fichte, that writers use not only manuscripts, but also diagrammatic working drawings in their creative processes to organize materials, to develop a story and to find new ideas (Ortlieb 2008).

It was literary scholar Wolfgang Iser, who introduces the act of reading and comprehending a text, picking up Roland Barthes's post-structuralist theory, as a process of interaction (Iser 1976, 38ff.), which was criticized because the text needs to become human-like for it, but results in the widespread belief, that "interactivity" is a property of media concerning their interpretation (Ryan 2001, 16f; GamesCoop 2012, 80f). Not only the text would be constructed while reading it. At the same time the text would control and touch the reader, by providing instructions for his ideas. Thus the work could be understood as a convergence of the interplay between text and reader. This means, the reception of texts and diagrams can start a

²⁰ It would have been interesting to take also the smart pen as an analogue-digital tool into account. Concerning the relationship of man and machine it was argued according to actor-network theory (Bruno Latour), especially with regard to the agency of digital tools, that interactivity had became more symmetrical (Seifert 2008, 9-14).

²¹ It would be fruitful to reflect the differences between the use of scripts and diagrams on paper and on a computer more detailed and link this up with the history of tangible interfaces.

²² Lexikon Medientheorie und Medienwissenschaft: Ansätze – Personen – Grundbegriffe, ed. Helmut Schanze (Stuttgart and Weimar: J. B. Metzler sche Verlagsbuchhandlung und Carl Ernst Poeschel Verlag GmbH, 2002), s.v. "Vorwort."

²³ That the later reception of an own text is different to the process of writing it concerning the "(auto)-reflexion" and the self has been discussed more detailed (Giuriato and Stingelin and Zanetti 2008, 13).

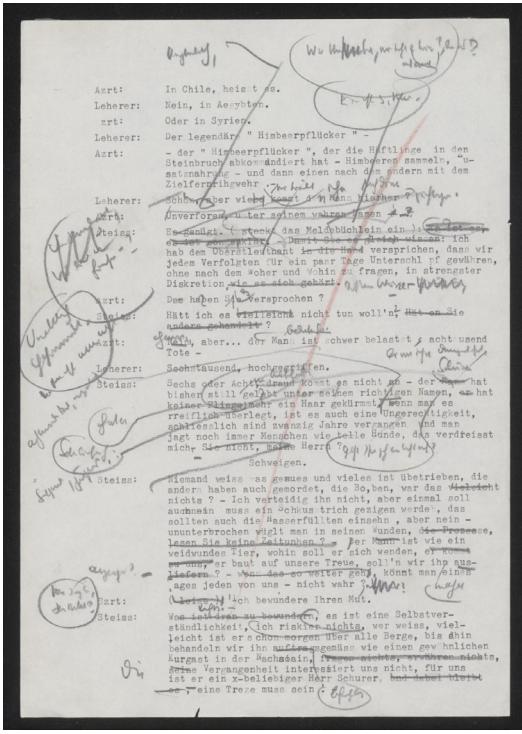


Figure 7. Fritz Hochwälder, manuscript of *Der Himbeerpflücker* with his own remarks and corrections. Source: Wienbibliothek im Rathaus, Handschriftensammlung, Nachlass Fritz Hochwälder, ZPH 678.

revision of our ideas by comparing them with the ones represented. Actually, scripts are more than written language and diagrams are more than representations of structural issues. Diagrams are regarded as “cognitive tools” (Bogen and Thürlemann 2003, 10). And especially in mathematics it becomes clear: “This script is a medium and instrument of brain-work; it serves less for communication, more for cognition”, as Sybille Krämer explained and complimented: “The exteriority of scripture serves also for solving problems in a monologue-style” (Krämer 2005, 30f). Medieval diagrams of cosmology were given as examples for “media of thinking” (Bogen and Thürlemann 2003, 10). With a view to Charles Sanders Peirce, it has been exposed that, via diagrams, “movements of thought” not only could be slowed down and revealed, but also controlled; there is a talk of “discursive expansion” and “upfolding” (Bogen and Thürlemann 2003, 8ff.). Thinking could be lead in the right channels, when connection lines in diagrams would be followed and contained elements would

be related (Bauer and Ernst 2010, 62). These aspects have a certain tradition in the context of antique mnemotechnics and were described for diagrams at the latest since Aristotle (Yates 1966, 206). According to the so-called *method of loci* familiar rooms like those of palaces should be filled in mind with knowledge. Corresponding diagrams offer places on the paper where knowledge can be situated and linked with. This way of proceeding is ascribed to Metrodorus of Scepsis, who extended the familiar circle diagram with the twelve zodiacs (Figure 8), which are easy to remember, to create places where mental contents could be put down and associated with (Yates 1966, 40ff.). As an aside, artist Davide Bevilacqua deals with this in a media-reflexive manner in his piece *Memory Wheel*.²⁴ “Diagrams can control our accessing to memories”, Bevilacqua said, referring to Giordano Bruno, who suggested that combinations of symbols could be used for storing and recalling information in the human mind (Yates 1966, 199ff., 243ff., 308ff.). Again, zones are providing areas for meaning.

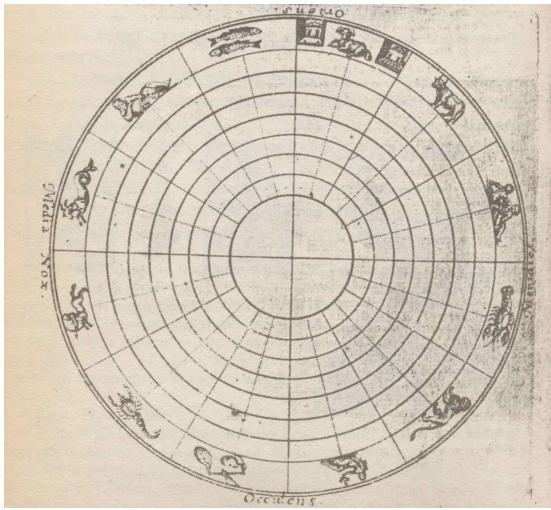


Figure 8. The extended Zodiac-diagram in a version of Robert Fludd (1612). Source: Yates [1966] 1984, 338.

²⁴ For more projects see also: King and Mignonneau and Sommerer 2008.

Let us now turn toward the aspect of operativity, which was already mentioned and is another reason why scripts and diagrams can serve for auto-interaction. They are not only static media: The represented knowledge cannot only *liquefied* in mind as demonstrated before. In this sense in Robert Fludd's circle-diagram is a kind of mechanical dynamics enclosed – one can imagine turning single circular rings. In fact, scripts and diagrams can also be operated. They allow an operating with symbols on their surfaces, thus they provide like human-computer-interfaces a "surface for operating" (Hellige 2008b, 11). They can be re-worked many times, not to say endlessly (Grube and Kogge 2005, 14). Words and passages can be deleted, overwritten or added. Using connection lines makes references between parts. All this Fritz Hochwälder's manuscript has impressively shown. Also diagrams allow the manipulation and re-arrangement of symbols on paper. For example in a tree diagram new connection lines can be drawn. In a mathematical matrix one can insert numbers and change them. Thus, diagrams are characterized with "configuration and re-configuration" (Bauer and Ernst 2010, 72).

And there is another kind of operativity: Scripts and diagrams can be equipped with an inner logic or a set of rules (for example a grammar). It fits in when diagrams have been described as combinatorial media (Bogen and Thürlemann 2003, 6) The number writing of mathematics shows, with numerals and operators like +, -, :, : etc. controlled transformations can be done, for example when a multiplication is executed following certain rules. As with such scripts, they can be calculated quasi-mechanically, they are called "symbolic machines" (Krämer 1988, 3). Thus, scripts and diagrams – depending on the notion of "machine" – can be regarded also as a special kind of a human-machine-interface: They are auto-interfaces in the sense of an interface for themselves. When they offer a logical play with elements, this stimulates to try out things in a systematic manner. It is not a surprise, that diagrams have been not only described as tools for cognition, but also for cre-

ative processes and design procedures (Bauer and Ernst 2010, 17).

Conclusion

In this paper scripts and diagrams on paper were presented as interfaces. Even Ivan Sutherland's *Sketchpad*, which could be understood according to its engineers as a digital-technological implementation of hand drawing on paper, indicates drawing (complemented by pushing buttons) as an interaction with the machine. According to the reconstruction of its historical discourse, the term interface was understood less as a (technical) device, but more as a place, where actions for interaction can happen, which influence someone or something. In a first step, historical case studies showed that scripts and diagrams on paper were used as human-machine-interfaces. While the punch-card was suggested to be considered more a diagrammatic than a scriptural interface, the introduced computer system *Analyzing Reader* used written natural language on paper as input. In a second step, scripts and diagrams on paper were identified as interfaces in a group-communication like a learning situation. Finally, scripts and diagrams on paper were suggested to be auto-interfaces, arguing that they influence and control our thinking and thus ourselves. With the examples of writers it was demonstrated that artists use these techniques to access to themselves and to stimulate the creative process. With regard to the postdigital-discourse, it would be interesting to reflect in a next step also hybrid tools like the smart pen.

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The Interactor Cedes Control An Heuristic for Planned Serendipity in Interactive Systems

Ricardo Melo¹
ricardo@ricardomelo.net

Miguel Carvalhais²
mcarvalhais@fba.up.pt

¹ ID+ / FBAUP

² INESC TEC / i2ADS / Faculty of Fine Arts,
University of Porto

Abstract

As part of our development for a framework for serendipity in interactive systems, we identified specific heuristics that, when implemented in the design of interactive systems, encourage serendipitous experiences, meaning experiences that are unpredictable and valuable. One of these heuristics—Interactor Cedes Control—and the subject of this paper, serendipity is not the result of a natural occurrence or a designed system to which the interactor is unaware, but occasions where the interactor purposefully relinquishes control from the interaction as a creative methodology or in order to increase the delight and surprise in both mundane activities, and in the creative and performative practices. To that end we begin with an overview of the serendipitous potential and history of the digital medium, followed by an argument for artificially created serendipity that enables the design of serendipitous systems. Lastly, we identify the distinct methods (namely Generative Systems, Automatisation, Randomisation, and Multiple Agents) which constitute the Interactor Cedes Control heuristic of the larger framework.

Keywords

Serendipity
Unpredictability
Uncontrol
Interaction
Digital Medium

1.A Serendipitous Medium

The digital medium is one that not only affords serendipity, but was born from the concepts that serendipity represents, and it can be found in both the medium's heart and genesis.

We can trace back the influence of serendipity in the foundations of cybernetics by Norbert Wiener. Citing Fred Turner, Sebastian Olma argues that the MIT's Rad Lab was an example of an institutionalised serendipity environment (Olma 2016, 136) which created the necessary conditions—namely openness and interdisciplinarity—that encouraged a transversal exchange of knowledge that, in turn, enabled Wiener to create the discipline of cybernetics, which itself allowed for the development of ARPANET, one of the technical foundations of the internet. As put by Olma: "ARPANET as the first iteration of today's internet can this be seen as the cybernetic materialisation of institutionalised serendipity, merging the academic gift economy with the cybernetic dream of self-organisation and self-governance through constant feedback loops." (2016, 145).

If serendipity is in the digital medium's genesis, it is also within its goals, for J.C.R. Licklider aimed for the intergalactic computer network to connect idiosyncratic scientific knowledge, a feeling that is echoed in Tim Berners-Lee's vision for the World Wide Web: "an open platform that would allow everyone, everywhere to share information, access opportunities and collaborate across geographic and cultural boundaries." (2017)

The digital medium was born due to serendipity and was created aiming towards serendipity. It is, as well, one that affords serendipity, due to how it allows for the free connection of people and information.

I happen to believe that the Web, as a medium, has pushed the culture toward more serendipitous encounters. The simple fact that informa-

tion "browsing" and "surfing" are now mainstream pursuits makes a strong case for a rise in serendipity, compared to cultures dominated by books or mass media. (Johnson 2010)

The sheer quantity of information that the digital medium allows one to have access to, in theory, multiples the possibilities of connections and encounters that are possible in the medium. In practice, the tools we have developed in order to manage and access that information have set restraints and limitations to the fortuitous encounters one might have.

While serendipity may, and does, occur naturally in the digital medium, it may likewise be provoked through the design of systems that create the appearance of chance in an interaction. If this chance occurrence is one that adds a particular value to the experience (REDACTED 2016), we may be experiencing a form of *artificial serendipity*: serendipity that resulted from a planned or designed experience.

2.The Interactor Cedes Control

In the case of artificial serendipity, it is the *experience* of unpredictability and apparent *accidentality* that allows for the feeling of *unsoughtness*. While this opens the opportunity for a designer to explore this concept into interactive systems—without user awareness—it is also possible that it is the interactor herself that chooses to purposefully introduce unpredictability into her interactions with a system as a way to inject serendipity into the process.

This is achieved by purposefully relinquishing control of an action or process as a way to let herself be surprised by a possible result, be it through generative systems, random or pseudo-random processes, or through multiple agents (human or otherwise). In the following sections we will explore our identified methods for achieving planned serendipity in these interactive systems.

3. Generative Systems

By *Generative Systems* we consider what Galanter referred to as rule systems with generative potential (2006), which describes systems capable of a certain degree of autonomy or “capacity to produce novelty and to take the creative control from the artist” (redacted 2010).

Here, the user cedes control of an action or series of actions to external processes (created by herself or others), as a method of introducing a level of surprise into the outcome, through instructing the system with a specific sequence of actions and operations that are done procedurally and without the user’s interaction, besides the initial setup.

Galanter lists twelve different rule systems which are generative systems: rules as algorithms, rules as recipes for autonomous processes, rules as a well-defined widely applicable process, combinatorial rules, numerical sequences as rules, line composition or drawing rules, the rule of serial generation, tiling and other symmetric composition rules, chance operation rules, clustering rules that create composition, mapping from one domain to another, and rules which create cycles and phase interactions (Galanter 2006). While we won’t go in detail in these rules, it is relevant to consider that all these systems, through the added generative process to the rules, introducing the possibility for autonomy in the process and, therefore, deviation in the final result (as opposed to non-generative rule systems, which would replicate the outcome without variation), is able to introduce unpredictability into the process, leading to moments of serendipitous epiphany.

4. Automatisation

While the following *Automatisation* can be considered an example for a *Generative Systems* (namely rules as recipes for autonomous processes), we single them out because of their other possible applications, as mechanics and not systems.

Automatisation, while with various possible applications, is often used in creative practices, both as a way of expediting and simplifying common and repetitive tasks, but also as a way on introducing surprise into the process, be it through variations introduced through the automatisation practice or through external interference.

While *Automatisation* is commonly used in software that allows for a type of task automation—as in the batch process functionality of, for example, *Adobe Photoshop*—this is often developed for fine control of specifically intentional actions, where the intention is more on saving time and reducing repetitive tasks, rather than the production of novel artefacts or encouraging surprise and unpredictability. Due to the complexity of certain implementations of the *automatisation* process, it is often inaccessible to non-experts.

Through simplifying the user experience of the automatisation process, systems are able to make it more accessible, as we can see the pre-defined filters available in popular mobile photo-editing software such as *Hipstamatic* (2009) and *Instagram* (2010). These filters, which often emulate the characteristics of specific cameras and films, offer an easy way to quickly manipulate digital photographs through pre-determined effects. These allow even the layperson to distinctively modify the photograph, with novel and often unexpected results, increasing the engagement between photographer and photograph.

However, we observed that the usage of these filters was mostly concerned with the formal qualities of the image and didn’t challenge its perception nor its subject, greatly reducing the potential for true novelty. We believe that this is due to the absence of an initial moment of surprise that could trigger a moment of defamiliarisation (Shklovsky 1917) of the image. In the case of *Instagram*, one of the most popular applications for mobile photography, it is the user who chooses the filter, as such, the rela-

tionship between expectancy and end-result is never challenged as the user is always presented with an image that is nearly identical to the one displayed in the screen when taking the photograph, and the choice to apply the filter came consciously and knowingly.

In order to test this hypothesis, we developed *Filtershuffle*, a mobile photography application that removes the steps between photographing and applying image filters. By introducing randomness to the image transformation process and, through it, removing the “burden of choice” (Leong, Vetere, and Howard 2008) from the user, we are able to reintroduce unpredictability to the process, which could lead to creative or serendipitous experiences through the juxtaposition between what is perceived in the photographing moment, and the surprising result of the random manipulations.



Figure 1. Some of the different, randomly generated results of *Filtershuffle*.

5. Randomisation

With *Randomisation*, the system utilises randomness or pseudo-randomness on a possible result or outcome in hopes to provoke a sense of unpredictability.

While *Generative Systems* may utilise a randomness component, this isn’t a pre-requisite, while in this method we focus on the process of randomness as a means to introduce unpredictability. Likewise, while the aim of *Generative Systems* is the creation or production of artefacts where the interactor is often the designer of the generative system and randomness is a method to achieve the generative process, in this case, randomisation is the key factor in the experience.

There is a long history of employing methods of randomisation as a way to derive meaning from randomness. The *I Ching*, *Sortes Homericae* or *Tarot*, all used a form of chance as to remove the control of the agent.

In computational systems, the computer takes the role of the *diviner*, it is, literally, the *medium*. Here, randomisation is utilised as a method to add meaning, taking advantage of the human tendency to see patterns in noise.

By choosing to release control of the interaction through *Randomisation*, the user opens the experience to allow for surprise, unpredictability and, ultimately, serendipity, as observed by Leong (2008) on consumption of media (namely music) when using the shuffle functionality of a media player. Leong’s argument is that the necessity of having to choose what to listen to within a large musical library can be “unpleasant and even paralysing”, particularly when the user doesn’t have a particular preference. As such, by abdicating their ability to choose what to listen to, it can lead to better user experience, an enriched listening experience and even encourage “encounters with serendipity”. This also encourages the interactor to create relationships between the different objects, as observed by Leong, noting that “when familiar

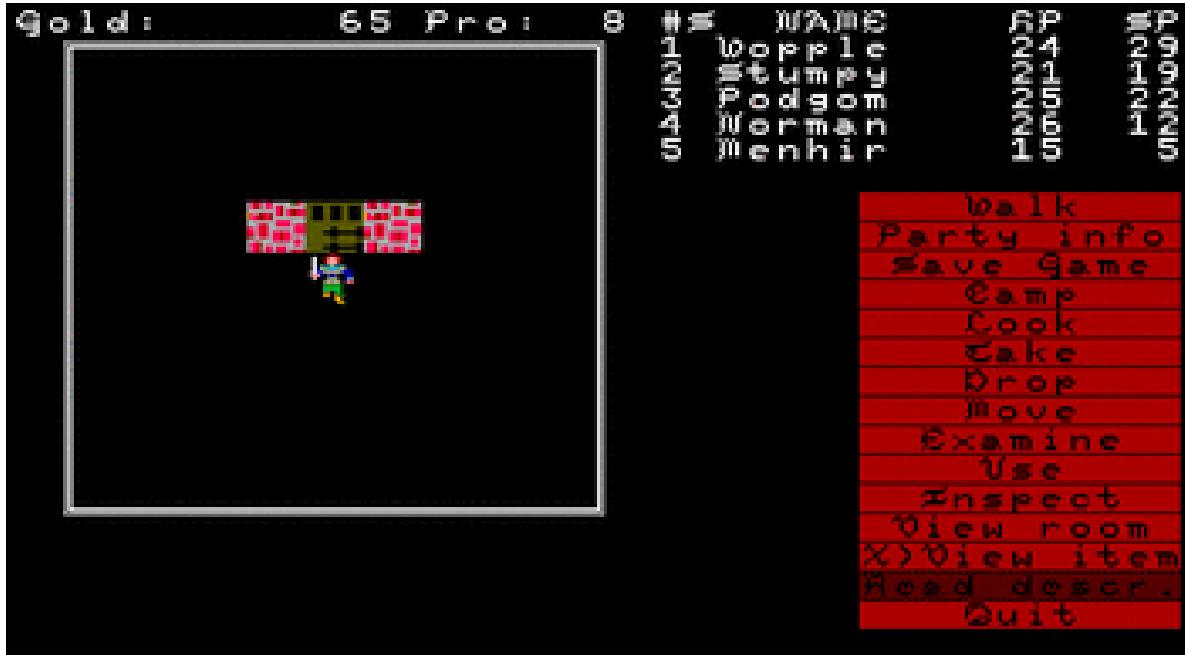


Figure 2. *Demon's Winter* (1988).

tracks are presented to listeners unexpectedly [...] listeners perceive the evocations of these familiar and personal associations as being slightly different, unfamiliar or even strange.” (Leong 2009). As such, systems that juxtapose content through this Randomisation enable and entice the user to draw connections and, through those, add meaning to them.

The same principle of abdicating choice can be seen in the website *StumbleUpon* as it relates to *information encountering* (Erdelez 1997) or, for example *100 Million Books*, a Chrome extension that randomly displays a book every time a new tab is opened in order to “help people realize the sheer breadth of smart ideas, emotional stories, and insightful perspectives out there they don’t know.” (Books 2017)

Randomisation is, likewise, a key mechanic in video game design, often used to introduce, in the words of Greg Costikyan, “a sense of drama”:

As a source of uncertainty in games, randomness provides one thing it is not normally credited for: a sense of drama. There is a moment of

tension when the dice are rolled, or the player otherwise commits himself to a course of action the outcome of which is luck dependent. When an underpowered character in a tabletop role-playing game succeeds in overcoming a fearsome foe by, say, rolling a critical hit, the player of the character is likely to experience a moment of jubilation, of real triumph over adversity—in a way that would be impossible with a system lacking random elements. (Costikyan 2013, 85-86).

The game *Demon's Winter* (1988) has procedurally generated items with randomised effects, creating this sense of unpredictability in gameplay, something that would be greatly explored in contemporary game design, such as in the *Diablo* series, where created items have a random variable that defines their characteristics, creating novelty when playing the game, encouraging repeated plays.

Randomness is also used to create the game world, such as the Roguelike genre, where game levels are randomly created every time the game is played, or as in *Really Bad Chess* (2016), a

mobile chess game where the chess pieces are pseudo-randomly distributed (player skill can affect the distribution of pieces). By randomly distributing the chess pieces, the game eschews traditional chess tactics and encourages the player to think and play extemporaneously.

6. Multiple Agents

By opening the interaction to multiple and simultaneous agents (human or otherwise), the system is relying on the unexpectedness of the crowd to introduce unpredictability to the experience. Examples of this method can be found in Tanaka et al.'s *CC-Remix*—a network-based collaborative music creation system—where up to four users in different locations were able to participate in a process of music collaboration by taking excerpts from existing songs and mixing them together, and *Malleable Mobile Music*, where using wireless ad-hoc networks and incorporating “sub-conscious gestures made in the act of listening” (Tanaka, Tokui, and Momeni 2005) such as gripping the device tighter or tapping along with the beat into the actual music creation.

Similarly, *Daisypnone* by Bryan-Kinns, aims towards a “novel environment for remote group music improvisation” with the aim to understand how musical environments can be designed to be more “engaging, social and serendipitous” (2004).

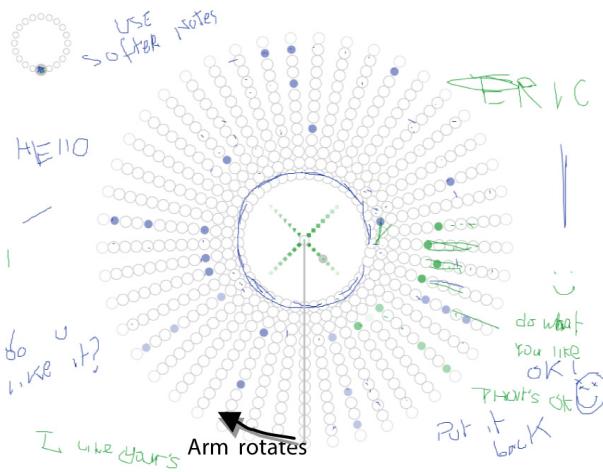


Figure 3. *Daisypnone* (2004) interface.

Starting with the premise that music has lost a fundamental part in our daily lives, being relegated to a “highly stylised activity requiring serious practice, performance, and accuracy”, *Daisypnone* is positioned as a means to reintroduce the “everydayness” into music, through the use of mobile devices (such as mobile phones or tablets). To this end, *Daisypnone* adopts a unique interface that distances itself from conventional GUIs, opting instead to represent music as a circle, with a play head that rotates, playing the notes underneath it. These notes are placed and removed by the users, by clicking on the small circles. When joining a *Daisypnone* session, a player is given a unique hue that represents her. Different musical sounds can be selected, represented by different shapes, such as square, round, diamond and triangle, which users can select by clicking on the centre of the system. Pitch decreases with distance from the centre and volume is represented by saturation of colour. Players are also able to easily add hand-written comments, be it notes or drawings. Through this visually rich and, possibly, “messy” interface, they hope to “encourage exploration, fun, and contextualisation”.

7. Summary

Here we observed methods to delegate control from the interactor to a system, in order to provoke the experience of serendipity in the former.

To that end, we identified a series of method that allow for this ceding of control: *Generative Systems*, in which the interactor purposefully gives control to the system, in form a rule that allows for a degree of autonomy by the system, in order to create novel results beyond those offered by the initial rule set; *Automatisation* and *Randomisation*, while both methods can be observed in *Generative Systems*, they can also be utilised in other applications as ways to remove control from the interactor and allow for unpredictability; and lastly, *Multiple Agents*, in which unpredictability (and serendipity) is the

result of dividing the interaction between multiple, autonomous actors (human or otherwise).

8. Limitations and Future Work

The methods that constitute this heuristic and here described are not all-encompassing but merely representative of the most common identified methods for the release of one's control of an interaction. Likewise, this heuristic is not focused to a specific area of interaction—such as information discovery, video-games, the creative practices, or interfaces for live performances—but, due to the nature of our research, the whole spectrum of digital interactions. Further work should, therefore, figure the identification of the specific methods where the interactor cedes control within distinct areas of activity and consider how they influence the practice and experience of that activity.

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The Ensemble as Expanded Interface Sympoetic Performance in the Brain Dead Ensemble

Thanos Polymeneas Liontiris
a.polymeneas-liontiris@sussex.ac.uk

Thor Magnusson
t.magnusson@sussex.ac.uk

Chris Kiefer
c.kiefer@sussex.ac.uk

Alice Eldridge
alicee@sussex.ac.uk

Emute Lab, University of Sussex,
Brighton, UK

Abstract

This paper reports on an interactive and interconnected music ensemble from the perspective of the interface. More specifically it aims to canvass the dynamic relationships established within the Brain Dead Ensemble. It describes how the reconfigured relationships between performers and instruments are inherent to this ensemble from a technical point of view. In addition, it aims to survey the phenomenological aspect of the relationships established between the performers of this ensemble and how these relationships suggest the possibility of an ensemble itself conceived as interface.

Keywords

Ensemble as interface
Brain Dead Ensemble
Feedback Resonating Cello
Feedback Resonating Double Bass
Threnoscope
Uncontrol



Figure 1. The Brain Dead Ensemble

Introduction

Four decades ago, Jean-Claude Risset wrote on the idea of the computer as a new paradigm of interfacing: “between different processes, material or intellectual, and also between people.” (Risset 1992,10). Since this time, significant research progress has been made in the development of technical and conceptual approaches to designing, building and framing attributes, affordances and capacities of acoustic, analogue, digital and hybrid musical interfaces. Current movements in the digital humanities suggest a turn to what is described as a *post-digital* aesthetic (Berry 2015). The postdigital in this case refers to media that do not prioritise their digital materiality or properties as something ground-breaking; the “post” in postdigital refers to the “beyond digital” rather than to the non-digital (Cramer 2015). Such interfaces combine both digital and acoustic processes as in Nicolas Collins’ *Pea Soup* (1974; revised 2001-2014), the “Trombone-propelled electronics” (Collins 1991), the Feedback Resonance Guitar (Overholt et al. 2011) the Magnetic Resonator Piano (McPherson 2010), the Feedback Lapsteel (Harriman 2015) or the Overtone fiddle (Overholt 2011). All of which achieve a rich, distinctive sonic aesthetic. This

conception of postdigital media challenges our understanding of interface as a discrete object. Moreover, it allows us to reinterpret the interface, re-conceptualise it and potentially apply it in different contexts.

In this paper we start with the notion of the interface as set of processes that establish new interactive relationships between the performers. The interface becomes a “transindividuated” process (Stiegler 2010), a process of individuation of the self through its interaction with technical objects or technical individuals (Simondon 2017) and other human individuals. The *Brain Dead Ensemble* emerged as a result of several on-going research endeavours at the University of Sussex Experimental Music Technologies Lab, with roots in live coding (Magnusson 2014), dynamical systems for interactive music (Eldridge 2008), musician-computer interaction, and general feedback instrument design (Ulfarsson 2018; Eldridge and Kiefer 2016). As part of this on-going research into digital and acoustic feedback instruments (and hybrids thereof), we consider a range of closely interrelated aesthetic, technical and phenomenological questions: *What happens when the playing of an instrument is not about the instigation of musical events, as in playing notes, but more about the shaping of an on-going, evolving, emergent sound in a self-resonating instrument? What would happen if we interconnect the sound from other actors within the functional structure of each of the instruments? How would we, as performers, perceive such delegation of agency to other performers and the functionality of their instruments?* In this paper we describe the instruments that make up the ensemble, and the specific acoustic networking which connects them. We then discuss the experience of playing in the ensemble as a form of making-with, or sympoetic performance, suggesting that this structural acoustic coupling establishes of a new type of involving, evolving musical relationship, distributing musical agencies across a meshwork of players and instruments and acoustic spaces.

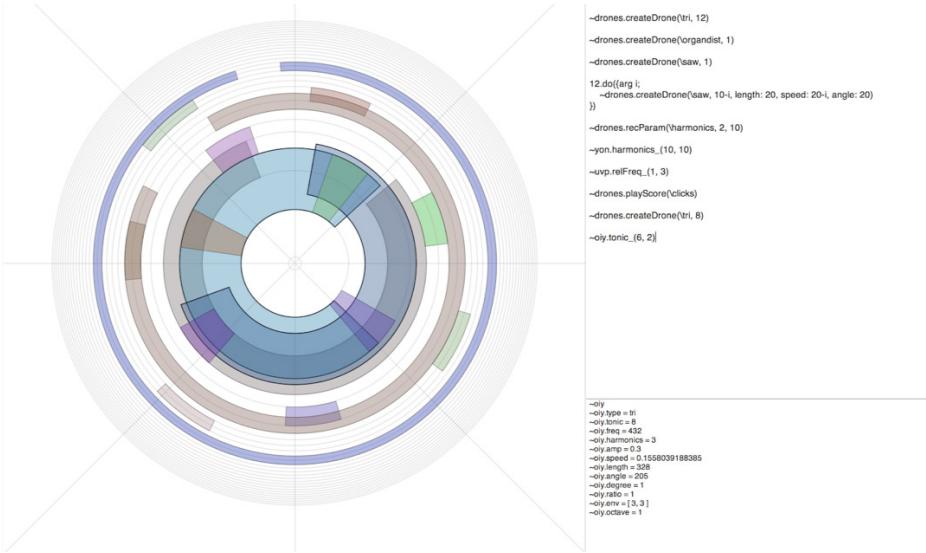


Figure 2. The Threnoscope

1.The Ensemble

Brain Dead Ensemble (Figure 1) consists of four performers whose instruments are acoustically networked: Alice Eldridge and Chris Kiefer on Feedback Resonating Cellos (FRC), Thanos Polymeneas Liotiris on Feedback Resonating Double Bass (FRDB) and Thor Magnusson live coding the Threnoscope.

2.The Instruments

The Threnoscope

The Threnoscope (Magnusson 2013) is a live coding environment developed by Thor Magnusson. The instrument produces rich spectral sounds that are sculpted in real-time, and output through an intricate multi-channel panning system. The Threnoscope's interface includes an absorbing graphic visualisation of the sonified and spatialised spectra. The graphic visualisation contains output "channels" (lines crossing the screen) and the "notes" move around the space by entering or appearing on a speaker channel. Harmonics of the fundamental frequencies are represented as circles, where the innermost circle represents the fundamental frequency (for example A at

55Hz). The notes or drones can be filtered, and this is represented by the thickness of the note (how many harmonics it crosses). Following a live coding fashion, the code, together with the graphic visualisation, is typically projected on a wall or a projection screen at the back of the stage (Figure 2).

The Feedback Resonating Instruments

The FRC (Eldridge and Kiefer 2016; Eldridge and Kiefer 2017) and the FRDB (Figure 3) are hybrid instruments custom-made by their performers. They are designed and developed in an on-going collaboration with instrument designer Halldór Úlfarsson, creator of the halldorophone,¹ a cello-like feedback resonating instrument. The principle behind both FRC and FRDB instruments is the same: electromagnetic pickups are placed under each string of the instrument. The signals from the strings are processed (in varying ways for each instrument) and fed back to the body of the instrument (Figure 4). This is possible through tactile transducers that are clamped onto the instrument, and by speakers that are mounted into the instrument body. The pick-up signals are mixed and sent to the transducers; energy from

¹ <http://www.halldorulfarsson.info/halldorophone5/index.html>



Figure 3. Two feedback resonating cellos and the feedback resonating double bass

the transducers vibrates the instrument’s body causing the strings to resonate and creating a signal in the pickups, so forming a feedback loop. This feedback loop is highly nonlinear, as energy is transformed through several media (acoustic, electric, digital), and it is forced, by intentional design, to follow indirect and *difficult* paths. This systemic nonlinearity radically transforms both the sound world and interactive model of the instrument, relative to their classical parents. Acoustically the feedback pushes the instrument into overdrive, creating a sonic complexity far from the familiar tones of acoustic strings; physically the instruments are no longer controllable in a linear way, rather the players now negotiate with an already-vibrating body: the strings no longer function as a means to inject energy into the system, but act as lively, resonating controllers by which the feedback running through the instrument can be shaped. These feedback instruments are good examples of postdigital instruments as they rely equally on analogue, digital and physical processes.

Each instrument uses different approaches to process the sound from the strings, one FRC uses purely analogue process controlled by foot-pedals, while the other FRC processes the signals digitally using SuperCollider via a control surface mounted onto the instrument. In the case of the FRDB the signal is amplified—and minimally processed—using SuperCollider² integrated in the Bela³ platform (McPherson 2017).

3.Understanding Feedback Musicianship

Whereas playing a traditional string instrument involves the performer inputting energy to excite the strings with their bowing arm or pizz finger, playing these self-resonating feedback instruments is more a dynamic negotiation with a self-resonating system. Due to the complex, hybrid feedback pathways the instruments can react in a highly nonlinear manner to any vibration (sound or movement) that can potentially stimulate and excite their strings. In this sense they are uncontrollable, under the traditional instrument interaction paradigm; a differ-

² <https://superollider.github.io/>

³ <https://bela.io/>

ent form of dialogue is established. Chadabe (2005) extended Xenakis' metaphor of composer navigating seas of sounds and described real-time interactive music as a process similar to that navigating a stormy sea, having to manage a sailing boat, taking into account the waves that thrash its hull, and the wind gusts that pull its sails. The additional feedback loops in these hybrid instruments makes navigating a route through an unfolding performance a very intuitive journey. They require adaptability and agility as all instruments, but their intrinsic non-linearities demand a non-conceptual, pre-conscious, almost meditative approach from their performer: music unfolds only in the absence of expectation, through a very subtle listening and nuanced embodied response.

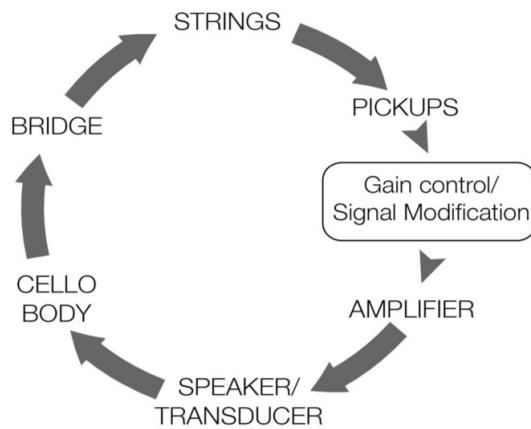


Figure 4. Schematic of the feedback instruments

Jon Drummond describes in detail the different types of interactive music systems and the relationship established between the interface and the performer (Drummond 2009). In these new systems, an increased level of musical knowledge is embedded in the body of the instrument itself, giving it an agency that becomes partly that of the instrument designer/maker and partly that of the performer. The instrument with its emergent properties and unpredictable behaviour challenges the performer in how to respond to it. From an enactivist perspective, the instrument can be seen as a realisational interface, (Armstrong 2006) and the performance becomes an emergent conversation between player, instrument and ensemble.

4. Acoustic Networking in the Brain Dead Ensemble

During performance, the behaviour of the self-resonating feedback instruments is periodically influenced by audio signals sent from the Threnoscope. The Threnoscope operates through the string instruments using its intricate panning system, exploring and exploiting them as resonating and reactive loudspeakers. Hence, in Brain Dead Ensemble performances the musical interface ceases to be merely the Threnoscope, the FRCs or the FRDB, rather the whole ensemble should be considered as musical interface, an extended and resonating multi-player performance system.

Regardless of the differences in how instruments manage their signal paths or whether they are built on analogue or digital processes, the three feedback resonating instruments used in the Brain Dead Ensemble have a basic common feature: they all receive external audio input from the Threnoscope, which can be then played back through the speakers and the transducers that are attached to their bodies (Figure 5). The acoustic properties of the string instruments shape this external signal. In addition, the sound of the Threnoscope excites the instruments' strings and makes them resonate. The combination of the Threnoscope sound together with the feedback properties of the string instruments afford even greater variety of sonic textures. The degree of influence from the Threnoscope is variable, and unpredictable to the receiving player; it may create interplay between the two instruments, but it may also override and saturate the feedback loop of the receiving instrument, making it temporarily insensitive or unplayable. At the same time any player can reduce the gain on the input from the Threnoscope, silencing this player's actions. This *acoustic networking* creates a fresh form of chamber music, where instruments can be "played" by other members of the ensemble, substantially reifying the musical influence implicit in traditional ensembles. The sound of a voice or of an acoustic instrument being processed and manipulated by an analogue or digital interface is nothing new. However, having an external sound being shaped by the internal acoustic properties of an acoustic instrument,

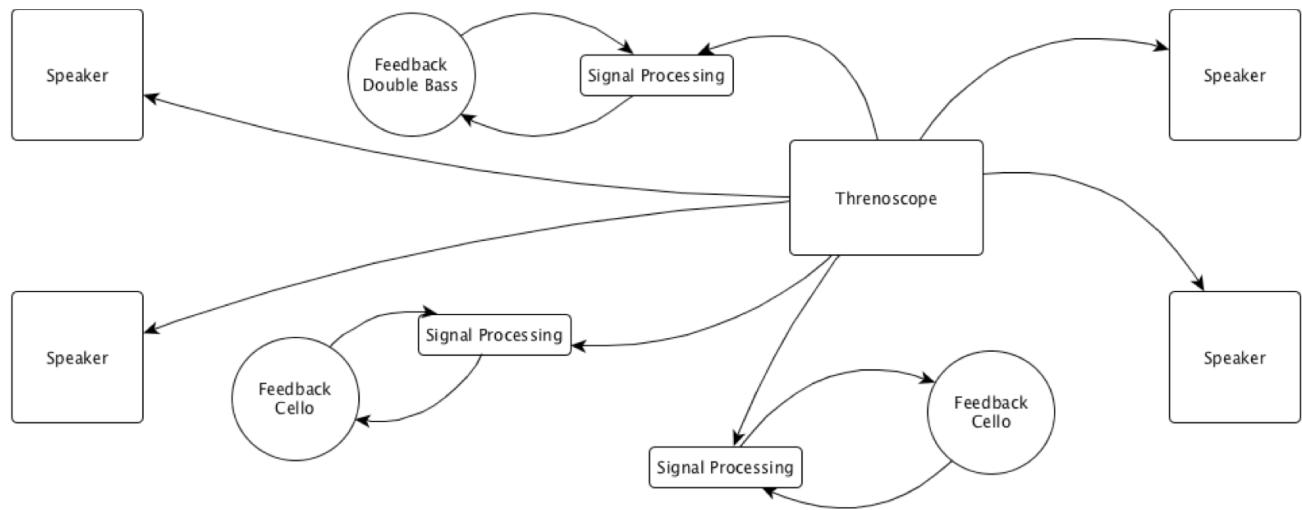


Figure 5. Audio pathways between instruments

while an actual performer is also performing that acoustic instrument, is quite unique. This process borrows the afore-mentioned postdigital capacities of the instrument (i.e. the hybrid analogue-physical-digital qualities of it) and it applies it on the entire ensemble. The ensemble's way of operating is shaped by interconnected yet often undifferentiable analogue, digital and physical processes. To extend the Xenakis/ Chadabe sailing metaphor further: we are no longer simply navigating stormy seas, but actively perturbing them in performance time, these perturbations being a defining language of the ensemble. The Threnoscope audio signal entering the feedback resonating instrument is an additional variable to the whole performance equation that at once distributes, and dissipates, musical agency across the assembled interface.

5. Brain Dead Ensemble as a sympoietic interface

The evolution of digital music interfaces has been as much about conceptual framing of musical attributes, affordances and capacities as their technical implementation and musical exploration. Early metaphors played on extant chamber models (Winkler 2001) and later forms of dialogue, conversation (Paine 2002)

and mutual influence (Bongers 2006). The traditional roles of instrument maker, composer and performer have been deconstructed and reconstructed (Schnell and Battier, 2002; Magnusson, 2009), and the inter-agency of performer and machine reconceptualised in terms of 'losing control to gain influence' and meta-control (Campo 2014).

Brain Dead Ensemble is an expansion of the performer's nervous system into a postdigital music system. The entire performance ecosystem (Waters 2007), has expanded to comprise equally code, bytes, metallic strings, analogue transducers and pieces of wood as much as the performers' proprioceptive biases, autonomic nervous system, musical impulses and muscular digits. The whole ensemble with its wired members suggests an interface that links interfaces, a multi-instrument. Moreover, in this ensemble-interface, a system that assembles—in a form of a network—other interfaces, the performers operate as much as observers as instigators.

Dunbar-Hester's description of cybernetic processes in music goes some way to describe the real-time composition and performance processes that govern the Brain Dead Ensemble, which can be understood:

as enrolling the performers, the instruments, and the audience into a “system” of experience that is distinct, and experienced as subjectively unique, and yet is part of an ongoing process. (Dunbar-Hester 2010, p. 125, emphasis in the original)

But the acoustic couplings of feedback instruments, which characterise the Brain Dead Ensemble, suggest a new form of music-making, a “music-making-with”, or *sympoietic performance*. Musical agency is not only distributed over a hybrid assemblage, but is fundamentally defined in relation to the co-assembled agents. Haraway (2017) adopts the term *sympoiesis* (Dempster 2000) to elucidate the deeply interpenetrative on-going relationships between biological systems. Sympoiesis is a word proper to complex, dynamic, responsive, situated historical systems, and is as useful in conceiving of dynamic musical relations as the biological assemblages of Haraway’s concern: “critters do not precede their relatings” and nor do performers, “they make each other through semiotic material involution, out of the beings of previous such entanglements” (Haraway 2017, 60).

6.The Sound of the Ensemble

The acoustic result of these feedback processes is characterised by a variety of sonic colours including airy microtonal micro-melodies, serene yet colourful drones, complex spectral gestures, and vast explosions surfacing gradually or unpredictably into screams. An audience member at our inaugural performance provided a fitting description: “the Brain Dead Ensemble sounds like the sonic encounter of Gérard Grisey with Sunn O))). The structural and systemic distribution of musical agency plays out in the sonic experience. Numerous audience members have mentioned that they were not able to tell which instrument produced what sound. Similarly, as a performer it is often hard to pin-point not only the source of a sound on stage, but even the origins of a vibration in one’s own instrument: it is often hard to tell whether the sound produced by a feedback instrument is a result of your own actions,

whether it is a sound caused by the inherent feedback properties of the instrument—the instrument reacting to the environment—or if it is a sound generated by the Threnoscope sounding through that instrument. This is the result of the integration of the ensemble’s parts into a whole. Just as a piano à *quatre mains* or a txalaparta are physical musical interfaces which afford multiple simultaneous players, through acoustic coupling the Brain Dead Ensemble create a distributed, yet integrated multi-player musical interface.

7.Live Coding the Ensemble

For the live coder performing on the Threnoscope, the options are to send signals out to the quadrophonic speaker system in the room or to the transducers and speakers in the feedback instruments. The live coder can therefore interfere or co-play the string instruments by sending signals into their feedback chain, (re) defining the acoustic properties of the instruments themselves. From the perspective of the live coder this is an unusual experience, as the output channel is “going through” a complex instrument, played by a human. By sending a signal to the string instruments, the live coder conditions them, listens to and observes the way the sound is changing equally the instrument and its performer’s behaviour, so there is an “interface” at various levels human-machine, human-other-human’s-instrument, other-human-instrument, human-human interaction, and so on. As a cybernetic system of sound and human behaviour, the ensemble is multiparametric, complex and difficult to analyse. Features emerge and disappear constantly, and language struggles with the analysis of the proceedings. Whilst the live coder is able to change the functions of the string instruments, the instrumentalists can of course reject that signal, by simply lowering the incoming signal from the Threnoscope. As such, the ensemble is a decentralised system of actors that are manifest in the human intentionality of the performers, instrumental behaviour as a result of design, behaviour of the particular room and PA system, and the audience.

8.Challenges

Playing in the Brain Dead Ensemble can be very challenging due to the very unpredictable and nonlinear nature of the instruments and the connections between them. Some of these challenges might be intriguing, inspiring and stimulating -- such as the aforementioned situation when the performer does not really know whether the sound produced by their instrument is caused by them, yet they have to react musically to it. The control has been distributed amongst actors that include people, instruments, stage technics, room acoustics and the audience. Alberto De Campo writes about this as losing control, but gaining influence. (De Campo 2014). In other cases the challenges can be somewhat more pragmatic, for example the ensemble cannot use stage monitors to listen to their sound because this might over-saturate the instruments, causing them to become unresponsive. A further challenge - and joy - is the near impossibility of making detailed compositional plans in advance, or trying to repeat collective musical moments due to the nonlinear nature of both the instruments and the ensemble. Other inspiring challenges include the way string players have to 'surf' the Threnoscope sounds as they take over their instrument and how they gear their own instrument to engage with it: the challenge of governing a smaller feedback system while being part of a much bigger feedback system.

Conclusions

This paper introduced the notion of ensemble as multi-surface interface. Such a definition of an interface will encompass the notion of the ensemble as a fluid assemblage of dynamic instruments, human-object relations and interpersonal relations. This was illustrated with the case of the Brain Dead Ensemble, an acoustically networked feedback ensemble/assemblage in which the structural acoustic feedback pathways within and between "open" instruments create a fundamentally distributed musical agency, which we might describe as sympoietic performance. We approach performance from a postdigital perspective, canvassing the dynamic relationships between performers and instruments. A new approach to ensemble performance is sketched, based on digital, electronic and acoustic networking of intrinsically uncontrollable feedback instruments. In this type of performance, there are no defined individual states or intentions that serve as a familiar platform to refer to, but instead the performance becomes one of search, exploration, interplay, challenging, teasing, supporting, testing, excelling and breaking *in relation to each other*.

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Listening Mirrors

Prototyping for a Hybrid Audio Augmented Reality Installation

Cécile Chevalier
c.chevalier@sussex.ac.uk

Chris Kiefer
c.kiefer@sussex.ac.uk

Experimental Music Technologies Lab (Emute
Lab), University of Sussex

Abstract

We introduce ongoing developments of *Listening Mirrors*, a sound art installation and live interface for musician and non-musician alike. The piece, in its construction and interaction design, investigates ways in which collective sonic expression can be made possible using Audio Augmented Reality technology (AAR) and acoustic mirrors, whilst asking how such environments promote collective sonic expression.

Listening Mirrors is composed of a virtual acoustic mirror (an iOS app built with OpenFrameworks, LibPD with bone-conduction headphones), parabolic acoustic mirrors (inc. piezo mic), networked with transducers for real-time collective performance. The installation creates interplay between real and virtual sound worlds, and explores the nature of human experience within these borders by drawing on Merleau-Ponty's *Ontology of the Flesh*.

Keywords

Augmented reality
Sound art installations
Collective musical expression
Mobile music making
Merleau-Ponty
Enactivism

Introduction

Listening Mirrors is an instrument for collective sonic expression building on an audience participation dependent system using real and virtual interfaces. This paper discusses the latest developments to *Listening Mirrors*, investigating ways in which realtime collective expression can be made possible using Audio Augmented Reality technology (AAR) and acoustic design, whilst asking how such environments promote musical expression?

Listening Mirrors has been designed as a space in which musicians and non-musicians can play and express themselves through listening to their own body and the bodies of others. This is made possible by constructing a system where environment, audience and interfaces feed off each other, whilst revisiting Merleau-Ponty's (1964, 1960, p67; 1945, p 190) notion of *carnal body* (*corps sauvage*) (e.g. listening to the breath in vocal expression), as the audience's own bodies become more technologised through the use of wearable devices.

The piece, in its aesthetic exploration between sound, space and body, is primarily influenced by the Sound Mirrors (Dungeness, UK), a redundant war technology, in their aesthetics and functionality; and by Bernard Leitner's *Sound Umbrella* (1990) and his view on corporeal hearing, where acoustic perception is heard through the entire body: "I can hear with my knee better than with my calves" (Leitner 2008).

In situating the piece within Merleau-Ponty's *Ontology of the Flesh* (1964, unfinished and published post-mortem), Radical Enactivist thinking (Hutto and Myin 2017; Zavota 2017), and through technological interfaces – more specifically AAR instruments – we aim to alter the way in which the audience *couples* or *intertwines* with the installation environment, to create new channels for sonic expression:

"[T]he body inhabits the world as its expressive place for action. The deftness of the pianist's hands is what transforms the keyboard into something to be played, revealing it as a place for expression, and the playing of this keyboard modulates and reshapes the pianist's general power for playing [...]. The body, then, must be recognized as essentially an "expressive space"; the body is "the very movement of expression". (Merleau-Ponty, 1945, p147)

In this sense we do not locate the body relations with technological interface as embodied, embedded or extended but instead as paradoxically intertwining "immanence" and "transcendence" of the body, as *chiasm* (Merleau-Ponty 1964). Next we clarify our theoretical position around chiasm, flesh and expression.

1. Chiasm, Flesh and Expression

The later work of Merleau-Ponty and related theories of Enactivism provide a theoretical basis for our design approach to *Listening Mirrors*. Merleau-Ponty shifts from his initial phenomenological perspective (1945) in which the body in consciousness is a prime source for knowledge, towards an ontological one in which the body, still in a prime position, is based in the intertwining of immanence and transcendence, the 'sentient' and the 'sensible' (1964, p.136,180), the *corps sauvage* and cultural body, as one 'chair' or 'flesh' (1964).

In defining what is meant by 'flesh', Merleau-Ponty states, '[w]e must seek space and its content together' (1964, p.141; 1968, p.157–8), that we are 'interwoven into a single fabric' (1945, p.413), a 'universal flesh' (1964, p.137), and 'he who sees cannot possess the visible unless he is possessed by it, unless he is of it' (1945, pp.134–35, 1968). The notion of 'flesh', therefore, is both the 'flesh of the world' and the 'flesh of the body', the relation of the *corps sauvage* and cultural world and its representations.

Merleau-Ponty's *corps sauvage* refers to the body before language, the body based on instincts and senses. 'Flesh' is not materiality, spirit or substance (1964, p.181) but an experience sourced from and based in and beyond perception; it is the paradoxically intertwining 'immanence' and 'transcendence' of the body as it is enveloped by and within 'flesh': [T]his occurs because a sort of dehiscence opens my body in two, and because between my body looked at and my body looking, my body touched and my body touching, my body heard and my body hearing, there is entwining in reversibility, there is chiasm, so that we must say that the things pass into us as well as we into the things (1968, p.123). *Chiasm* is an intertwining of relation such as the visible and the invisible, touched and touching. (Landes 2013, p38).

From this perspective, it becomes possible to think of the body no longer as a main point of perception (Landes 2013) but as pre-body-subject/object, as the *corps sauvage*, and as part of a reciprocal relational system with the 'flesh in the world' as they reflect, encroach and become inseparable (*ibid*, p.248): *Raising the description of the intentional arc to an ontological level, it seems that the body 'holds things in a circle around itself' such that things of the body's milieu are internally related to what the body is, they are part of its 'full definition' – the body is then, essentially relational.* (Landes 2013, p76)

In this relational system, new forms of sonic expression are found in action. Landes (2013), in discussing Merleau-Ponty, highlights how "[...] given the paradoxical logic of expression, all action is writing and all perception is reading", reflecting Merleau-Ponty chiasm as the "body makes itself the outside of its inside and the inside of its outside" (1968, p144), as my body hears and is heard.

More recently new forms of Enactivism draws strong links with Merleau-Ponty's Ontology of Flesh. Jenkinson (2017) and Zavota (2016) comment on how Enactivism has heavily drawn from Merleau-Ponty's early work (primarily

Phenomenology of Perception, 1945) but by adding Merleau-Ponty's Ontology of the Flesh to the Enactivism discussions, challenges existing dualism between cognition and the body: "*The nature of our conscious experience of being embodied human beings is thus conditioned by the particular structure of our sense organs and their interaction with the environment, in line with embodied and embedded theories of cognition*". Merleau-Ponty goes further than this, however, to argue that "[t]here is a human body when, between the seeing and the seen, between touching and the touched... a blending of some sort takes place.". (Zavota 2016, p114); and also bring new challenges in thinking "*how body and world are discretely distinguishable*" (Jenkinson, 2017).

In addition, Armstrong (2007) draws links between enactive theories of cognition and musical instrument design, setting out the conditions for embodied coupling between human and instrument: situatedness, timeliness, emergence, multimodality and engagement. We see AAR as an opportunity to experiment with, modulate and disrupt these conditions to create new audience collective experience.

Further to Enactivist approaches, we draw from the work of gaming theorist Karen Collins (2011), in the exploration of sound in relation to the body in game worlds. Collins discusses how sound can become a sensory extension of the self when exploring a virtual world. In discussing Chion's notion of ergo-audition, which suggests that we have a strong embodied connection to self-produced sounds, it can be argued that self-production of sound is a form of physical exploration of an environment. Consequently, we can consider the fine-tuning of mappings in the installation to encourage self-vocalisation as a form of exploration and self-establishment within a game world, as well as a form of sonic expression. Collins approach sound as a transcendent medium and how in the mixed reality context, the audience can hear and their body be heard, thus echoing Merleau-Ponty's *chiasm*.

In summary, we have presented theories that continue to influence our thinking around the ingoing design of this installation. Next we introduce our instrument design and aesthetics around audience's bodies and mixed reality worlds.

2. Design Aesthetics

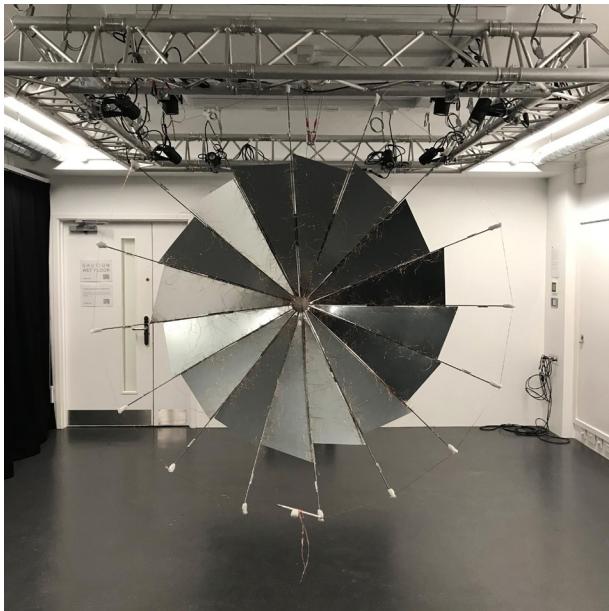


Figure 1. A Listening Mirror

In designing Listening Mirrors the main ambition was to offer new experience and expression through the combining real and virtual world manipulation. The development of the Listening Mirrors began in Summer 2017, by initially developing our concept and reflecting on others and our own position around AR technology with the “*Forum for Augmented Reality Immersive Instruments*”, which invited multidisciplinary artists and researchers to discuss AR and the arts (Chevalier and Kiefer, 2017).

Once we had experimented with different software mappings and looked at a wide range of practical designs for acoustic mirrors, we decided to use as pattern a parabolic design for DIY solar reflectors (Zhu, 2002) combined with aluminium material to maximize the acoustic resonance for collective immersive experience.

We ran a formative audience study, to elicit initial feedback about the audience experience of the installation elements with the aim to establishing key issues (Kiefer and Chevalier, 2018). The results demonstrated the potential of the system to be immersive, to encourage playfulness within the installation environment and to provide a space for collective musical expression: “*It did feel like a safe environment to experiment in, because you kind of feel enclosed in this sound world ... a big safe space which is making your voice sound really great*”. It also highlighted issues around social inhibition in collective environments: “*I was a little bit reticent to use my voice*”, and the fine-tuning of balance between virtual and real worlds. This feedback led us to the iteration we are currently testing, that uses networked audio and transduction in the mirrors, giving more opportunities to the audience for expression and interaction. As Listening Mirrors reaches its final design stage we will be conducting further audience studies to fine-tune the mappings, in the context of the relational system earlier mentioned.

3. Listening Mirrors Prototype

The installation is an audio feedback system that channels and transforms sound through real and virtual domains. It merges together audience worn AAR with shared physical acoustic objects. These are linked through transduction of sound through the physical objects and the environment. Figure 2 shows the objects in the system and how they are connected.

Audio Augmented Reality & Virtual Mirrors

The AAR system comprises an app running on a mobile device, paired with bone conducting headphones. These headphones are worn in front of the ears, allowing the wearer to hear digitally processed sound layered with normal hearing. The sound environment is monitored using the microphone of the mobile device, reprocessed and played through the head-

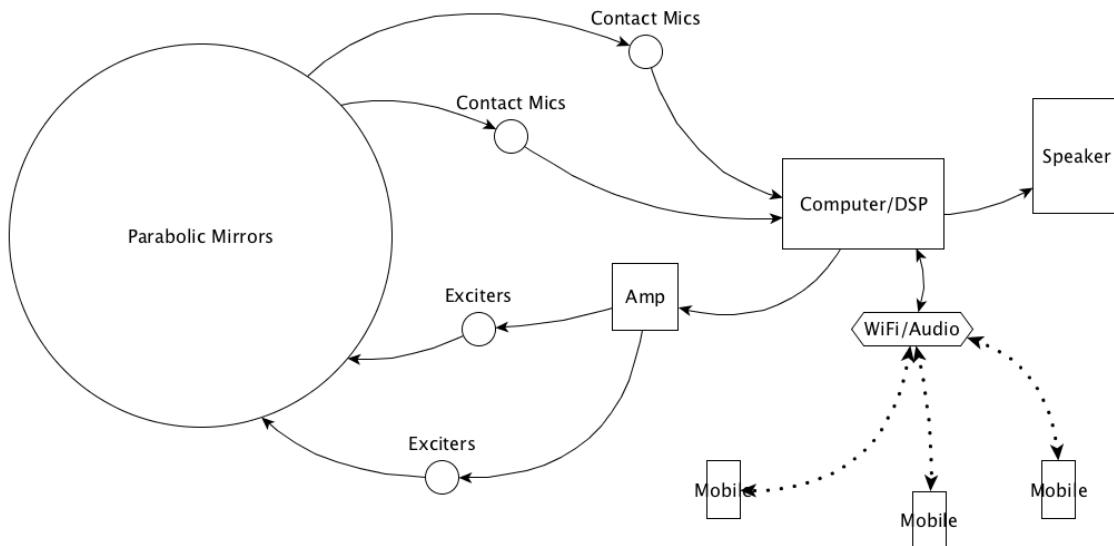


Figure 2. The objects in the installation and their connections

phones, thereby creating an augmented audio environment which is a mixture of the natural environment and synthetic reprocessing of it. The mobile device runs an iOS app, which hosts a Pure Data sound engine (using LibPD, Brinkman, 2012) within an OpenFrameworks app. The sound processing uses heavy compression coupled with mid to high frequency emphasis of the microphone signal, emphasising the sound of the breath, with the addition of a convolution reverb to modify the sense of space.

Parabolic Mirrors

The physical objects in the installation are two identical parabolic mirrors (see figure 1). These are constructed from cut aluminium sheeting, wired to 3mm diameter piano wires in a circular formation. The support wires are mounted on a central plastic support, and have plastic connectors on the end through which bass strings are fed. The strings are pulled tense, to draw the structure into a parabolic shape. The mirrors are augmented with two types of transducers: (a) contact microphones are mounted to record vibrations in the structure and (b) audio exciters are mounted to induce vibrations in the structure. The design

of the mirrors lend them multiple roles; as reflectors of environmental sound, as transmitters of sound and as responders to physical manipulation by the audience.

Audio Connections

There are several vectors for sound in the installation. The acoustic environment echoes sound made by audience members, and is shaped by the focusing of sound between the parabolic mirrors. A computer acts as a hub for further sound routing. It is connected to contact microphones on the parabolic mirrors, collecting acoustic sounds made by the audience manipulating Listening Mirrors. It is also connected to the audio exciters on the parabolic mirrors. The computer also hosts an audio-over-IP server that allows it to exchange networked audio streams with the audiences' mobile devices. This creates a network of audio routings that allows exchange of sound between audience, environment and the parabolic mirrors.

4. Listening Mirrors and Collective Expression

We consider Listening Mirrors as a mixed reality relational system and instrument from which new expressive, playful and collective experiences take place. In *Augmented Reality in Art*, Geoffrey Rhodes (2014) discusses AR as an *inhabited environment* from which the digital and the physical *co-produce and co-construct one another*, from which expression can be found in its enmeshment (Chevalier and Kiefer 2018). This recalls Merleau-Ponty's discussion on *chiasm* and *flesh* and new forms of Enactivism earlier mentioned, leading us towards further investigation of the potential value of this work as a theoretical basis for our approach to audio augmented reality and other work in AR and the arts. We continue to develop and test this installation, but we believe that AAR demonstrated abilities to enhance collectiveness through sound and network technology, suggesting that how AAR is a form of *chiasm*: my body hears and is heard.

To conclude, we have described an installation environment that employs a combination of audio augmented reality with a physically augmented acoustic environment, designed to encourage collective sonic expression. The design uses mobile AR technology, together with acoustic reflectors that also double as sound transducers between real and virtual worlds. We have outlined the development history of the project, and introduced the theoretical background we are drawing on to help us to understand new modes of collective sonic interaction that involve hybrid real/virtual interfaces. We see Merleau-Ponty and theories of Enactivism as a way forward to think about AAR technology and collective sonic expression. Questions in future development of this piece concern how the body is conceptualised at the borders between real and virtual worlds, and how AR interventions in perception can lead to collective expressive interaction.

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Guido and Am I Robot?

A Case Study of Two Robotic Artworks Operating in Public Spaces

Paul Granjon¹

pgranjon@cardiffmet.ac.uk

Patrick Hénaff

patrick.henaff@univ-lorraine.fr

Alain Dutech

alain.dutech@loria.fr

LORIA UMR 7503, University of Lorraine-INRIA-CNRS, F-54506 Nancy, France

¹ Cardiff School of Art and Design,
Cardiff Metropolitan University, Cardiff UK

Abstract

This article is a case study of two artworks that were commissioned for and exhibited in art venues in 2016 and 2017. The first artwork, *Guido the Robot Guide*, guided the visitors to an art-science exhibition, presenting the exhibits with a robot's perspective. *Guido* was the result of a collaboration between artists and engineers. The concept was an irreverent robot guide that could switch transparently from autonomous mode to operator control, allowing for seamless natural interaction. We examine how the project unfolded, its successes and limitations. Following on *Guido*, the lead artist developed the robotic installation *Am I Robot?* where the idea of a hybrid autonomous/remote-manual mode was implemented fully in a non-utilitarian machine that was exhibited in several art galleries. The article provides a concise contextualisation and details technical and design aspects as well as observations of visitors' interactions with the artworks. We evaluate the hybrid system's potential for creative robotics applications and identify directions for future research.

Keywords

Robotic Art

Robot Guide

Collaborative Robotics

Dynamic Robot Autonomy

Telepresence

HRI

Robot-human Interface

Introduction

What is a robotic artwork? As some readers may not be familiar with the term, it is important to begin by stating clearly what type of robotic systems belong to the category. Traditional media such as painting or sculpture are just some of the means used by contemporary artists, whose practice can be expressed through many different media. In a similar way to how video art was invented by artists who, in the 1960s, chose to make art with television sets and video cameras, robotic art is made by artists who choose robots as their medium. The artworks thus produced often comment on the relation of humans and technology, providing metaphors, unfolding speculative scenarios or exploring technical possibilities in a non-scientific or commercial manner. The practice of artists working with robots has sometimes been described as creative robotics, “a transdisciplinary practice that builds on the history of robotic and cybernetic art to explore human-robot configurations from a critical, socio-cultural perspective. It brings together concepts and methods from experimental arts and engineering, performance and the social sciences” (Gemeinboeck, 2017). This artistic integration of robotics and computer science started in the 1950s. Notable examples include Nicolas Schöffer’s *Cysp1*, (from Cy-bernetic and Sp-atiodynamic) a mobile sculpture that responded to sound and light (1956), Nam June Paik’s *K456* remote-controlled flimsy humanoid (1964), Edward Ihnatowicz’s *Senster* (1970) a large scale pneumatically driven beast that moved its long neck towards visitors, as well as Stelarc’s cyborg-like *Third Hand* (1980).



Figure 1. *The Fluffy Tamagotchi*, video still, P. Granjon, 1998

Paul Granjon, the lead artist for both artworks discussed here, has been making robots for live performances and exhibitions in galleries and museums since the mid 1990s. Self-taught in coding and hardware, he makes simple programmed machines that aim at provoking in the audience a reflection on what he often refers to as the co-evolution of humans and machines (Granjon, 2013). For example one of his first working robots was the *Fluffy Tamagotchi* (1998) [Figure 1], a teddy bear-sized noisy and messy robot that claimed to bring back the physicality of pets to the sterile interactive toy. The robots he made since continue to raise questions about our needs and uses for robots and other contemporary technologies while exploring in a practical manner some of the possibilities offered by these technologies. We will examine two robotic artworks operating in public spaces : *Guido the Robot Guide* (2015), a museum guide robot created in collaboration with a team of artists and engineers, and *Am I Robot?* (2016) an art installation featuring a talking mobile robot.

Museum guide robots have been tested in real guiding situation since the late 1990s. Some of them are wheeled platforms fitted with more or less expressive “faces”, for example *Rhino* (Burgard W. et al, 1999), *Minerva* (Thrun et al., 1999) and more recently *FROG* (Karreman et al., 2015). Humanoid robot guides are also tested such as

Robotinho (Faber et al., 2009), *TT2* [7], *ASIMO* (Falconer, 2013). A common design of existing robot guides is a centaur-like set-up, where a full size humanoid, with or without legs, is mounted on a motorised base as seen in *Hermes* (Bischof et al., 2002), the working version of *Robotinho* and *TT2*. The guide robots mentioned above operate autonomously for both navigation and audience interaction. They are all research robots and are presently not active in galleries and museums on a full time basis, if at all.

There are cases of autonomous mobile robotic artworks sharing space and interacting with members of the public, unburdened by the task-based function of being a museum guide or another utilitarian function. Examples include Max Dean and Rafaello d'Andrea's *The Table* (1984), a mobile table interfering with visitors motions, Simon Penny's *Petit Mal* (Penny, 1997), an awkwardly balanced machine that visitors could approach for playful interaction, Maria Velonaki's *Fish Bird* (Rye et al., 2005), a pair of graceful wheelchair robots that dropped poetic notes on the floor while engaging in motion with visitors, Kacie Kinzer's *Tweenbots* (Kinzer, 2011) that were left free in Central Park, depending on the public's good will to reach their destination, as well as Carsten Holler's *Two Roaming Beds (Grey)* (Kennedy, 2015) that visitors could book for a night in the Hayward Gallery in London. All the examples above provide situations where humans and robots can share a space and interact in real time in a playful and/or exploratory fashion.

Interest in physical implementations of AI is widespread among the general public, as evidenced by the commercial success and the abundance of films, graphic novels and novels featuring intelligent machines. Celebrity robot expert Rodney Brooks has identified "a mismatch between what is popularly believed about AI and robotics, and what the reality is for the next few decades" (Brooks, 2017). Both the artworks described in the article recognise this gap and the lack of an even remotely satisfactory general artificial intelligence, the intelligence

of "autonomous agents that operate much like beings in the world" (Brooks, 2017). To address the issue, both artworks use a concealed (*Guido*) or semi-concealed (*Am I Robot?*) hybrid autonomous/remote-manual mode that makes use of human intelligence in a basic implementation of collaborative robotics.

Concealed remote-control can be traced back to Baron Von Kempelen's *Mechanical Turk* automata (1770), a seemingly autonomous chess playing humanoid that was in fact operated by a short person hidden under the chess board. *The Wonderful Wizard of Oz* (Baum, 1900) is a concealed host, monitoring and affecting Dorothy and her friends' environment. Closer to us, children taking part in MIT's Personal Robots Lab experiments with cute *Dragonbots* are actually interacting with hidden researchers who control the robots' speech and motion. The set-up is semi-concealed as, after the experiment, the researchers "show [the children] the teleoperation interface for remote-controlling the robot. All the kids try their hand at triggering the robot's facial expressions" (Kory-Westlund, 2017).

The growing field of collaborative robotics provides numerous examples of approaches to partial autonomy, for example with the notion of dynamic robotic autonomy explored by Schemehorn and Scheutz, where the sharing of a given task between the robot and the human operator varies according to the complexity of the task and the abilities of the robot and of the human. Their experiments in human-robot collaborative tasks demonstrated that subjects "accepted robot autonomy and seemed to prefer it [to non autonomous mode], even going so far as to ignore instances of disobedience and attribute greater cooperativeness to the autonomy mode" (Schemehorn et al., 2009). A related approach to dynamic autonomy is coercive design, "a way of characterizing an approach to the design of HRI that takes interdependence as the central organizing principle among people and robots working together in joint activity" (Johnson et al., 2014). In both cases the system aims at optimising the output of a robot-hu-

man team by dynamically allocating tasks to the human and/or the robot according to their strengths and weaknesses.

In the field of robotic museum guides, the collaborative approach has been explored by a transdisciplinary team in the Politecnico de Milano with a robot guide called *Virgil* (2015) that combines a human museum guide and a telepresent robot. *Virgil* possesses navigation and obstacle avoidance algorithms that operate jointly with the museum guide's commands. The authors' "new robotic service implements the concept of human-robot collaboration [...]. Conversely to many robotic solution applied in museums [...] the storytelling activity continues to be entrusted to the museum guide and a robot assumes the role of a remote collaborator, which explore the areas inaccessible for people." (Lupetti et al., 2015).

Guido the Robot Guide was commissioned as an artwork for a science-art exhibition in Luxembourg. Granjon's brief was to lead the creation, in collaboration with team of engineering and fine-art students, of a mobile robot that would guide the public through parts of the exhibition. The concept was to provide information on the artworks from the imagined perspective of an intelligent robot with an irreverent sense of humour. Unlike the robot guides mentioned above, *Guido* did not use machine vision or speech recognition. The artist's intention was that, operating by default as an autonomous machine with pre-programmed paths and speeches, the robot's voice and aspects of its motion and navigation could be over-ridden by a professional human museum guide at the touch of a button. This hybrid autonomous/remote manual mode was intended to provide the robot with a flexible, knowledgeable and responsive presence, akin to that of a human guide. A full account of the project is provided below.

Some aspects of *Guido*'s concept were developed further in another robotic artwork by Granjon called *Am I Robot?* (2016). The *Am I Robot?* installation features two parts: a mobile

robot called *Combover Jo* and a semi-concealed control room. *Combover Jo* is let loose in the exhibition space, moving freely among visitors and static exhibits. Unlike *Guido*, *Combover Jo* has no utilitarian function, no job. It cruises at a leisurely speed, pronounces randomly selected sentences and navigates around obstacles and visitors. At times, the visitors can engage in complex conversations as well as interactive motions with the robot where for example the robot follows a specific individual or responds to verbal commands. This intelligent behaviour occurs when some visitors have discovered the control room and realised that they can control *Combover Jo*'s motion and speech. Other visitors might not be aware of the existence of a control room and assume that the robot is intelligent, until they, in turn, find the controls and have a go at driving the robot if they wish.

Am I Robot? relies on the playful dimension of the interaction and on the unfolding of the manual control trick to question visitors' assumptions about the current state of AI and robotics. The mismatch between most people's expectations and actual possibilities of contemporary robotic systems is significant, as was confirmed when observing *Combover Jo* moving among visitors: although incredulous about the insight of the robot ("How does it know my name?!!" was a comment heard several times), a majority of individuals did not question the autonomy of the robot. The hybrid autonomous/remote manual mode is an effective way to not disappoint audiences' science-fiction-fed expectations, yet the control room operation offers a playful reminder that artificial general intelligence is not available yet and that HI (human intelligence) still has the upper hand.

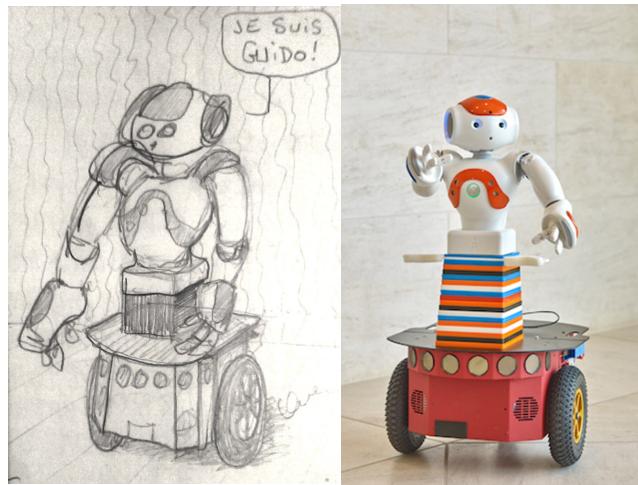
In its current state the *Am I Robot?* installation offers a simple and effective system for implementing experimental HRI in real situations. The basic structure of the system provides a clear platform for observing public engagement and for testing different relational scenarii in research or commercial contexts. Future developments, discussed below, will likely imply a

more advanced autonomous mode integrating aspects of Levillain and Zibetti's concept of "behavioural objects" (Levillain et al., 2017) and a co-active mode (Johnson et al., 2014) instead of the simple remote-controlled manual mode.

1. Results

Guido the Robot Guide

In 2013, Clément Minighetti and Marie Noëlle Farcy, curators at the MUDAM Museum in Luxembourg, started to work on an ambitious exhibition project titled *Eppur Si Muove* — and yet it moves — amous sentence attributed to Galileo. The show was going to pair science and technology artefacts from the collection of Musée des Arts et Métiers in Paris with contemporary artworks exploring scientific or technological aspects related to the artefact. In 2014 the curators commissioned Granjon to develop a robot guide for the exhibition, in collaboration with engineering, fine-art and business students from the ARTEM Alliance of higher education institutions in nearby Nancy, France (<http://www.alliance-artem.fr/>). The MUDAM curators had contacted the ARTEM alliance and it had been agreed that the robot guide development would be run as an ARTEM project in 2014-15. Granjon's role as lead artist for the project was to design the overall objectives for the robot, its personality, liaise with the engineering team, led by Patrick Hénaff, for hardware and interface design aspects, and to supervise the deployment of the robot in the museum. Granjon proposed that the robot was to present the exhibits from a robotic perspective, with a slight superiority complex and a deadpan sense of humour.



*Figure 2. a. Original sketch for Guido, Granjon 2015
b. Guido the Robot Guide in MUDAM Museum, P. Granjon 2016*

The budget did not allow for the fabrication of a bespoke machine. The Computer Science department at l'Ecole des Mines de Nancy owned several *Nao* robots and two Pioneer wheeled platforms that they agreed to lend for the duration of the project. After assessing the *Nao*'s walking capabilities, it was quickly established that the robot's speed and balance were not sufficient for robust delivery of guided tours. Two of the lab's *Naos* were torsos, identical in specifications and looks to full *Naos* but deprived of legs. The team tested mounting one of these on the Pioneer platform and decided that *Guido* would be built on that model. The centaur design [Figure 2b] combines the robustness and precision of a differential drive wheeled robot with the appeal of *Nao*'s cute humanoid features and access to its built-in social robot capabilities such as speech, speech recognition, touch sensors, realistic humanoid motions and prehensile hands. Granjon decided to call the robot *Guido*, a friendly name that refers to its job in the museum.

The engineers' main interest in the project was to program a mobile platform for pre-determined navigation task using odometry to access a series of via-points, while being able to deviate from and return to its route if an obstacle blocked it. They were also keen to devise a

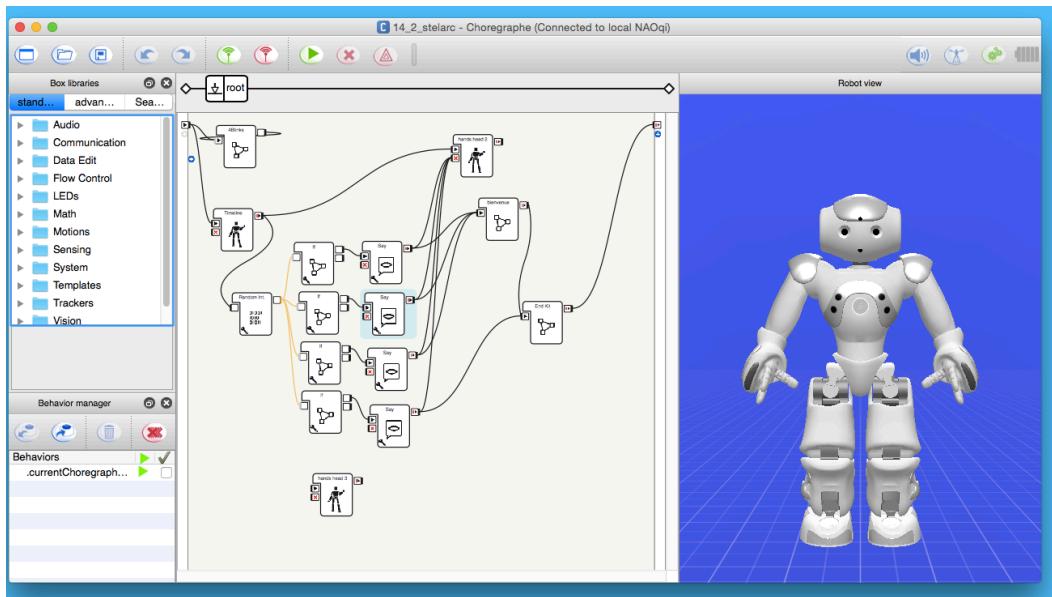


Figure 3. Aldebaran *Choregraphe* programming environment screen shot

robust integration of the Pioneer base and the *Nao* torso.

The fine-art students started to experiment with scripting monologues and matching gestures for the robot using the Aldebaran's *Choregraphe* visual programming application [Fig. 3]. Some of the test scripts written by the students contained verbal interaction with the public, the robot branching in one or other behaviour depending on the response. The *Nao*'s speech recognition system quickly showed its limits, achieving a recognition rate of less than 20% for simple words like yes and no in a reasonably quiet office environment. We decided to use this feature sparingly in the final design, given that the robot would have to be deployed in large rooms with the visitors standing at a distance of one or more meters from the robot. Due to other commitments, all fine-art students but one did not follow the project until the end. The remaining student Alix Désaubliaux and her tutor Maxime Marion became very apt at programming the *Nao* with *Choregraphe* and custom scripts [Fig. 8]. They contributed significantly to the timely delivery of *Guido*. In agreement with

the curators it was decided that *Guido* would speak French, one of the three official languages spoken in Luxembourg. As *Nao*'s makers Aldebaran are based in Paris, French was *Nao*'s first language. The robot's speech synthesizer is apt at producing a clear and melodious child-like French voice.

Granjon worked with the curators to make a selection of 17 exhibits from two connected spaces of the *Eppur Si Muove* exhibition. The two spaces were located on the same level, separated by a 20 meters long hallway, and all the floors were made of smooth stone very suitable for the robot's wheeled motion and odometric navigation. The robot was programmed to follow a series of via points that led it from artwork to artwork. It stopped and delivered a scripted comment in front of each artwork. A set of custom gestures was programmed for each artwork and for several interstitial behaviours. One of these behaviours was a Tourette function where the robot would briefly interrupt its current action and gently swear. Another was a walking-like arm motion and a musical clock-work sound when the robot travels between two

exhibits. The detailed content of the visit is not within the scope of this article, but we provide two examples of scripts—one for a technological artefact, the other for a contemporary artwork—so as to give the reader a clearer idea of the guide's robotic perspective and of the familiar relation the robot was attempting to create with the human public. The first speech comments on a vintage car battery: “The following example is a Tudor lead-acid battery made in 1947 for automobiles. We can see that the quality of machine food is improving rapidly. This is not yet of cordon bleu standard, but it smells quite good electrically speaking, even if the old lead acid technology is a bit like baked beans: rather heavy and emitting lots of gas. Personally I prefer lithium ion, much more energetic and sooo tasty!”. The second example was related to the *Tool Bones* sculptures by Damian Ortega (2013), a set of traditionally cast bronze objects combining features of human bones and common tools such as hammer or pickaxe: “Well, I went a little too far earlier when I spoke about you humans as an obsolete species. An alternative exists which has already begun: a future where human and machine merge and become a hybrid entity called cyborg. These intriguing objects made by Damian Ortega evoke a likely alternative to the obsolescence of

homo-sapiens, a deep bio-technological mutation where the tool integrates with the skeleton. Your children or grand children might benefit of this new potential, living in harmony with my future cybernetic fellows”.

The original idea was that after *Guido* delivered its speech on a given exhibit, it would answer visitors' questions. This would be done by switching to remote-manual mode, a human operator temporarily and transparently becoming *Guido*'s ears eyes and brain. A basic function was created that provided a joystick for over-riding the autonomous navigation and a keyboard interface for speech input. This version was sufficiently developed for testing and for planning improvements but not enough for use during visits. We will analyse the subsequent shortcomings on the robot's potential to engage with the public in the discussion section of the article. *Guido* delivered a couple of public visits a week in MUDAM between July 2015 and January 2016 [Fig. 4]. It was then returned to the Ecole des Mines de Nancy where it was painted white and made into a dancing robot called *Minoid*.



Figure 4. *Guido* and young visitors during a guided tour, P. Hénaff, MUDAM 2015

Am I Robot? robotic art installation

In October 2015 Granjon started work on a new commission for a robotic art installation. He had been invited to contribute to a new exhibition curated by Clare Gannaway in Manchester Art Gallery (UK), titled *The Imitation Game*. According to the gallery's website "*The Imitation Game* was an exhibition by eight international contemporary artists who explored the theme of machines and the imitation of life. [...] With a title inspired by Alan Turing's *Turing Test*, devised to test a computer's ability to imitate human thought, introduced in an article while he was working at The University of Manchester, *The Imitation Game* included three new commissions and works never before seen in the UK." [22].

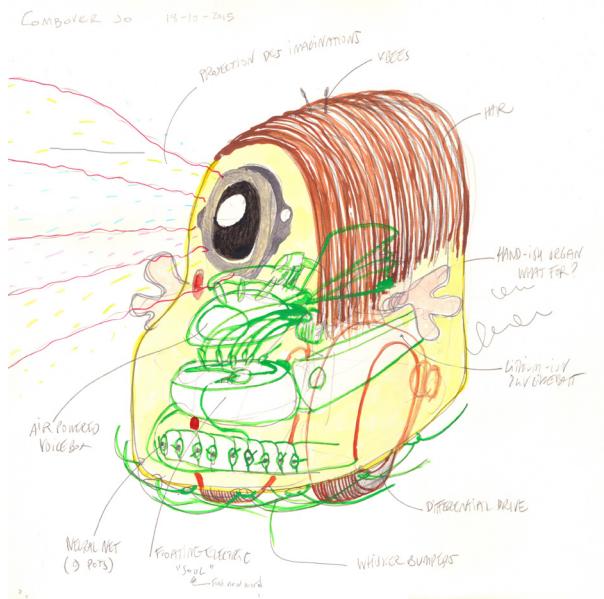


Figure 5. First visualisation sketch for the Am I Robot? robot Combover Jo, P.Granjon 2015

Granjon's project was to push further the concept of a hybrid autonomous/remote-manual system touched upon in *Guido*. He imagined a non-utilitarian non-humanoid mobile robot that would roam on the gallery floor [Fig.5]. The robot would be able to talk, navigate and display several behaviours autonomously. It would also be at times remotely controlled without a

noticeable change in voice or motion. The curator found the idea interesting and Granjon was given the green light to build the installation that he called *Am I Robot?*, turning the title of Isaac Asimov's famous collection of robot stories *I, Robot* (Asimov, 1950) into a question that gave an indication of the robot's partial autonomy. The exhibition occupied two levels of the building. The robot was allocated a large roaming area on the first floor while the control room was installed on the second floor. The control room was not advertised or sign-posted as such. It was installed inside a specially built cubicle that visitors could freely access [Fig. 6c]. Most visitors would have already visited the first floor and seen the robot prior to entering the control room. In the room they found two monitors, speakers, a joystick, a microphone and a keyboard [Fig 6b]. One of the monitors displayed a live video feed from the robot while the other showed text that could be inputted through the keyboard or the microphone. The speaker played live sound captured by the robot's on-board microphone.

The robot itself [Fig. 6a], like *Guido*, was based on a differential drive platform. Unlike *Guido*, it was built from scratch in a manner more similar to Granjon's usual method where a "low-level, empowering methodology [is] based on a first hand understanding of principles at work in the electronical-mechanical objects I build" (Granjon, 2007). Significantly less complex in software and in hardware than *Guido*, the robot's body was built from a Beseler Vu-Lyte 2 epidiascope (1956), a distant ancestor to the data projectors now used in education environments, providing a bulk slightly smaller than an R2D2 unit. The robot was not given a face but had two three-fingered hands and a mock combover of brown electrical cable running across its top. This last feature provided the robot's name: *Combover Jo*. The motorised hands originally fitted on the robot were removed in the final version of the robot due to catching walls and fixtures, leaving the robot without any humanoid characteristic but the lens of the epidiascope turned into a sort of eye with a circle of green

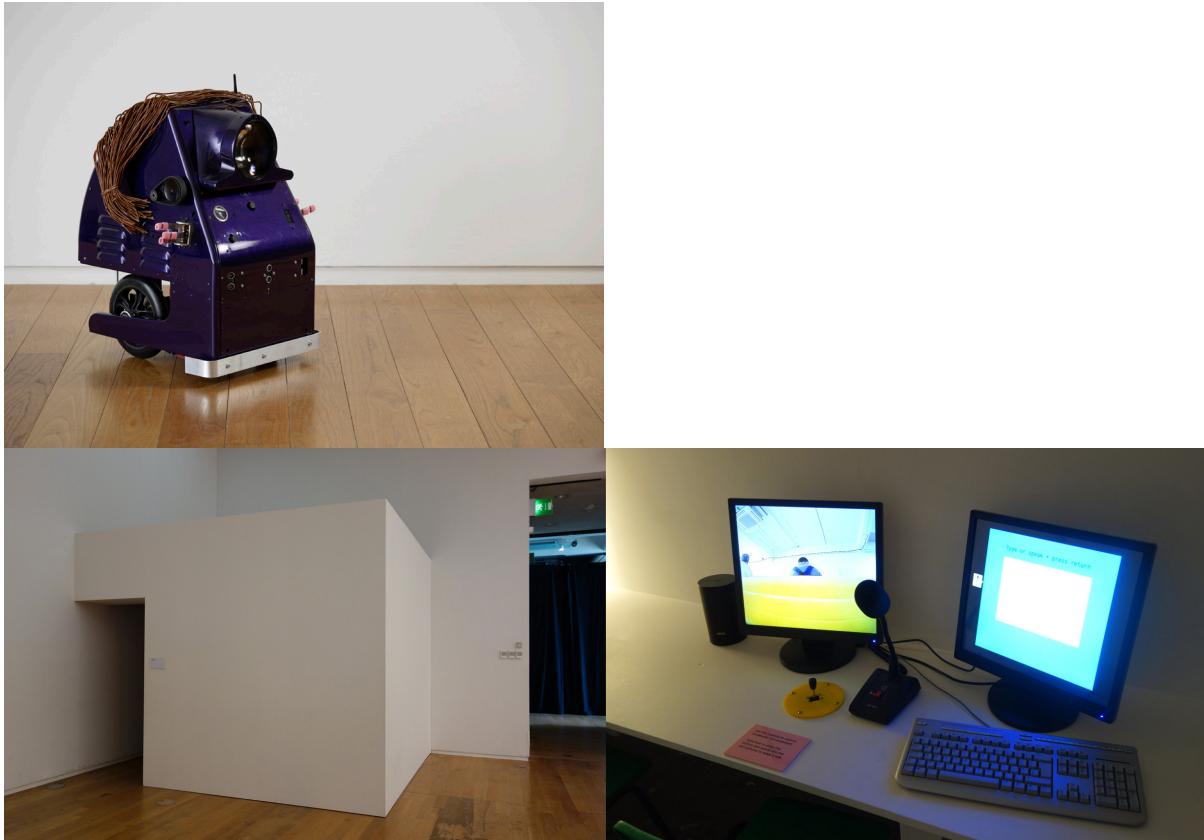


Figure 6. clockwise from top: a- Combover Jo robot version 1 (Manchester), photo credit Michael Pollard b- Am I Robot? control room controls, P. Granjon c- Am I Robot? Control room outside, P. Granjon.

LEDs. The robot's non-threatening, almost comical appearance aims at putting the visitor at ease, removing apprehension, fear or uncanny valley-related unease. *Combover Jo*'s top speed is approximately 0.5 m/s. In autonomous mode it avoids obstacles, including visitors and pronounce randomly one of 200 pre-programmed sentences at irregular intervals. It speaks English or Spanish with a distinctly robotic voice that is neither male nor female. The sentences range from humorous greetings such as "Hello Dude", "Hello Dudette" to deeper existential reflections like "Where is my soul?" or "I was not born". Green coloured stripes on the floor mark the limits of the robot's domain. A colour sensor fitted under its base triggers a u-turn manoeuvre when it detects green. Detection

of a red floor area activates the robot's dream state, where it will stop when close to an obstacle and project through its eye-lens a short pre-recorded video sequence, presented in the exhibition catalogue as a "robot dream" (Furber et al., 2016). The dreams feature non-narrative edits of technology and science footage combined with images of nature. As soon as a visitor touches the joystick in the control room, *Combover Jo* switches to manual mode. Text typed or dictated in the control room is transmitted to the robot and pronounced in the same voice and tone as the pre-programmed sentences. The robot moves under joystick command with an overriding avoidance manoeuvre taking over when it is too close to an obstacle while moving. When the robot is not moving while under

manual control, visitors can get to touching distance.

Am I Robot? has been exhibited in three different exhibitions at time of writing, with a significant upgrade installed for the last showing. In all cases three main types of interaction with the robot were observed:

- No interaction, the visitors avoids or ignores the robot and continues on their initial destination
- Attempt to interact physically, for example by standing in the way of the robot or dancing.
- Talk to the robot.

The last two types interactions do not last more than approximately one minute when the robot is in autonomous mode (unless the visitor is a child). When in telepresent mode, the interaction becomes much more involved and complex. When the visitor in the control room has mastered the controls, *Combover Jo* becomes really responsive. It can comment on a visitor's clothing or even, when the driver

knows the person in front of the robot, call them by their name or ask knowing questions. It can also follow or avoid specific members of the public or perform basic dances. More than half of the visitors observed assume that, when in tele-operated mode, the robot is autonomous and driven by an AI program. Children tend to question less than adults the personal knowledge the robot might demonstrate and enjoy playing and conversing with it. Some adults will react incredulously ("How does it know my name?!") but still not suspect that another human is behind the intelligent behaviour of the robot until they enter the control room or another visitor informs them about its existence [Fig 7b]. In the control room, visitors tend to behave like tricksters [Fig 7a], giggling and prompting each other to enter text that will trigger optimum response from *Combover Jo*'s current interlocutor. Other visitors who might not suspect another human to be in control when the robot simply greets them become suspicious when it starts to show too much knowledge, humour or general intelligence.



Figure 7. a. visitors in *Am I Robot?* control room. b. *Combover Jo* version 2 (Hull) and visitors in the gallery space.
Photos credit Tom Curran



Figure 8. *a.* Alix Desaubliaux and Maxime Marion working with Naos in Ecole des Mines de Nancy, 2015. *b.* Mehdi Adjaoue and Romain Schumers with two Guidos in MUDAM, 2015. All P.Granjon

2.Discussion

Guido

The navigation and spatial accuracy of the robot were very good, *Guido* succeeded in positioning itself by the artworks for script delivery with an approximately 20 cm precision, even if it had encountered obstacles on the way. The integration of the *Nao* torso with the Pioneer P3DX base was also very functional and robust, with seamless communication between the two units.

During the preparation of the *Guido* project, the MUDAM Museum guides expressed a semi-serious concern about the future of their jobs: would visitors prefer the robot guide's visits to the ones they were paid to deliver. After seven months of robot visits they were fully reassured: a common response from visitors was that after an initial peak of interest due to the unusual nature of their guide, they realised its limitations, the rigid nature of its performance and lost interest. This had been anticipated by Granjon whose response was to imagine a robot with a hybrid autonomous/remote manual mode manned by a trained operator. The rationale behind the decision to implement a hybrid system was motivated by two main factors:

- The budget, timescale (8 months), and workforce available for delivering a fully functional robot guide were tight.
- More crucially, the natural interaction that was sought to achieve required a level of general artificial intelligence significantly superior to any system presently available, including all the guide robots mentioned above. Even Honda's famous *ASIMO* was not up to the task. In 2013, "to test the robot in real-world conditions, Honda set up *ASIMO* as a tour guide at Japan's National Museum of Emerging Science and Innovation. The company want[ed] to see if the robot c[ould] autonomously interact with visitors, answering questions and explaining things" (Falconer, 2013). *ASIMO* repeatedly failed to recognise visitors' raised hand motions and relied on tablet input to overcome the difficulties of real-time speech recognition in actual museum conditions.

Despite the engineering team's efforts, *Guido*'s complete hybrid mode was never delivered due to two main reasons:

- The budget was not sufficient for training and paying the wages of a professional museum guide who would have supervised all the visits throughout the exhibition. This

person would have had a key role, ready to switch to remote manual mode anytime a visitor had a question, or when he/she would have spotted a good moment for snapping off the recorded script and comment, for example if someone's phone was ringing or if a child had a robotic toy.

- The speech input function, that would have allowed the responsivity required for a full conversation level of interaction with *Guido*, was never implemented.

In their work with the human guide-controlled telepresent robot *Virgil* mentioned above, Lupetti et al. state that "keeping the storytelling activity performed by the museum guide is fundamental due to the fact that only a human can provide the interpretative aspect. The interpretation [...] is the process in which the museum guide can create links between the visitor culture and the heritage contents. This process allows visitors to develop an empathic relationship with both the museum guide and the cultural heritage itself." (Lupetti, 2015). Similarly Granjon places a crucial emphasis on the role of the human in the loop as a factor of empathy with the robot. He favors a collaborative approach where the robot is given space and time to operate in full autonomy while a human operator monitors the activity and can take over aspects of the interaction when the robot is not able to deliver a convincing behaviour. Granjon sees variations on this approach, at least for the present and mid-term prospects of general artificial intelligence, to be the only available tool for answering the audience's expectations for a truly engaging robot.

Am I Robot?

The conclusions drawn from the *Guido* project strongly informed the conceptual and design decisions for the *Am I Robot?* installation. Most importantly, *Am I Robot?* delivers a fully functional hybrid mode. In addition, *Combover Jo*'s non-humanoid design and the lack of a utilitarian role are intended to reduce the amount of pre-conceived opinions regarding the robot's

role or intelligence. Levillain and Zibetti examined several non-humanoid, non-utilitarian robots in their research on behavioural objects, artifacts with life-like interactive behaviours made possible by techno-scientific developments, shifting away from the status of simple objects. They posit that "the appearance of a humanlike robot prompts attributions of the capacity to feel and sense. This kind of assumption may conflict with the actual behavior of the robot, which is often not as sophisticated as its appearance" (Levillain et al., 2017). *Combover Jo*'s lack of humanoid or zoomorphic features does not generate the same level of assumptions (although several visitors have enquired about its ability to hoover, drawing parallels with a cleaning robot). The absence of a clearly defined function produces a similar effect: as *Combover Jo* is not presented as a guide or a receptionist, visitors do not assume that the robot will deliver a set behaviour inspired from a human guide or receptionist. Such a behaviour would most likely be inferior in presence, interaction and engagement compared to a human professional, which would leave the visitor dissatisfied as was apparent in the *Guido* project.

The notion of behavioural object can be applied further to *Am I Robot?* Levillain and Zibetti state that, "unlike the social robot, behavioral objects are not specifically conceived to serve, help, or cooperate with humans. Although they can sometimes mimic human social behavior, they are not designed to engage a user with human-like social skills, or features such as gestures, posture, body and facial traits that organize the social interaction" (*ibid.*) Behavioural objects can be used for exploring aspects of HRI, especially playful and explorative interactions, that would be more difficult to access with task-oriented anthropomorphic social robots. In the same way as a humanoid robot elicits a specific set of expectations, a social robot will also be expected to behave in a helpful, utilitarian and benign way. Granjon examined the limitations imposed on the exploration of the true potential of machinic life — a notion explored by Johnston as the capability of a machine "to alter itself



Figure 9. Visitors socialising with *Combover Jo* during the *States of Play* exhibition, Hull UK, 2017. a: photo credit Tom Curran. b: P. Granjon

and to respond dynamically to unknown situations” (Johnston, 2010) — by constraining social robots to a benign role. He suggests a creative robotics approach to non-benign experimental robots where “non-benign [...] does not stand for malign, but instead aims to define an area where a wide range of autonomous behaviours are possible, covering a full gamut of possibilities which may include aggressive as well as friendly traits.” (Granjon, 2017). The notions of behavioural object and of non-benign robot share the characteristic of not being designed for serving human needs, allowing exploration of speculative HRI scenarii not subjected to utilitarian, commercial or scientific constraints.

In that manner, *Combover Jo*’s non-utilitarian and non-humanoid characteristics, combined with a robust, safe, human-friendly design and an absence of instructions not to touch or get too close to the robot aim to lay the foundation for an open human-robot relationship. Granjon’s observations of visitors’ interaction with the robot confirm that in many cases a natural interaction occurred, especially with children but also with adults. Largely perceived as a friendly creature, *Combover Jo*’s unassuming presence is a simple but effective way to engage humans. The semi-concealed control room trick is not a

lie, as visitors are implicitly invited to discover the controls. The trick operates instead on two levels:

- It allows the emulation of an intelligent robot (of the future?), capable of initiative, humour, conversation, and moods.
- The robot’s disclosed reliance on HI for delivering an intelligent presence raises questions about the capabilities of general artificial intelligence in comparison to humans’.

Directions for future research

There is no plan at this stage to continue research and development of a museum guide robot. After the initial exhibition in Manchester, the *Am I Robot?* installation was shown in the Oriel Mostyn Art Gallery in Llandudno UK and in the *States of Play* exhibition organised by the British Craft Council in Hull UK. It was included in *Prototipoak*, a creative robotics exhibition in Azkuna Zentroa Arts Center in Bilbao Spain in summer 2018. Public interest in and engagement with the installation motivates further development of non-utilitarian collaborative robotic artworks. Two main aspects need to be addressed in future projects:

- improving the quality of the autonomous mode by integrating machine vision aspects such as people detection and face recognition, basic speech recognition, and more importantly a learning function that would allow the robot to generate new behaviours from past experience. The learning function would include a curiosity factor inspired by Kaplan's work with *Aibo* robot dogs [31]. The autonomous mode could be further improved by studying visitors' reactions to various programmed behaviours following on Levillain and Zibetti's concept of behavioural objects.
- develop a more complex and integrated collaborative mode instead of the current basic tele-operation. More functions could remain shared between the robot and the human. Some of these functions would be influenced by the learning engine of the robot, acting as a sort of personality that could be only partially over-ridden by the human. This advanced collaborative option would implement aspects of the co-active approach described by Johnson et al., where the robot and the human operate as interdependent team partners.

3. Materials and Methods

Guido

Hardware

Guido was based on a standard *Pioneer P3-DX* differential drive mobile base on which a *Nao T14* torso was attached. The torso was raised with a stack of perspex slabs so as to bring Guido's head to a height of approximately 60 cm. Communication between the base and the *Nao* was effected by an on-board NUC computer connected with an ethernet cable. The Pioneer base was fitted with two 12 V lead acid batteries that were also used to power the NUC and an on-board Wifi unit. The base was connected to the NUC by USB. The *Nao* torso was powered by its own built-in battery. An emergency stop

button mounted on the platform could interrupt the supply of power to the motors. At times an amplified speaker and an external microphone were used to amplify Guido's voice. We also experimented telepresence with a Wifi camera installed at the front of the Pioneer base. Built-in ultrasound sensors and bumpers on the P3-DX, combined with on-board odometric hardware were used for navigation and obstacle detection.

Software

The Pioneer mobile base embeds the Aria operating system that allows real-time execution of low-level programs for control and management of sensors. It was programmed with the Aria API. The program integrated specificities of the robot's field of operation such as the percent of wheel slip on the stone floor, calibration of the magnetometer according to the ambient magnetic field as well as the maximal and minimal values of emergency acceleration and de-acceleration. The *Nao* torso runs Gentoo Linux from a built-in computer located in the robot's head. The two robots have been integrated into the framework ROS (Robotic Operating system) running on Linux Ubuntu 12.04, installed on an on-board NUC PC [Fig. 10]. ROS allows communication and exchange of informations between several communicant objects in a robotic project. Here it allowed to build the control architecture of Guido by creating software links between the *Nao* (using Aldebaran's *Nao*-dedicated programming environment *NaoQI2+* and the *Pioneer P3DX* (using its specific layer *ROSAria*) and the remote monitoring computer through the Wifi network. All the programs of the control architecture are coded in C++. An algorithm based on Braitenberg's vehicles was used for a fluid obstacle avoidance. The voice and gestures of the *Nao* torso were programmed with Aldebaran's *Choregraphe*. *Choregraphe* uses a visual timeline and drag and drop function boxes that also give access to C-like scripting. Pre-scripted functions can be called sequentially or in response to sensor inputs or Wifi commands.

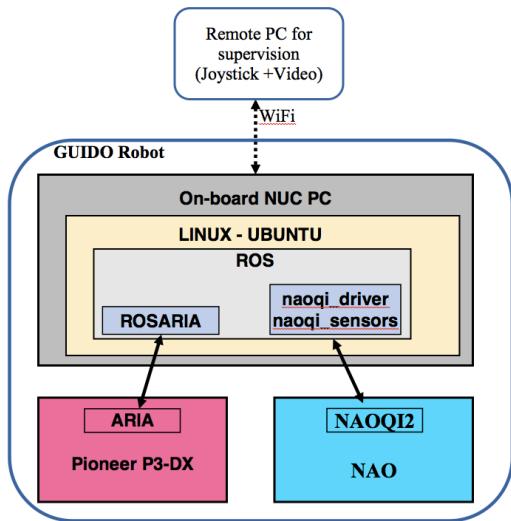


Figure 10. Guido's software architecture

Am I Robot?

Hardware

Combover Jo's body is based on the shell of an *ITM Vu-Lyte II* epidiascope, sprayed metallic purple. The shell is mounted on a bespoke aluminum platform. Two DOGA 12 V 60 W motors provide up to 80 rpm to the 20 cm diameter polyurethane scooter wheels. Two free spinning caster wheels support the front of the robot. Power is provided by a 12 V 16 aH Lithium Ion battery connected to an 8 V, a 5 V and a 3 V low drop voltage regulators. An Arduino Mega microcontroller [32] runs the main program that deals with navigation in autonomous and remote-controlled states as well as state monitoring and selection. Another Arduino Mega controls the Parallax Emic 2 text to speech synthesizer and the dream function's on-board Pico PK-120 pocket video projector. An Arduino Nano connected to the main Arduino Mega is dedicated to reading data from the floor colour detecting sensor. Three HS-04 ultrasound sensors and a front bumper are used for obstacle detection. The eye-lens cavity carries a circular array of 24 ws2812 addressable RGB LEDs and the video projector. A motor can move the lens forth and back but this function is not imple-

mented in the current version. A Sony camera module connected to a Tramtec 2.4 GHz dedicated encoded transmitter provide video monitoring to the control room. A Sennheiser wireless microphone and transmitter provide the audio monitoring. Combover Jo's voice comes from a front-mounted speaker connected to a 12 V 20 W mono audio module that amplifies the speech synthesizer's output. Two Zigbee modules receive data from the control room: one for the joystick and one for the ASCII speech stream.

In the control room, processing is done by an Apple Mac Mini. An AKG dynamic table microphone connected to a compact 4 way USB audio mixer is used to collect the user's speech input. The base of the microphone was modified with addition of a push button, a reed relay and an Arduino Uno. The Arduino Uno controls the reed relay that cuts speech input after a set duration so as not to overload the speech to text software (see below). The Arduino also reads keystrokes from a modified PS2 keyboard used to input typed speech. The Mac Mini's keyboard is concealed, used only by staff to start and stop the installation at opening and closing times. Dedicating a keyboard solely to the speech input function is a fool-proof way of preventing unwanted user interference. Such interference happened in the first version of the installation that operated from a Chrome web interface in kiosk mode with a single keyboard. A small audio amplifier and a speaker are used for audio monitoring the on-board microphone. From the control room, several connections lead to a shelf located in the same room as the robot. The shelf carries an xBee module connected to the Mac Mini for speech transmission, an Arduino Mega connected to the Joystick and to the other xBee module for the transmission of manual navigation data, the Sennheiser audio receiver and the Tramtec video receiver. The transmission range from shelf to robot is variable depending on walls and other obstructions, averaging at 25 meters approximately for a robust video signal, and significantly more for the xBee modules' text and joystick data transmission. We

observed no interference between the xBee modules and the video system or with the local Wifi network, that all operated at 2.4 GHz.

Software

Combover Jo runs on standard Arduino code, using several timers to monitor and actuate its different functions. The Mac Mini in the control room runs an application written in Xojo to manage text input from the microphone and from the PS2 keyboard. The keyboard strokes are decoded by the Arduino Uno in the base of the microphone, sent serially to the Xojo app that displays the text on the monitor. Text is sent to Combover Jo's text to speech unit either if the user presses return or if the input exceeds a set number of characters. If the user pushes the button on the microphone base, speech input is prioritised and treated by the Dictation speech recognition application built-in Mac OS X 10.10. The speech recognition software used in the first installation of *Am I Robot?* was running CMU Sphinx on a Linux machine, but this proved too inaccurate for reliable public use. The Apple Dictation and Xojo solution is very robust and approximately 80% accurate. It deals well with ambient noise and different accents. The timing device that cuts microphone input after 20 seconds was implemented to avoid overloading Dictation. Prior to that patch, the software was constantly trying to process microphone input while the user kept the button depressed and eventually crashed if the user kept the button pressed for too long. The time limit relay resolved the problem. The increased accuracy and ease of use of the speech input combined with software updates to navigation and to the dream mode brought the second iteration of *Am I Robot?* to a robust professional exhibition standard.

Conclusions

Observations of both *Guido* and *Am I Robot?* artworks in action confirm that some humans are ready to embrace friendly robots as agents, at least in the context of art exhibitions. Presently

the current state of general artificial intelligence robotics is not matching humans' expectation for a robot agent, a gap that generates frustration and lack of engagement from the visitors. The collaborative robotics approach, of which several examples are mentioned above, is an effective way to overcome this expectation gap as well as being a solution for exploring speculative HRI scenarii and future human-machine cooperative systems. Granjon's ongoing interest in exploring the co-evolution of humans and machines is underlined by a belief in the importance of cultivating innate cognitive and physical human abilities. Playing a transparent trick on the viewers, who might be lead to believe they are interacting with an autonomous intelligent machine when in fact they are in contact with another human intelligence, aims to provide a playful counterpoint to the false expectations fed by science-fiction movies and non-specialist media.

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Digital Media, Live Interfaces and Inclusion Ethnographic Perspectives

Koichi Samuels

k.samuels@qub.ac.uk

Hadi Bastani

hbastani01@qub.ac.uk

Sonic Arts Research Centre, Queen's
University Belfast, Northern Ireland

Abstract

This paper discusses the potential of digital media and live interfaces in musical composition and performance for subverting exclusionary structures towards inclusion. Coming from backgrounds in electronic music and ethnography, the authors present two case studies that investigate music making practices with live interfaces. These case studies explore the relation between musical experimentation and the use of digital media in catalysing new forms of practice that move beyond restrictive categorisations and limiting boundaries constructed as a result of historical, social, and political processes. While the cases are differentiated in their approach, they converge in their emphasis on the inclusive potential of the digital media.

Keywords

Inclusion
Musicking
Electronic music
Experimental music
Ethnography

Introduction

The proliferation of widely-accessible, increasingly mobile, and low-cost interfaces for musical/sonic practices has posed challenges to established norms and power structure through resetting the aesthetic boundaries for creative practice and de-centralising the means of experimentation for producers and prosumers. (Bowers, 2002; Katz, 2004; Théberge, 2004; Born, 2005; Waters, 2007; Prior, 2008, Butler, 2014; Taylor, 2014; Samuels, 2015, 2016). While acknowledging the asymmetrical distribution of such effects across different cultures and communities, in this paper we present two case studies from each of our interdisciplinary work with music/sound and ethnography. Coming from distinct backgrounds in the field of ethnographically-informed research in relation to music/sound and digital technologies, our concerns intersect on the issues surrounding inclusion and relationships of power.

In this paper, Samuels discusses his ethnography of the The Drake Music Project Northern Ireland (DMNI), a charity that works with people with disabilities to provide access to music composition and performance through the use of digital music technology interfaces and computers. Through introducing his interactions with two of his research participants, he argues that “inclusive music”¹ emerges through communication, creativity and human relationships, in combination with the affordances of digital music technology interfaces, in a network of dynamic interrelations.

Drawing on his practice-based study of an experimental music “scene” in Iran, Bastani offers a broader socio-political perspective. He argues that digital technology and new media platforms have facilitated the negotiation of new boundaries for musicking in Iranian society; an area strictly controlled by the political system. He draws on his involvement with the “scene” at hand as both an ethnographer and an artistic collaborator - a ‘participant-experiencer’ (Wal-storm, 2004).

¹ We use the term “inclusive music” in this paper to denote a varied and growing field of organisations and individuals working with music technology for providing access to people with disabilities. Rather than “disabled people”, in this paper we use the term “people with dis-

The Drake Music Project Northern Ireland and “Inclusive Music”

Samuels conducted an ethnographic study of The Drake Music Project Northern Ireland (DMNI) from 2014-2015. DMNI is a registered charity, which is part of a UK-wide organisation² established by Adele Drake in 1988. The vision of the organisation is divided into four points: i) to deliver a unique approach to independent music making for musicians with disabilities of all ages; ii) using state of the art musical instruments and adapted interfaces; iii) delivered by professional associate musicians with and without disabilities; iv) employing the best of evidence-based practices.

Today, DMNI has separated into three independently operating charity organisations. The Drake organisations are part of a wider field of disability arts and community music activity that has been called “inclusive music” (coined by Tim Anderson³).

1. Technical and Human factors

Technological assistance and solutions to disabling barriers are at the core of DMNI ethos and activities. DMNI promotional literature states that the organisation uses “adapted computer interfacing technology matched to the musician’s physical and cognitive ability”, and that through this “these musicians are enabled to express their creativity as equal and valued members of the community”.⁴

DMNI CEO Michelle McCormack shared with Samuels what she feels are important qualities in her access music tutors:

Somebody who can actually go in and hold people’s attention and in our work as well, somebody who’ll go in and take that few minutes longer than they want to take when it comes to the coffee break, to listen to that person who has very slow speech, and hear just that wee bit they want to tell on how that impacted on them, or take that minute to say

abilities” as this is the language The Drake Music Project Northern Ireland themselves use.

² Drake Music (England), The Drake Music Project Scotland and The Drake Music Project Northern Ireland (DMNI). Each offshoot from the original “Drake” organisa-

"did that actually go the way you wanted it to go?" rather than walking away and thinking god that was great, that switch worked and I'm a happy puppy. (Samuels, 2016: 31)

She emphasises rather than technical skills, that communication and an inclusive attitude are key. This is because they can lead to actions that give people with disabilities in DMNI workshops the space as well as at times the encouragement to be creative, compose, and perform with music technology. As Michelle's comment indicate she was hesitant to place too much emphasis on the role of the affordances of technology in inclusive music making. Similarly, Samuels (2016) found throughout his ethnography that for the workshop participants, who have a broad spectrum of abilities, it is through the dynamic interrelations between all the musicians and the music technology interfaces in the workshop environment that inclusive musicking emerges. Next we will turn to an example of this kind of musical emergence drawn from Samuels (2016) ethnographic study.

2. Mapping the Blues

One of DMNI's longest standing musicians, Marylouise McCord (Marylou), has been composing and performing music in various DMNI ensembles for over 20 years. She is also active in Belfast's community arts scene taking part in inclusive dance productions as well as painting and art workshops. To explain the nature of her disability, Marylou has cerebral palsy and is a wheelchair user with limited use of her limbs and hands. Her self-expression by speech takes time, although she can engage in spoken conversation if given sufficient time. She often communicates through her assistive speaking device and Samuels also communicated with her via email. Samuels found that she has a superb sense of humour and brings a lot of joy and laughter to the workshops she is involved in. Marylou commented on her experience with DMNI:

I've been a Drake Music student since 1992 when the equipment was out-dated compared to the fantastic instruments we have now. I have always had a great interest in music but because of my disabilities and my fellow Drake Student's disabilities before we came to drake it was not possible to do music, but because of drake music the possibilities are endless, I love it. (Samuels, 2016: 37)

Over the many years she has been composing and performing with music technology interfaces in DMNI workshops she has gained an intuitive and in-depth knowledge of MIDI controllers, types of sensors, and accessible devices. Marylou is often a driving force in the creative direction of DMNI workshops. One example of her ideas for creative input into the ensemble she is part of took place when Samuels was conducting his fieldwork with DMNI.

Marylou's father, Davy, had recorded two guitar tracks into the ensemble project; the first track consisted of a chord sequence that added to the rhythm section of the overall piece; the second track recording was improvised blues licks, adding a soulful embellishment. Danny, the lead access music tutor, edited the recording into short samples of individual blues licks in the DAW software that was being used as the hub of the project. His idea was to map a guitar lick sample to each of the sixteen pads on the Akai MPD18⁵. Marylou tested out the guitar-mapped pads. Through a short discussion, everyone agreed that they fitted well and that we should include this in the overall piece. The MPD18 has a full-level velocity function so each hit plays at full volume once triggered, overriding the touch sensitivity function of the pads. Because the tempo of recording was "snapped" to the global tempo of the project, Marylou triggering them live also worked in exact sync with the rest of the project.

tion has its own individual focus on projects and operations.
The Drake organisations .

³ <http://www.inclusivemusic.org.uk/>

⁴ Extracted from <http://www.drakemusicni.com/about-us>

⁵ A MIDI-over-USB pad controller produced by Akai: <http://www.akapro.com/product/mpd18>

After Marylou had experimented and decided how she would trigger the licks, Davy picked up his guitar and started playing along with her. Intuitively, Marylou responded to the licks that Davy was playing on his guitar. They started to play together in call and response, father playing guitar and daughter interacting back by triggering the pre-recorded samples of her father playing the guitar. Davy would mimic and embellish on the licks that Marylou would trigger. A communicative musical interaction was achieved. There was a moment in the workshop when everyone fell still and silent, engrossed in watching Marylou and her father improvising together. Through some planned mapping and low-level (consumer) interaction design with the MPD18 interface, the duo was able to improvise together.

3. Redistributing Musical Processes

Often in DMNI workshops it is the readily available, simple to use but generic consumer music technology interfaces that are utilised, such as the Akai MPD18. This is in contrast to the growing availability of open-source computer and sensor technologies, which are highly customisable to a user's specific requirements, and thus afford great potential for unique and bespoke designs catering to an individual's specific needs (Jewell and Atkin 2013). Despite these kinds of devices' high level of customisability, they require specialist expertise to build, operate, and maintain. Thus, although open-source technology is increasingly low-cost and accessible, they are not in fact "open" to many users with disabilities (Samuels 2015).

Speed and directness of connectivity and ease of configuring and mapping is prioritised in DMNI workshop settings over more advanced and bespoke device set-ups. This is because workshops last only 1.5 hours, as well as due to facilitators lacking the required expertise in DIY digital musical instrument design.

Delegating musical processes to the computer is a common solution to overcome DMNI musician's physical barriers to music making with traditional musical instruments. This means performance processes can be broken down in to parts and redistributed between several performers (as opposed to a solo performer), or a single mode of interaction could control several modes of musical manipulation. Anderson and Hearn (1994) argue that this use of digital music technology is especially relevant to disabled musicians, who may find performing pre-constructed musical material, or the control of multiple parameters in one mode of interaction more suitable to their specific requirements.

4. Human-Machine Configurations

In the context of DMNI workshops human-machine configurations are formed of performers, music technology interfaces, computers, musical instruments, assistive technology, the performance space itself and people's spatial position in it, the volume of the music being played, the noise from the world outside the studio, the attitudes of participants, group politics, the rules and regulations set by the management company maintaining the building the studio is a part of, and so on. A material-semiotic approach to understanding how the musicking dynamically emerges through these kinds of human-machine configurations provides an alternative to either viewing a person's ability or disability in relation to music making as a physical attribute residing within an individual (medical model of disability) or removing the focus from the body entirely (social model).

Rather, a perspective of performative and distributed agency between human and non-human actors acknowledges the multiplicity of the experiences of being a person with disabilities. It does so by simultaneously addressing the interactions between the impaired body, disabling social and institutional barriers, and inaccessible technological devices and environments (Galis 2011). As Galis (*ibid*, 835) writes:

The important point here is that disability does not reside solely in the body or in society. Disability is an effect that emerges when impaired bodies interact with disabling infrastructures/culture.

From this theoretical standpoint, concepts often assumed to be stable and static attributes belonging to an individual or a piece of technology, such as “disability”, “enabling”, “exclusionary” can be viewed as relational, performative and enacted. Thus, Samuels (2016) argues that inclusion in music making at DMNI is able to be enacted through the dynamic interrelationships between people, things and their environment. At the same time, ability is performed and exclusionary social attitudes and assumptions are performatively challenged and deconstructed in DMNI workshops.

Digital interfaces and experimental music in the Iranian State

In the last 10 years, a new wave of experimental digital arts and music practices has emerged from Iran. A small “scene” is now recognised beyond the Iranian geopolitical borders and is represented in *public* venues across the country. Public presentation is of crucial significance, as a large proportion of the music produced never finds the opportunity to be shown due to the state’s mechanisms of monitoring and filtering. Without the Ministry of Culture’s permit system approval, any public presentation or dissemination of a cultural product is banned by law.

However, the permitted and prohibited areas of practice have changed increasingly in favour of including and tolerating a broader set of aesthetics. Viewed in the context of technological-social-political transformations, this has been made possible partly as a result of cultural producers’ consistent and uncompromising practice and partly due to the advancements in the area of digital and new media technologies. Alireza Farhang, a cofounder of the “association

for Iranian composers of contemporary music”, and the author of “Electronic Music in Iran” (2009), observes:

The new generation was much more aware of what was happening in the world and, therefore, things developed quite rapidly afterwards. Composers were re-introduced to music technologies and electronic music, this time thanks to the internet and advancements in music and audio-related software technologies. This developed gradually until around 2007-9 when it came to fruition and became visible on the surface of the society. (Alizera Farhang, Interview via Skype, August 2017)

Likewise, as noted by Farhang, digital technology and the internet have been instrumental in enabling a younger generation of musicians to explore new expressive possibilities as they negotiate a space for their creative practice in society, pushing back on the inherited ideological and political restrictions in a constructively dynamic dialogue with the system.

1. The hot zone

Systemic control in relation to art and music in Iran stems from various historical, socio-political and cultural contexts that have been in part related to the religious views held amongst Muslim theorists, scholars, and rulers. However, the latest setting against which such a mechanism was re-vitalised was the 1979 revolution and the subsequent war with Iraq (1980-88).

The revolution, particularly, was the scene of complex plays of identity and has been partly regarded as the rejection of Western cultural hegemony. As such, it led to a decade of partially self-imposed isolation, most notably from the countries of Western Europe, North America and their allies, a period in which the settling regime anxiously attempted to disentangle itself from the web of neo-colonial influences, interventions and dependency.

Having been understood among the revolutionary forces as a crucial facilitator of the said hegemony, music (particularly pop music) went under substantial attack. Comprehensive bans and controlling measures were applied to a range of musical activities from teaching to performing and even selling musical instruments. Such policies forced musical practice further underground and into the safety of people's most private spaces for almost two decades.

2. Political shift, digital technologies, and new media

The above dynamic started to shift significantly, in part as a result of Mohammad Khatami's (president 1997-2005) relatively more tolerant cultural policies, but perhaps more importantly due to the developments in the areas of digital technologies and new media. Since its "inception in 1993" (Rahimi 2003) in Iran, the internet has been particularly instrumental in providing alternatives outside the state's boundaries of control. Khatami's government policies regarding economic integration also offered a context for the technology providers to broaden their reach inside the country.

While affording new means for sonic experimentation, digital interfaces such as laptops, computer programming environments, software synths, and midi controllers also helped practitioners disentangle musical presentation significantly from the forms previously known to and frowned upon by the state. However, it took these new experimentations a couple of years to mature. It was only around 2007 that the earliest indications of a growing experimental electronic music and digital arts practice surfaced within the society.

Although under the relatively more tolerant policies of Khatami various forms of music found spaces to manifest, the deeper paranoia about pop music remained almost intact among the more conservative forces who have traditionally had substantial control over the security forces. As such, the public presentation of pop music

(mostly in the form of Rock and Hip-hop concerts) caused several clashes. As a result, gigs were raided and cancelled by the security forces, performers were pushed to abandon their activities, their instruments were seized, and arrests took place. Such events inevitably affected the musical scene. Arash Molla, a composer based in Tehran notes:

A lot of people who recorded stuff in small studios across Tehran, started learning how to work with digital interfaces and software themselves to offset the difficulties of gathering people together, rehearsing, recording and developing a collective vision in an environment so hostile to music. Via digital interfaces they could write everybody else's parts in the band and easily get to the finished demos. At least It made production much easier. (Arash Molla, Interview vis Skype, August 2017)

Hence, not only for aesthetic reasons and an exploratory approach towards finding new expressive territories, but also due to the practical issues of sustaining a band activity with very little future prospects, more and more musicians started experimenting individually with digital interfaces, particularly software.

3. Cosmopolitan musical affinities, digitally produced/Performed music, and aesthetics

A new musical scene started taking shape. Although this time the practices were mainly based on the efforts of the individuals, they quite rapidly connected. The connection was facilitated by the means of new media and digital technologies. Social media platforms, particularly Soundcloud and Facebook, and musical forums provided contexts for these individual practices to be shared online and find peers. Shahin Entezami (aka Tegh), an electronic producer who started his practice under hip-hop influences but re-oriented towards ambient music puts it this way:

I got to know these people who are now my friends and colleagues from social media. [...] The relationship with our audience is also made possible via these networks. We promote our music, share it, send it to labels and our peers across the world. We also sell tickets on social media. We wouldn't even have an audience inside the country if it wasn't for the possibilities of social networking and the internet. (Shahin Entezami, Interview via Skype, April 2017)

Thus, the rather non-mainstream musical practices that were rendered hopeless and pushed underground by the state's oppressive behaviour, became animated once more. This time the link initiated from the safety of the individual's bedrooms, via their personal computers. Digital and new media technologies also afforded musicians/producers in Iran contexts for learning skills, sharing materials, connecting with peers, and imagining alternatives for musicking beyond the boundaries of the state control and social dogmas. This has been a major transformation in the Iranian art and music scene, which has allowed the artists and enthusiasts to move in synchronization with the developments in their preferred areas of practice and to contribute to their progress.

In this context, an understanding of Mark Slobin's notion of "affinity interculture", Martin Stokes concept of "cosmopolitanism" as an analytical tool within ethnomusicology, and Thomas Turino's "cosmopolitan subjectivities" are helpful in the theorization of how shared musical preferences travel in our time across the world and connect. All three concepts are significant as they help "restore the human agencies and creativities to the scene of analysis allowing us to think of music as a process in the making of "worlds", rather than a passive reaction to national or global "systems"" (Stokes 2007, 6). Tsioulakis (2011, 177), drawing on Slobin's "affinity interculture", proposes that an understanding of the social imaginary (Castoriadis 1987, Gaonkar 2002, Taylor 2002) is most relevant in the description of music

networks that incorporate global/cosmopolitan aesthetics and ideologies.

Siavash Amini, a composer and producer based in Tehran, stresses the significance of imagination in the ways his musical practice and aesthetic preferences, mediated by the internet and communicated via digital interfaces, led to the emergence of a successful and enduring experimental electronic music festival in Tehran (2015-present), i.e. the SET experimental arts events. He says:

I believe our scene is fundamentally related to imagination and dream: the way we have imagined new worlds, where relations are different from what we experience as social reality. This [SET] is our city [referring to Calvino's *Invisible Cities*] and we have been building it consciously or unconsciously to get to the dream. The dream of living a different reality.

Conclusion

In this paper, both authors presented case studies in which the involvement of live interfaces and digital media for music making help facilitate modes of practice that challenge and subvert traditional and accepted modes of production, consumption and distribution. The significance of this is not only material and technological. It encompasses wider negotiations of social and political agencies on the macro-level of societies, as well as in the attitudes and actions of individuals.

While Bastani's study takes a broader socio-political stance over the use of digital technologies and new media platforms in mediating the contested space of musical performance in the Iranian society, Samuels' takes the perspective of ethnographic inquiry into modes of localised performance utilised to uncover the relational effects of digitally-mediated musicking in a musical community of musicians with disabilities.

In the case of DMNI the digital medium is exploited to assist and encourage the flow of agency in such a way that reconfigures performer's capacities for action, the effect of which performatively challenges exclusionary social attitudes and assumptions regarding people with disabilities. This is because DMNI ensembles give the participants the time and space, as well as the personal encouragement and technological tools necessary to enact performances of their abilities.

In a similar vein, the practices involving the use of digital technologies and new media in Iran have enabled a new generation of musicians to significantly challenge conventional boundaries of musical activities enforced by the state. Since their earliest appearances in the public domain in 2007, these relatively novel and continuously evolving forms of musicking facilitated an ongoing negotiation between musical practice, systemic control, and social dogmas by radically transforming conventional boundaries of musical aesthetics within the society.

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As such, although different in approach, both cases emphasise the transformative potential within live interfaces and digital media in that they can provide a platform for musicking across barriers that are constructed through social and political categories and labelling. These transformations are enacted in material, aesthetic, and political planes, and can lead to effects that are both inclusive and empowering.

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Bridging Abstract Sound and Dance Ideas with Technology

Interactive Dance Composition as Practice-Based Research

Jung In Jung

JungIn.Jung@hud.ac.uk

Centre for Research in New Music,
University of Huddersfield,
Huddersfield, UK

Abstract

In this paper, I review recent interactive music and dance collaborations and discuss my composition interest in mapping sound to bodily movement

in the field of computer music. I argue that the engineering perspective of this field of research should be broadened to include, in particular, creative composition processes in collaboration with professionally trained contemporary dancers. I then introduce my investigation into using the Gametrak controller to create choreographic stimuli via the choreographic methods of the contemporary dance choreographers William Forsythe and Wayne McGregor, and set up a compositional model based on that proposed by the composer Simon Emmerson. Finally, I demonstrate how my research is articulated through a presentation of my original works.

Keywords

Interactive dance
Composition
Practice-based research
Methodology
Gametrak
Restriction

Introduction

As a sound artist and a researcher who creates interactive sound and dance collaborations, I have sought a methodology for my practice-based research. This paper presents my thoughts on this topic and an inquiry into a possible way to make this research valuable. I should emphasise that what drives me to create interactive systems is the facilitation of a dialogue between the sound system and the dancer so as to devise choreography and sound compositions together. I find that in the field of computer music this type of work focuses on technological development in terms of new interfaces or mapping strategies for generating music, but lacks a choreographic concern based on dance practice. Since interface technology seeks a use in corporeal dance performance and is of an interdisciplinary collaborative nature, I propose another perspective from which to conduct this field of research, giving as an example my own original works with contemporary dancers.

1. Background research to raise questions

The term *interactive dance* typically refers to dance works created with an interactive system that perceives movement data from the dancer in real-time to produce other events in other media such as sound or visuals. In turn, the sonic or visual results affect the creation of the choreography. The term has been in frequent use since the genre of *dance and technology* or *dance tech* emerged at the end of the 1990s as seeking the usage of newly developed tools “to reinvent the perceptual and ontological role of dance in the context of a digital zeitgeist” (Salter 2010, 261). Although the origin of interactive dance can be traced back to John Cage and Merce Cunningham’s collaboration *Variations V* in 1965, the active research on developing wearable or camera-based motion-tracking sensors has been conducted since the 1990s by composers. For instance, Todd Winkler created interactive dance works in Max¹ using analysis

of gestural movement and musicality (Winkler 1995a), and published a pedagogical book in interactive composition (Winkler 1998). Wayne Siegel developed wearable motion-tracking interface using flex sensors in collaboration with contemporary dancers (Siegel and Jacobsen 1998). Because of its use of technology, interactive dance has also attracted scientific, engineering and computing research centres looking for artistic and real-world applications (Salter 2010, 262–263). One example is the EyesWeb system, using gestural analysis of emotional and expressive values and developed by Antonio Camurri and his research team from Info-Mus, University of Genoa, within the European Union-sponsored MEGA project (Camurri 1997). The fever for the genre became obvious as the entire *Dialogue* section of the 1998’s spring volume of *Dance Research Journal* was dedicated to discussion about dance and technology, with both Richard Povall and Robert Wechsler writing about the subject.

As a consequence, debates and criticisms followed regarding the usage of technology. How it could “enlarge dance as a historical and cultural practice” and what kind of aesthetics could be aroused with gesture-driven computer music in dance (Salter 2010, 263)? Scott deLahunta (2001) expresses the irony of considering the new musical instrument learning process as dance training in the field of computer music. Julie Wilson-Bokowiec and Mark Alexander Bokowiec (2006, 48) point out that mapping sound to bodily movement has been described in utilitarian terms: “what the technology is doing and not what the body is experiencing”. According to Johannes Birringer (2008), developing interactive systems with this utilitarian perspective creates “disjunction” between movement data and the outcome media whether that is image or sound. This is because the system requires performers to learn “specific physical techniques to play the instruments of the medium”, which dancers find hard to think of as an “intuitive vocabulary” that they have gained through their physical and kinaesthetic practice (Birringer 2008, 119).

¹ <https://cycling74.com/>

Discussions about creating musical instruments are still valuable to the development of interactive systems. However, I find that this narrow focus on the gestural or postural articulation of technology misses the aesthetic concerns in creating choreography with dancers.

Wilson-Bokowiec and Bokowiec (2006) provide honest insights about their Bodycoder System, a musical interface with sixteen bend sensors that can be placed on any flexing area of the body and a pair of gloves designed as switches. Similar glove-based interface designs have been used previously in Mattel's Nintendo Power Glove (1989) and the *Lady's Glove* (1994) by the composer Laetitia Sonami to capture sophisticated finger movement. Winkler (1995a) also began his research in movement by observing hand and finger gestures to help design musical instruments. Wilson-Bokowiec and Bokowiec (2006, 50) write that their initial idea to adopt physical techniques from contemporary dance seemed logical, but they stopped soon after realising that the system was associated with "specific economic movements" like playing an instrument. In interactive dance and music collaboration the dominant compositional approach has been to translate gestures into sonic results. This process of translation is usually initiated by composers and computer scientists with their interpretations of movement qualities, and then realised by dancers. Unfortunately, due to the limits of time and budgets, it is not easy to collaborate with dancers throughout the entire composition process to find out which sounds feel most suitable for controlling the synthesis with their diverse range of movements. Thus composers have mostly sought ways to capture the most natural and precise movements by preserving dancers' free motion for movement analysis. However, I believe this effort ironically caused a disjunction in the sonification of movement for some dancers because the assumed mapping scenarios and interpretations were not directly related to their dance vocabularies, but rather to an engineering perspective.

Here, two research questions arise: 1) How can my interactive sound system aid collaboration by encouraging dancers to use their intuitive vocabulary, not just demand that they learn the technological and musical functions of the interface? 2) Once I have considered the sounds to be used in a piece, how should I direct dancers to create choreography as well as sound composition with my interactive system? I decided to adopt a more rigorous approach to integrating interactive system into the creative processes in sound and dance, and their resulting performances investigate ways to carefully structure the relationship between music and dance when involving interactive systems in the creative and performance processes. To situate my work within a research perspective, I undertook a survey of papers focusing on dance or choreography from *The International Conference on New Interfaces for Musical Expression (NIME)*, *The International Computer Music Conferences (ICMC)*, and *Sound and Music Computing (SMC)* from 2001 to 2016 to find what other approaches have evolved since the 1990s interactive dance scene. The reason that I chose this period was because the survey was done in 2016, and I decided to search the papers published from the 21st century strictly. When I found interesting approaches from these conference proceedings, I looked up other related publications.

Based on his research on the choreographer Doris Humphrey's classification of rhythms in dance, Carlos Guedes (2007) created Max objects that can extract rhythmic information from dance movement captured with a video camera. Capturing data and analysing patterns to create art became a method when art research combined with Human Computer Interaction (HCI) (Polotti 2011). With this rather scientific approach to human movement, I noticed that some researchers tried to capture even more sophisticated data from dancers using physiological data capturing facilities. For example, Jeong-seob Lee and Woon Seung Yeo (2012) captured dancers' respiration patterns to improve the correspondence between music and dance, and Javier Jaimovich (2016) used

electrocardiography and electromyography to reflect the biology of emotion in music. Nevertheless, these analytical approaches to evaluating the relationships between music and dance still caused me to ask where choreographers might put their aesthetical decisions during the compositional process.

The research I found interesting was the empirical research done by Anna Källblad et al. (2008) for their interactive dance installation for children. They developed their installation in several steps: First, they observed children's movement in a free space with different types of music. Second, the dancers looked at the video recordings of the first step and created a choreography. Third, the composer created an interactive sound composition for the choreographed movements and installed this interactive system in areas occupied by the children. The interesting part of this research was that the analysis of the children's movement became the choreographic challenge; the researchers found that there was "no expression of anticipation, planning or judging" in the children's movement, whereas the adult dancers found it very hard to have the same intent (Källblad et al., 2008). Another interesting work is the prosthetic instruments designed by Ian Hattwick and Joseph Malloch (2014). Although the dominant perspective of Malloch's (2013) thesis was an engineering one, as its purpose was to design instruments that were usable by professional dancers, the design process was done in conjunction with frequent workshops with the choreographer Isabelle Van Grimde and her dance troupe Van Grimde Corps Secrets. They were aware of how the dancers predominantly create movement within a visual domain, as opposed to musicians, and took advice from the dancers when deciding on the appearance and material of their instruments (Malloch 2013). I found their *Spine* instrument for the performance *Les Gestes* (2011–2013) remarkable because it provoked the dancers to create choreography in terms of the relational movement between their head and lower back, which in turn played

the instrument. This way of triggering an interactive system with wearable motion-tracking sensors is not common as usually the sensors are placed on limbs or the joints of limbs to receive more natural movement of dancers.

Amongst works outside of *NIME*, *ICMC*, and *SMC* communities, I find the collaboration *Eidos: Telos* (1995) by the choreographer William Forsythe and the Studio for Electro-Instrumental Music (STEIM) composer Joel Ryan the most interesting, even though it was developed at the very beginning of the period of experimentation in interactive musical synthesis with computer in the 1990s. Across the stage, a net of massive steel cables are set to be amplified by contact microphones and in turn become a large-scale sonic instrument when plucked by the dancers. The instrument was "audio scenography: the replacement of visual scenography with a continually transforming audio landscape" and showed "the shifting of dance music composition in Forsythe's work towards the design of total acoustic environments" (Salter 2011, 57–58). Unfortunately, Ryan's initial idea of using wearable acceleration sensors to control the signal processing techniques applied to a violin and the lights in the Frankfurt Opera House auditorium did not happen because of unstable communication between the STEIM-built sensor device and the house lighting console (Salter 2011, 71). However, the instrument created simple and modern-looking scenography without superfluous technological aesthetic, which Forsythe usually seeks in his other works too, and acted as work's core compositional as well as dramaturgical strategy.

2. Integrating choreographic method with technology

To answer my first research question, I decided to study first how choreographers and dancers create choreography and seek ways to integrate motion-sensing devices as primarily a choreographic tool. Some criticisms have arisen in the dance technology community towards artists who were "eager to work with newly arising

digital tools”, but who had “little understanding of the inner workings of electronics or computer code”, which in turn created trivial works that were mere demonstrations of the technology (Salter 2010, 263–264). Although this is a critical point of view, I found it not entirely fair towards the artists. The graphical interface of Max (Winkler 1995b), as well as flexible and user-friendly tools like Isadora developed by Mark Coniglio (Dixon 2007, 198), were made to help composers and artists who were not necessarily software developers. I thought the problem was not lack of knowledge of how to adapt the technology effectively, but a lack of investigation and observation required to comprehend artistic media that the artists did not primarily practise. For instance, Winkler’s research into gestural composition (1995a) neglected dance practice or techniques, but assumed that their interactive syntheses could be used effectively for dance composition. Marcelo M. Wanderley (2001) thoroughly analyses the gestural qualities of expert instrumentalists during performance, but does not explain how this movement analysis is valuable for dance creation.

What, then, is choreography? Can the instrumentalist’s movement be assumed to be dancing? “The term choreography has gone viral”, says Susan Leigh Foster (2010). She writes that since the mid-2000s the word has been used as “general referent for any structuring of movement, not necessarily the movement of human beings” (Foster 2010, 32). I saw a good example for Foster’s statement when I recently attended the conference *Moving Matter(s): On Code, Choreography and Dance Data* in 2017. The artist Ruairí Glynn presented his choreographic idea in his work *Fearful Symmetry* (2012), but the work did not include a human figure. It was a kinetic sculpture that encouraged the audience to react and move along with it. Perhaps the reason this kind of movement from non-dancers and also non-human movement has come to be recognised as “choreographic” is because dance has changed dramatically since the mid-twentieth century

to eliminate virtuosic postures. For example, choreographers such as Paul Taylor and the Judson Dance Theater deliberately incorporated everyday movements such as walking, running, and sitting into their work (Au 2002, 161, 168). Also, as shown at the 2011 exhibition *Move: Choreographing You: Art and Dance since the 1960s* at the Hayward Gallery, the term has been used to describe the process of paintings, sculptures, and installations by artists such as Allan Kaprow’s movement score *18 Happenings in 6 parts* (1959), Bruce Nauman’s *Green Light Corridor* (1970), and Pablo Bronstein’s *Magnificent Triumphal Arch* (2010). These works were focused on certain movements of the artists or the viewers, and were, therefore, choreographed. In his essay *Notes on Music and Dance*, Steve Reich (1974, 41) writes that the Judson group choreographers have embraced “any movement as dance”, equivalent to Cage’s statement that “any sound is music”. It seems that dance has become a more approachable place for laypeople to propose ideas.

Yet, what I have learnt from my previous collaborations with dancers is that I should be aware that dancers and musicians have acquired different physical practices². I therefore felt the need to understand what choreography means in dance first. I investigated the dance movement theory by Rudolf Laban as well as some studies in which this analysis was used. These included the sonification of dance movement research from InfoMus based on the emotional quality of movement and music from choreutic theory, the dance movement archive project by Royce Neagle et al. (2002), and the movement library *Topos* for dance and music gesture control by Luiz Naveda and Ivani Santana (2014). However, what I found the most interesting from Laban’s analysis was that he sees choreography as a “continuous flux” of movement that should be understood alongside both “the preceding and the following phases” (Ullmann 2011, 4). Laban’s dance notation shows movement “trace-forms” through directional symbols inside the kinesphere rather than specific postures, and it inspired me to

² In case more scientific proof is needed about how musicians and dancers perceive movement differently, ongoing research is being conducted by Hanna Poikonen at the University of Helsinki into how musicians and dancers use their brains. Poikonen explains that musicians have a

tendency to seek precision in certain acts whereas dancers see the entire flow of a movement that uses the whole body. See her article at <https://www.helsinki.fi/en/news/health/a-dancers-brain-develops-in-a-unique-way>



Figure 1. Motion-sensing device as interface to preserve the dancer's freedom of movement.

think about what principally stimulates which movement, beyond fragments of gestures. The common way of using motion-sensing devices in interactive music and dance collaborations is to use the technology as a mere interface for preserving the freedom of the dancer's movement, and to connect the presupposed musicality of movement data to the output result (Figure 1). Instead, to actively stimulate and engage dancers to create choreography with the interactive system, I decided to provide a physical and tactile motion-sensing device – the Gametrak controller – that primarily challenged performers to 'dance', and to let these movements create the sounding results.

Gametrak was developed as a pre-wireless motion-tracking technology and disappeared quickly after the introduction of Nintendo Wii Remote controllers or Kinect cameras. In comparison with wireless motion sensors, Gametrak's motion tracking system is simple and limited. Each unit has a pair of potentiometers tethered by red cables that users can extend to direct the controller through 360°; the controller tracks the movement direction and length of the cable. Originally the controller comes with a pair of gloves that let users play a golf game. However, I removed the gloves so as to prevent the dancers from using the controllers only with their hands. Instead, I connected carabiner clips to the end of the controllers so that they could be hooked onto belts and bracelets. The kinetic characteristics of the Gametrak invite dancers to move in certain intuitive ways by playing with the cables – pulling and twisting them, for example.

However, the dancers soon understand that they can only reach a limited distance with the tethered controllers. As a consequence, the difference from wearable sensors is that I am 'restricting' the dancers' bodies instead of letting them dance freely.

Gametraks were used by the musician Yann Seznec for the live performance of the composer Matthew Herbert's album *One Pig*, and the artist Di Mainstone developed Gametrak-inspired controllers with her research team from Queen Mary University of London for large-scale installations (Meckin et al., 2012) such as *Whimsichord* (2012) at the Barbican and *Human Harp* (2013) on Brooklyn Bridge. Seznec created The *StyHarp*, using the cables of Gametrak controllers to mimic a pigsty as well as a new musical instrument. Although Mainstone's works were performed by dancers, her primary focus was on the use of the controllers as a visual element with the surrounding architecture while triggering sound simultaneously in an interactive installation. It is apparent that the appearance of the Gametrak has attracted artists to its visual characteristics, but I have not yet found any work primarily integrated with choreographic composition technique.

I found Forsythe's choreographic approach was interesting because he extended Laban's notion of the kinesphere, as shown in his lecture video *Improvisation Technologies* published with ZKM in 2011 (cited in Clark and Ando, 2014: 182). In the video, Forsythe demonstrates possible movement variations depending on a newly given axis without stepping away from the first

position. Furthermore, Forsythe asks his dancers to imagine objects or geometric lines to create movement with or around. Re-orientating physical perception with these imaginary space and objects is Forsythe's core movement creation technique. Similar to Forsythe, choreographer Wayne McGregor proposes his dancers to imagine an object as well as some other sensations to compose choreography. Another technique he uses is to provide dancers with a physical problem, which they have to solve through movement. For example, dancers are asked to "picture a rod connected to their shoulder, which is then pushed or pulled by a partner some distance away" (Clark and Ando 2014, 187). McGregor describes these ways of creating movement phrases with specific physical conditions as a "physical thinking process" (McGregor 2012).

Both Forsythe and McGregor use mental imagery as a choreographic stimulus. Instead of freely improvising, they restrict their physical condition with the imagined objects and space. Inspired by this method, I decided to replace the mental imagery with actual physical restriction using the cables of the Gametrak controllers. In this way, the Gametrak provides a technological restriction that governs my sound composition and movement creation as both an interface and a physical limitation that has to be accounted for by the dancers. This intrinsic physicality of the Gametrak made it possible to provide concrete movement tasks to the dancers, who could then play sound naturally as a result of executing these tasks. This process is explained in Figure 2, which shows the transition between different media from body (dance) to sound via visible and tactile technology.

3. Proposing a methodology: physical thinking and action process

My background research indicates that the primary concern in research so far into new interface design for dance has focused on the kinds of motion that can be captured to control musical parameters, either in one-to-one or more complex interactions. However, this prevalent

concern in mapping body movement to sound is limited to musicians and computer scientists (Wilson-Bokowiec and Bokowiec 2006, 48), and rarely takes account of a purely choreographic perspective. My purpose in this research is not necessarily to hand over control of the music to the dancers. Rather, my main interest is in what kind of dialogue can be created between music and dance as a stimulus to collaborative composition, not necessarily that one medium has to determine the other.

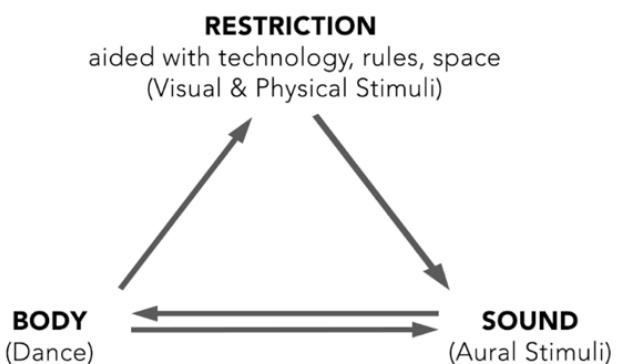


Figure 2. A diagram between dance and sound through Gametrak controllers.

To answer my second research question, and also in order to create a dialogue between music and dance it was essential to look at how they have served as impetuses for each other both historically and more recently. Traditionally choreographers made choreography for already written music, and dance had to be organised to synchronise with music that had been composed for it (Percival 1971, 17). However, since the twentieth century, there have been huge changes in this traditional relationship. Vaslav Nijinsky premiered the ballet *Afternoon of a Faun* in 1912, using Claude Debussy's music "purely as an accompaniment", to demonstrate that the music and the stage design were "equally important in setting a mood" and "equally irrelevant to the movements being performed by the dancers, except that the total length of the action was determined by that of the music" (Percival 1971, 16).

Around the same time, Laban choreographed to a very minimalistic use of percussive musical instruments or sometimes even in silence so as to preserve dance as an independent art form, as seen in his works *The Deluded* (1921) and *The Swinging Temple* (1922) (Laban 1975, 89, 96). Laban did not agree with the dance theatre tradition of that time, according to which dance had to be organised as a literal translation of music (Laban 1975, 175–179). Later, from the late 1940s, Cunningham and Cage started collaborating using methods of indeterminacy and chance, treating music and dance as independent entities (Au 2002, 155–156). From my research the most frequently referenced example as the origin of interactive music and dance collaboration is Cage and Cunningham's *Variations V* (1965), yet notoriously they did not seek to connect expressive musicality and movement. In contrast to these movements, music and dance had a close relationship in Philip Glass's opera *Einstein on the Beach* (1976), with Lucinda Childs juxtaposing slow and almost static movements to Glass's fast and repetitive music (Obenhaus 1985). Similarly, Anne Teresa De Keersmaeker was deeply influenced by Steve Reich's music structure, and choreographed repeated and contrapuntal movement variations for her work *Fase, Four Movements to The Music of Steve Reich* (1982). However, De Keersmaeker explains that although Reich's music "supplied a number of principles of construction", her work "did not copy the musical structure" (De Keersmaeker and Cvejić 2012, 25–27). As a more recent example, at the 2012 Dance Biennale, Forsythe explained that his dance company uses music like "film music"; music can "colour the perception of the event", but it is not necessary to organise a dance according to the structure of the music (Forsythe 2012).

It seems natural to have these constant changes in dance from the twentieth century in particular, since music has also actively changed into various unconventional and uncountable forms through the use of new materials and sound (Cunningham 1968; Percival 1971: 15). However,

in gesture-driven music and dance research I feel these kinds of dialogues between music and dance have been neglected because 'interactivity' is considered a crucial element that has to be demonstrated to the audience. This view can easily restrict interactive dance to the folly of mere demonstrations of technology, and fail to make use of it as choreographic tool. Furthermore, what I could see from the dance notations from the seventeenth century (see Weaver 1706) and De Keersmaeker's score for Reich's music was how these two media have changed from rather absolute and common code to abstract ideas. The dance notation from the seventeenth century indicates positions of feet and limbs related precisely to the musical notes, whereas De Keersmaeker's score is drawn with more abstract shapes, directional marks, and numbers. In my previous collaboration with contemporary dancers, I mostly sought ways to orientate the dancers towards the interactive system to help them perform better 'sound'. However, I was aware of the irony in teaching the abstract ideas of music composition to dancers. Instead, I thought these abstract ideas could be bridged through a concrete medium – for me, it was what the restrictive motion-tracking technology could serve – to successfully conduct this interdisciplinary collaborative composition.

I proposed using the Gametrak controllers as a visual stimulus and physical restriction to my main collaborating dancer Katerina Foti. As she was aware of Forsythe's approach she was interested in the method. Yet, this was my first time composing an interactive music with physical restriction, and I thought the best way to find out the most suitable compositional method was simply to try them out. *Locus* was my first composition, using four different sections of sound variations throughout time. I planned several steps to guide Foti and another dancer Natasha Pandermalı to gradually construct a choreographic composition with my interactive sound synthesis. Video 1 demonstrates the composition process: First, I asked the two dancers to tether four cables each to

their bodies and to improvise to find out how to move within the restrictive conditions without sound. Second, once they got used to moving within the conditions, I then provided more specific choreographic tasks section by section depending on the structure of the sound composition. During this process, the dancers proposed how they would create choreography with my movement tasks and I selected good materials. Finally, we repeated the proposing, selecting, and modifying process several times until we completed the composition.



Video 1. The demonstration of composition process of *Locus* (2015). See: vimeo.com/252392147/29e5af8932.

My dancers quickly adapted my composition process as they were trained with similar choreographic techniques. This way of proposing and selecting choreographic materials is the common approach in contemporary dance nowadays, as exemplified by the choreographers Forsythe and McGregor. While I was searching for the origin of this choreographic method, I found that some contemporary dance choreographers in the 1960s used the so-called “problem-solving” concept as research in information theory and artificial intelligence awakened around that time (Rosenberg 2017, 185–186). This technique adopted improvisation as a choreographic compositional method. For example, the Judson Church group choreographer Trisha Brown first provides movement tasks to her dancers and the

dancers create movement in response to them. Second, Brown “intervenes as a composer to select, edit, and reorganize this raw material as choreography” (Rosenberg 2017, 185). The consulting historical scholar at Trisha Brown Dance Company, Susan Rosenberg, writes that “Brown cast her dancers into what problem-solving theorists call a ‘problem space’ defined by an ‘initial state, a goal state, and a set of operators that can be applied that will move the solver from one state to another’” (Rosenberg 2017, 186). This algorithmic process is also apparent in Forsythe’s choreographic procedure *Alphabet* (Forsythe and Kaiser 1999) and McGregor’s “if, then, if, then” process (McGregor 2012).

I also find similar algorithmic thinking in the composer Simon Emmerson’s model of compositional process. In seeking a methodology by which to conduct my practice-based research it was helpful to look at it. Since electroacoustic music does not use traditional musical notation systems and materials, Emmerson (1989) writes about composing strategies and pedagogy, and proposes a compositional model for contemporary music. The model consists of a cycle of actions: the composer does an action drawn from an action repertoire, which then has to be tested. After testing, accepted materials reinforce the action repertoire and rejected ones can be modified for the action or not. Emmerson explains that research begins when one “tests” the action, and new actions need to be fed into the action repertoire to evolve the research further (Emmerson 1989, 136). Similar to Brown’s technique, John Young (2015, 159) describes the process after testing in Emmerson’s model, in which the composer decides whether to accept or reject materials, as a “problem-defining and problem-solving process”.

The unique compositional feature of Emmerson’s model is that there is the test procedure. Emmerson explains this in “the composer/listener chain”: the test has to be done with a group of listeners – not any listeners, but a “community of interest whose views we trust

and value” – since there is no common code for building the same expectation as there used to be in traditional (Western) music (Emmerson 1989, 142). In my composition process my collaborating dancers are not only the performers, but also the primary listeners as they devise choreography that interacts with my sound system. We try a certain condition, explore our experience, and reflect on the next phase. My compositional cycle of actions as an adaptation of Emmerson’s model of composition process is: I provide choreographic tasks (*new action*) and the dancers devise choreography with restriction and rules (*action*) drawn from their movement *repertoire*. And then I examine (*test*) the materials created through this process to *accept* or *reject*. Therefore, one composition is completed with multiple iterations of these actions; furthermore, my entire research is structured within this action cycle.

4. My original works

Here, I offer some examples to demonstrate how I mapped movement and my sound synthesis. To prevent the dancers from being too busy dealing with just the musical functions of the technology, I first reduced the number of sound parameters to be performed by the dancers. Mostly only the z (length) values of the Game-trak controllers were used to control the sound parameters; sometimes the x and y values were used to in support to detect more specific locations of the dancers in the performance space. Although I simplified the number of sound parameters each controller could control, I provided different choreographic tasks strictly in order of the allocated time frames. I also wanted to have both direct and indirect interactions between movement and sound so that the dancers could have various conditions within which to devise choreography with differing amounts of freedom.

In *Pen-Y-Pass* (2016)³ I provided various choreographic tasks throughout time: For the first section of the composition the dancers were asked to tether cables onto their limbs, moving

only one arm at first and then gradually use all their limbs. Movement and sound had a direct one-to-one relationship here, and the dancers had to be careful not to move their other limbs from the beginning. As a result, the silent space gradually filled with more and more sounds. For the second part, the dancers were asked to attach one part of their body as though their limbs were extended diagonal lines tethered like the cables as well as the projected visual work behind them. Then the dancers tried to extend their limbs towards the gaps between their bodies. In this section, the dancers’ limbs only affected the volume of the sound files, allowing the dancers to focus more on devising choreography. For the third part, they were asked to detach the cables, leaving only one cable each. In this section, there were only two different sounds, one for each dancer, with one-to-one interaction. The dancers were asked to create a circle with their movements and then pause for a while, and repeat this movement. As a result, some silence was created in between. For the fourth section, the dancers were asked to attach one more cable to their limbs, making two for each dancer. One dancer was asked to perform solo, and then the other, and then duet until the end. For this section I programmed different sounds depending on the length of the cables. In return, the more the dancers moved towards the other side and crossed with each other, the louder and more dynamic became the sound.

For other works, I created more game-like tasks between movement and dance. For example, I attached the cables of Gametraks to two chairs in *Temporal* (2016).⁴ For the second section of the piece I mapped sounds to be randomly triggered at various locations in the performance space. The dancers were asked to move in response to what they heard. As a result, they moved around the room holding chairs and sometimes even dragging them to make a scratching noise. Depending on the triggered sound, the dancers created dynamic movements from fast to slow. Another example is *The Music Room* (2017), and here sound worked also as a restriction

³ See the video demonstration here:
vimeo.com/254723449/2f56001b94

⁴ See the video demonstration here:
vimeo.com/247499380/46af82a55d



Video 2. The composition process of *The Music Room* with my collaborating dancer Katerina Foti.
See: vimeo.com/247731900/494d98e0ea

to control the dancer's movement (Video 2). I programmed some piano notes to be triggered when the cables were pulled to a certain length. The dancers were asked to stop moving once the piano notes were triggered, and to wait until the note had finished playing. As a consequence, the dancer moved very carefully and created cautious and slow movement variations.

Conclusion

I have introduced my compositional approach in interactive dance focusing on integrating interactive system into the creative processes in both sound and dance. Throughout this paper what I would like to draw out is not only the technological development or mapping interactive sound synthesis as a compositional act, but also the holistic compositional cycle in collaboration as a composition to support interdisciplinary art research.

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Trans-Disciplinary Tools for Collaborative, Choreographed, and Embodied Audio-Visual Live Coding

Renick Bell¹
renick@gmail.com

Joana Chicau²
joanabcq@gmail.com

¹Tokyo, Japan

²Rotterdam, The Netherlands

Abstract

Seeking balanced and mutual interaction, the authors designed and implemented tools to connect a live coding system for audio built in Haskell with Javascript tools for live coding browser-based visuals to enable a collaborative audio-visual performance. Each system generates and emits OSC messages through functions developed by the authors and triggered by preexisting functions in those systems. The systems also gained subsystems for receiving incoming messages and modifying system state according to those messages. Means for displaying transmitted data were also implemented, allowing audiences greater insight into performer interactions. The system was designed to enhance the possibility of equal dialogue between the performers and avoid disastrous changes to a partner's system state. It was developed following an ongoing research and recollection of musical and choreographic scores that reference principles of non-linear composition, non-hegemonic time and space constructs, and techno-feminist perspectives.

Keywords

Live coding
Audio-visual performance
Collaboration
Choreography
Web environments
Techno-feminism
Improvisation

Introduction

This research focused on techniques for achieving a philosophically-grounded collaborative improvisation between a live-coded visual system and a live-coded audio system and the corresponding new software tools required to support that improvisation. This paper first explains the philosophical basis for the collaboration which underlies the techniques and tools, then describes the technical goals which the authors targeted. It proceeds to examine existing works which informed this research. The two systems involved are described briefly, followed by a more technical discussion of how the two systems were made to interact and the tooling necessary for that interaction. The paper concludes with a brief analysis of the results of this research.

1. Philosophical Intention

The authors began this research with the intention of collaborating in a way that reflects developments in theory on feminism, interfaces, and live coding to achieve the maximum balance in collaboration possible while still achieving particular technical and aesthetic goals.

Live coding performances, like other forms of improvisation, are a constant negotiation between different forms of agency and computers. Schroeder writes that “Live coding practitioners ask the audience to share the risk and the fascination of live making. By emphasising the risk of such making, these practices deliberately expose the body in flux, the body in constant negotiation with the environment and the instrument, itself in flux.” (2009) While acknowledging and accepting this risk, certain technical choices can be made to reduce some of those risks, correspondingly granting additional freedom in different areas.

It is also important to consider the role of the environment, as described by Rodaway: “... The concept of ecological optics (and ecological formulations of other sensuous information)

emphasises the role of the environment itself in structuring optical (auditory, tactile, etc.) stimulation. Potential sources of stimulation pass through the environment and are encoded with the structure of that environment as they are modified in their passage. It is this structured stimulus which the sense organ ‘read’. Therefore, the environment becomes a source of information, not merely raw data.” (Rodaway, 2002) In a collaborative performance, the other performer can also be seen as part of a performer’s environment.

The authors sought to reflect and practice alternative uses of technologies and the pursuit of new resolutions. Every decontextualized materiality may be immediately re-contextualized inside another already existing paradigm or interface. In *The Interface Effect*, Galloway writes that the interface is “not a thing, an interface is always an effect. It is always a process or translation” (2013) Users may completely depend on their conditioning every time they deal with data, so the possibility of escaping the normative or habitual interpretation of interfaces was of interest. The authors intended to include the activity of the other in a deeper way than simply reacting to how that performance is perceived through the five senses. In this way, the data flow from the other as part of the total environment becomes a central part of the structure of each performer’s output.

The authors aimed to expose the process, making digital literacy and experimental tools part of their strategies. TOPLAP has long called for live coders to “show us your screens” (McLean, 2010). The authors intended to take this still-radical concept of the openness of the performer further by showing how the data of the other is actively affecting each performer’s activity.

This approach of each system modifying the other is built on feminist pursuit of “decentered, multiple, participatory practice(s) in which many lines of flight coexist.” (Galloway, 2013) The platforms and tools chosen to integrate this

performance, for example the OSC feature later explained in detail, allow for constant and immediate interactions, intending to remove hierarchy, which necessarily means eliminating patriarchy, and reflecting the fact that influencing interactions necessarily involve being influenced in turn. Rather than an enforced equalising of roles so that there is a one-to-one matching of influence, the authors sought to achieve a balance of control appropriate to each situation. Through the data-level connection between the systems, a dialogue can be carried out, and an additional dimension of performativity is opened.

Through the appropriation of interfaces not originally intended for performance, as well as the creation of new vocabularies that form plural and therefore more inclusive views, feminist practices were in part brought into the project. Allowing possibly the world's most common interface, the web browser, to communicate with a very specific interface in the form of the custom Haskell interface, shows that inclusivity. Using feminist perspectives in the interface design means redefining what efficiency and functionality mean.

2. Technical Interaction Goals

There were several key concerns in developing the interaction and tools to make it possible. The principal concern was to enable a balanced interaction between performers; exactly what "balanced" means depends on the demands of particular situations. In accordance with the goal of allowing the other's data to become information for each performer's system, methods were required to pass that data and then make it meaningful.

Some additional concerns related to the interaction included how the performers could switch roles. Different types of activity levels were targeted: being active, being passive, being active simultaneously, having multiple agents active while the performers themselves are not, and so on.

The authors also examined how to avoid demolishing a co-performer's work when domain knowledge was insufficient, which in part reflects the de-emphasis on skill, removing some risks in order to allow more emphasizing mutually supporting communication. This required the authors to consider strategies and means for mapping data flows and then ways to quickly recover when unwanted state modifications take place.

The authors have not always relied on the same set of rules and interactions between the two systems. For example, wait times in one system might be remapped to spatial parameters in another, or an array of strings might be remapped to a graph of parameter values in another. The authors sought as much freedom of mapping as possible within the encompassing technical constraints of the systems involved. Messages could be urgent and acted upon immediately, or they could be deferred and acted upon when the context became appropriate.

The authors were also keen to avoid a mechanical correspondence between the two systems. For example, it was not our intention to make the visual system pulse perfectly in sync with the rhythms presented by the audio system. Deep ways to map the data were sought, yet some mappings that would still be obvious to the audience were also sought so that the audience would not just be aware of the interaction between the two performers but also might be able to follow it to at least a limited degree.

The goal of openness described above led to exploration of ways to reveal to the audience the nature of the interaction as it unfolds through a performance. This required display of those flows and their effects for not just the performers but also to the audience. Because the interfaces of the two systems were different, different means for displaying those flows were required.

Finally, all of the above goals had to be reached while still making sure that the tools function adequately for real-time performances, meaning avoiding unacceptable jitter, delays, glitches or other unwanted system malperformance.

3. Literature review

Collaborative live coding is not new. A number of performers have developed group practices and systems to enable their audio performances. Those include groups such as:

- The Hub (Gresham-Lancaster, 1998)
- OFFAL, “a non-hierarchical collective [aiming] to connect an international group of women engaged in electronic music by developing technological systems and organisational structures that facilitate collaboration.” (2018)
- BiLE (Birmingham Laptop Ensemble) (2018)
- Benoit and the Mandelbrots, who use their own BenoitLib and MandelHub (Borgeat, 2010)
- Various groups using David Ogborn’s collaborative editor Estuary (Ogborn, 2017)
- Live coding group Glitchlich, which used SuperCollider and their own bespoke tools written in C++

Some systems allow collaboration between audio and visual live coders, such as Charlie Roberts’s *Gibber* (2012). There have been some live coders whose practices involve choreography, such as the work of Kate Sicchio (2018) and some pieces by Marije Baalman (2018). However, the authors are unaware of data sharing via OSC between two different live coding environments for the purpose of executing a collaborative audio/visual performance with choreography.

4. Audio System

The live coding system in Haskell (Jones, 2002) uses a text editor and ghci with a SuperCollider audio back-end (the SuperDirt sampler, which is a port of Alex McLean’s Dirt sampler to SuperCollider done by Julian Rohrhuber (McLean, 2018)), to which the system communicates

through OSC (Wright, 2005). OSC is handled by the hosc package written by Rohan Drape (2010). The audio system uses more than 10 autonomous processes which, in addition to triggering audio synthesis events, also change data used in pattern generation, synthesis, and the state of the other autonomous processes. The processes refer to a set of shared data stores containing tables of rhythms, density patterns, sample patterns, parameter patterns, and so on. Each process runs in a loop, executing a side-effect-producing function and then waiting according a timing function each refers to, as long as it is active. Whether it is active or not is determined either by the operator or another autonomous process which has been assigned a function to start and pause other autonomous processes.

5. Visual System

The visual system involves a choreographic score written in web programming languages (HTML, CSS, JavaScript). The performer uses the browser (Firefox) console to write functions that draw on choreographic concepts and use both local files and already existing interfaces, such as Google search, to explore different functionalities of online interfaces. The performer live codes in Javascript in the web browser, embedding new canvas elements and manipulating various visual elements text, images, modifying in real time sourced web pages, and reading from JSON data stored on the local disk. OSC is handled by Node.js and the osc.js library (Clark, 2014).

6. Inter-system Communication and Interaction System

To achieve the collaboration goals described above, some tools for dealing with OSC messages were developed. OSC messages were designed according the approach described above. The messages are structured to show where they come from, in the following manner:

```
(/aud&gt;(audio or visual)/processA/messageType [  
... (an optional array of floats or strings  
to be received by a system)...]
```

“Audio” is replaced with “visual” in the case of messages coming from the graphical system to the audio system. With such a message structure, it is possible for each system to respond to the data in an appropriate manner as deter-

mined by the coder/performer. The message types reflect where the data was taken from.

Messages belong to one of three types: trigger messages, arrays of numbers, or arrays of strings. The effect is that one performer has passed to the other a critical piece of its inner activity, which the other is free to react to in any way. For example, the audio system might

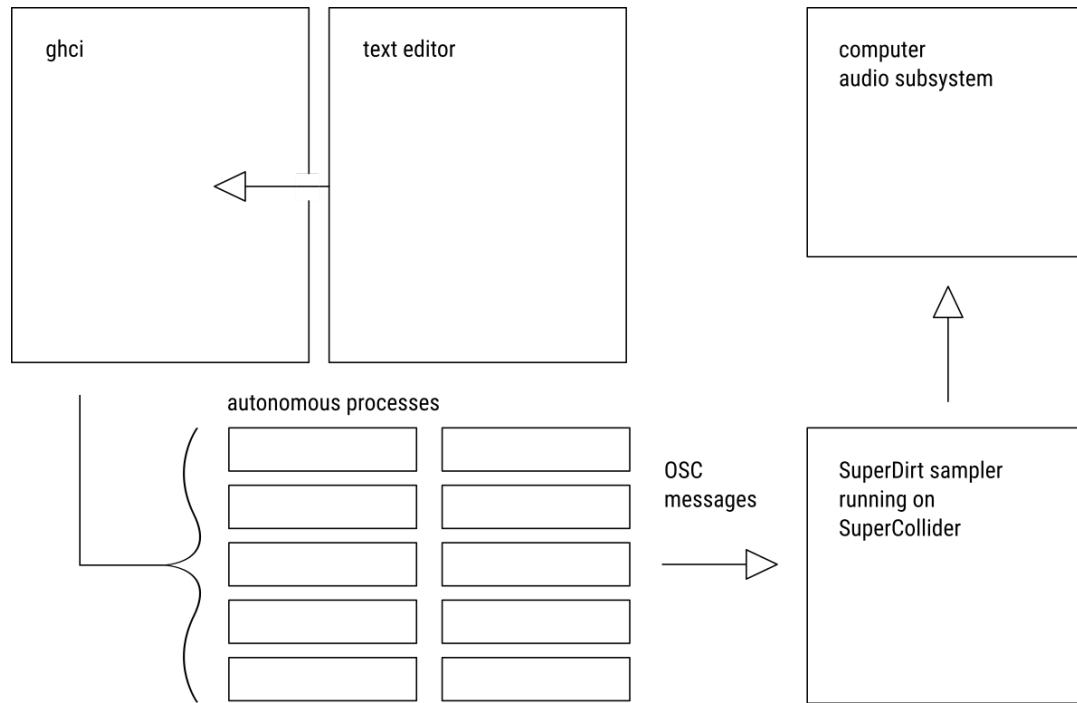


Figure 1. Audio system

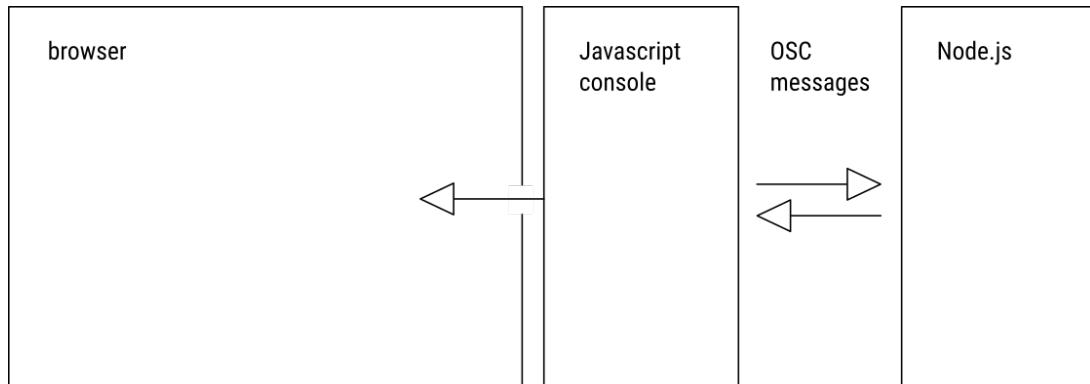


Figure 2. Visual system

send a “rhythmTableRow” message, which is followed by the delta values contained in the selected row of a selected rhythm table. The coder of the visual system is then free to use that data in any manner deemed useful to the performance, such as using these delta times to determine refresh rates to a line of text which changes periodically.

Some examples messages include:

/audio/playerKick/trigger

/audio/density [0,1,16,1.4,20,1.2, 28,1.7,31.9,1.9] <- a linked listed displayed as a flattened array

/visual/browserWindow1/trigger

/visual/browserWindow1/waitTimes [1,1,2,1,1,3]

/visual/searchStrings [“The center of”, “Spheres”, “Equidistant”]

Mapping is flexible and can be decided at performance time by the performer so that it becomes an element of the improvisation. However it is also possible to pre-map incoming data before the performance, and the preparation of various mapping functions before performing makes use of the data in performance safer; in rehearsals safe mappings can be decided that would allow those messages to be passed and executed

without disastrous changes in system state or otherwise negatively influencing the performance. Users are able to map the messages so that critical data is protected and that the effects produced are within a safe range.

Some functions were developed in order to reshape data for different uses, such as normalizing values to usable ranges or converting string data to numeric data and vice versa. Received messages can also be handled in two different styles: immediate dispatch or dispatch according to sequence. The meaning of the former should be clear; in the case of the latter, messages are queued and dispatched in order of arrival according to the timing of a sequence determined by the operator of the audio system.

An OSC listening/sending subroutine for the audio system was implemented using `hosrc`. Received messages are interpreted by the listener and displayed in the interpreter, which is visible to the audience in one terminal. Those received messages then trigger corresponding functions which in turn modify or replace the various stateful data of the system. For example, a trigger message can be used to force a change in rhythms, or wait times can be interpreted as a graph for density to be used by some or all of the autonomous processes. An OSC listener for the visual system was implemented in `osc.js`. It involves a Node.js-based listener which receives messages from the network and passes them to the visualization system running in the browser.

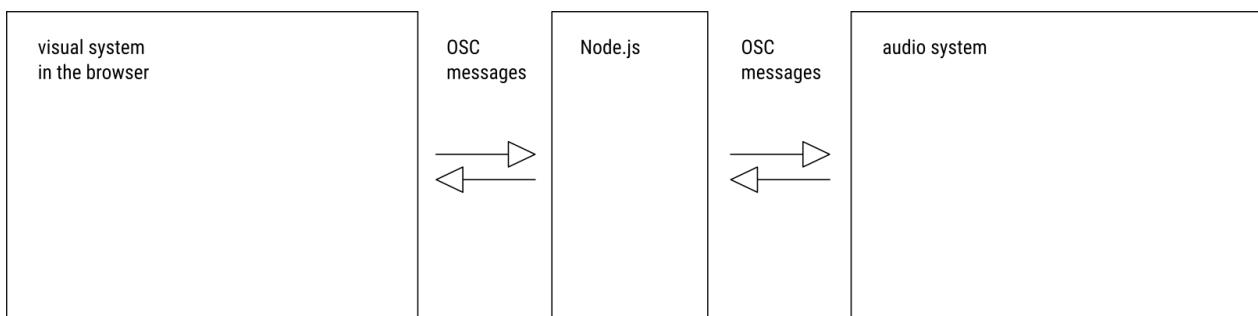


Figure 3. Inter-system communication

The visual system might map incoming messages to things like delta times in page animation, spacing of graphical items, or angles used to skew graphical items.

At the same time, the audio system sends OSC messages to the visual system. Autonomous processes following the same rhythms and densities as the processes triggering sample playback send messages via OSC to the visual system, where they are received by a corresponding listening server. The functions for doing so are designed so that different processes can send different types of messages and at different timing. The visual system has OSC-message-passing functions built into standard functions used for modifying the browser environment so that through normal operation, OSC messages are passed to a node-based server which then sends the messages via OSC to the audio system.

Revealing the interaction required using meaningful naming conventions and crafting messages to be shown in always-visible post windows. Those messages also required particular highlighting so that they would not be lost amidst the data present in those post windows.

The visual system displays the received messages in the DOM as alerts or as text messages in the browser to highlight the communication, while special text formatting was used for received messages in the Haskell interpreter so that those messages would be more visually emphasized than other messages that appear in that window.

7. Evaluation

Basic technical goals were achieved. While there are some advantages to including the functions to send OSC messages to the partner system in embedded functions that are triggered during standard system operation, it was decided finally not to do so in order to allow for a more flexible and therefore timing-appropriate usage of the message-passing functions. It

is still challenging to adapt to unfamiliar data from the other system in real-time. It is worth investigating whether this is a matter of practice or if technical solutions can reduce the difficulty of doing so. The authors settled on a simplified message system in which the origin and a string argument are passed. This was done for two reasons. The first of which was that the specification of the more complex message in the performance was too demanding and error-prone; becoming familiar with a more complex form would take more rehearsal time than was available for the initial performance using the system. In addition, the authors decided on an explicit shared vocabulary for conceptual and aesthetic reasons. This shared vocabulary then was given a behaviour in each system. For example, “spacing” in the visual system increased the spacing between letters in text, while in the audio system it increased the distance in time between events. These were defined in advance so that they could be used more immediately in the performance according to timing chosen by the users. Most in-performance mapping was dropped for the performance in order to keep the pace of the performance fast enough to meet aesthetic goals and avoid errors. If mapping is to be done dynamically in a performance, faster methods will be required. Queueing of messages was also not used in order to maintain the transparency of one performer passing a message to the other and then immediately causing a change in the other system.

Conclusion

The authors intend to use this system for a number of performances, testing it further to determine whether it achieves the goals outlined above, how those goals might be revised, and how the system can then be adapted further to meet those goals. The implementation also remains very specific to the two systems involved; future work includes generalizing the system and documenting it so that it could be more easily used by others for their performances.

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Vibez
**A Small Sense
of Presence at
a Distance**

Joanne Armitage¹
j.l.armitage@leeds.ac.uk

Shelly Knotts²
knotts.shelly@gmail.com

¹ Leeds University, Leeds,
United Kingdom

² Missing Information

Abstract

The paper describes a performance by live coding duo ALGOBABEZ in which they communicate telematically using biometric sensors and haptic devices. Inspired by the recent relocation of one of the band members to Australia, ALGOBABEZ are interested in how they can recreate a sense of the other's physical presence in performance and/or what additional data they could share to build a sense of empathy between performers. As algorithmically inquisitive beings, they are also interested in how algorithms may disrupt, disturb or subvert this process, and give the opportunity for performer's to actively adjust the honesty level of their biometric data stream.

Keywords

Biometrics
Haptics
Telematics
Live coding
Algorithmic systems
Improvisation
Presence

Introduction

Vibez is a telehaptic live coding performance where performers share their biometric signals across the internet with algorithmic intervention. In this project, several streams of ongoing research intersect: haptics, biometrics, telematics and algorithmic systems. In Vibez we expand on our previous research using these technologies in performance, and contextualize ongoing research at SensiLab in haptic devices for social cohesion, in a specific performance context. We combine these interests with the aim of creating a sense of embodied collaboration at a geographical distance, exploring how we can extend our senses to negotiate a reduced bodily presence and situating our research in the needs of an evolving performance practice.

ALGOBABEZ are a recently geographically separated, transcontinental Algorave duo who, until recently, were regularly performing in a co-located live coding collaboration. We embarked on this research project in an effort to find technical solutions to performing at a geographical distance. In recent months, we have been performing telematically at raves around the world, sending one physical body to the performance space while beaming in the audio waves of the other half of the duo over the internet. In this project, we have been working on methods to extend this sense of trans-location, by mechanically replicating¹ ourselves through sensors and vibrations.

Building on previous work (e.g. *BabeNodes*, a system embedding sensor data related to audience dance activity into the sound generation), in *Vibez*, ALGOBABEZ perform with a networked sensor/actuator system developed to incorporate biophysical data into telematic performance. Through this, we embed a greater and extended sense of physicality into performance, and share with each other, and the audience, a representation of our levels of stress, moments of stasis and general head-bobbing enjoyment. We use sensors such as Heart Rate and Galvanic Skin Responses to detect biophysical markers of stress and

enjoyment, and accelerometers and key-presses to detect and amplify physical interaction with the sound and interface (keyboard).

In collaboration with researchers at Monash University, we have developed haptic armband devices which amplify these biometric signals through pressure and vibration. We have integrated a set of algorithms with this hardware which translates the incoming data into a vocabulary of haptic sensations, making use of the tactile modalities available in the armband. The data is shared telematically via a remote server, so that each armband receives the biometric data of the other performer.

Responding to ethical implications of the performance (e.g. biometric privacy), and the mediated nature of haptic sensation at a distance, we also implemented algorithmic means to subvert the process. The performers have the option to switch the armband of their collaborator to conveying different levels of randomised information ranging from unmodified data direct from the sensor inputs to entirely random data. As is standard practice in live coding (See Fig. 1), the performers project their code interface (Brown 2007), however we also augment this information by using the sensor data to generate visuals relating to mood and mediation.

1. Background

Systems for improvisation are negotiated by performers bodies in the critical moment of performance. They can work to constrain a performer, facilitate a (new) collaboration or reveal a different way of negotiating or experiencing a performance. Many systems are motivated by presenting opportunities for performers to experience new challenges (through instability or pushing their physical limits), novel interactions or controls, and representations performance elements in novel ways. All these approaches work to reveal new ways of knowing through and in performance. In this section, we situate *Vibez* within the field of improvisational systems and provide context to its development.

¹ Though fully engineered, self-aware replicants (Fancher and Peoples 1982) are beyond our technical capabilities, we propose through this research that some aspects of humanity may be replicated by circuits and data.

The design of our system intersects several areas of research and technological development which impact presence in digitally mediated performance. This investigation grew out previous experiments with embodiment in live coding (Armitage and Knotts 2017), and experiencing a sense of loss of connection when transitioning to performing through telematic technologies. Presence is of particular concern in the context of our current performance setup as outlined through this section.

Our approach to interrogating presence in this project centers around using interventionist technology to produce tactile sensations that draw the performer's focus towards awareness of a collaborator. Digital performance tools exist on a spectrum of embodiment, where highly embodied tools typically induce a continuous form of interaction with sound and instrument, and highly cognitive tools (such as live coding) introduce friction in the interaction between performer and sound (Sa 2017). Though Csikszentmihalyi's theory of flow states (Nakamura and Csikszentmihalyi 2014) proselytizes uninhibited interaction with tools, and is often cited as an ideal for improvised creative expression, Rose (2014) suggests that discontinuities and frictions in improvisation can work to bring the performer's attention back in to the context and present moment. In collaborative improvisation this can be an important catalyst to returning attention to working in a mode that foregrounds co-development of a performance narrative (Gifford et al. 2017). Initial experiments on SensiLab project *Improvisational Intimacy and Haptic Interfaces* revealed that haptic devices have the potential in digitally mediated performance to break performer focus on the interface and signal a change point in improvisation to a collaborator. In this paper, we explore how awareness of the physiological state of a long-distance collaborator may feed into working more fully in this 'collaborative mode' through perceptions of stress and activity of the other performer. We also propose that sharing biometric signals coupled with activity levels may help to facilitate understanding of activity

levels and contribution from the other performer and build empathy between distant collaborators e.g. by highlighting when reduced activity may be due to technical problems.

Live Coding performance practice foregrounds human interaction with technological processes, and centers exposing the process as integral to performance. However, emphasizing the technical often comes at the expense of the embodied/physiological process. Live coding already implicates bodies in interesting ways and this is something that we have explored individually and collectively (Knotts 2016; Armitage 2016). With our shared interest in process, we were interested in exploring the human biological processes alongside the technical processes revealed through code projection. Through the co-creation of sound through code, live coders are performing complex relationships with machines and demonstrating technical expertise through the banal activity of editing text. The combination of large scale projections and bodies behind poorly-lit booths in Algorave performances could be seen to displace the body and its movement into the visual representation/projection. The cognitive load of live coding is somewhat higher than in embodied performance practices (Sayer 2016), making peripheral focus on collaborators and factors beyond the immediate needs of coding more difficult. Awareness of surrounding and contextual factors such as audience and collaborators can be reduced for large portions of performance due to the central visual focus on the screen. The mundanity of the 'act' of live coding, navigating code and de-pressing keys, causes some performers to attempt explore mitigating the cognitive load (i.e. preparation or terse languages) or embellishment of it through visualization.

As performers, we find that the pressures of high concentration on coding activity means we often don't feel present and connected in the collaboration. What brings us (back) together are fatal or highly disruptive errors—where verbal cues are necessary.² In the current formation of ALGOBABEZ we have the additional hurdle

² Examples of where technical friction has structured our communication and musical output and informed our collaborative practice include a high-profile gig at Liverpool Philharmonic: <http://www.getintothis.co.uk/2017/02/nik-colk-void-klara-lewis-algobabez-philharmonic-music-room-liverpool/>.

Limited sound check time and network issues prevented us from having a reliable clock sync. During performance we each restarted our systems, which involved negotiating appropriate times to do this with the other performer and providing audio cover while the other performer's system is down.



Figure 1. A typical ALGOBABEZ co-located performance setup (left). Knotts testing a prototype biometric sensor wristband (right).

of performing telematically. This further reduces the awareness of the state of the other performer. Attention to collaboration is focused solely on the audio output of the other performer, and occasional messages via internet chat where needed—e.g. informing the other performer of a system crash. This is a very different sense of presence to that in co-located performance where you can use verbal, visual and physical cues to sense the other performer's emotional/physiological state. Playing telematically, we have found it challenging to engage with chat as our coding environment immerses the visual, and audible notifications are turned off to avoid sonic disruptions.

Haptic technologies present an opportunity to create new tactile experiences when collaborating within a digital space. These devices have been applied in consumer electronics to heighten a user's bodily connection within a virtual system (in gaming) or as a form of notification to a digital communication (mobile phone). Other haptic devices allow users to gain a tangible sense control whilst kinaesthetically interacting within a virtual system to form a sense of presence of a distant other, or 'co-presence'. These systems are designed to remove an individual from their physical environment and transport them to the virtual space. In such applications, haptic representations are often designed to reflect real life interactions that can be measured and recorded, then simulated on a mechanical device. An example of this is the 'PHANToM' device, whereby users can telem-

atically input and output gestures—allowing human to human communication that is mediated via touch (Paterson 2008). This replication and remediation requires expensive hardware systems, and approaches the haptic as a direct representation of exteroceptive motion.

Armitage (2017) discusses how haptics can facilitate new tactile relationships in performance, extending touch beyond the mimetic and representational to facilitate new modes of 'knowing' through performance. In this work the haptic, used telematically, facilitates a sense of presence at a distance in collaborators. Turchet (2017) suggests the need for haptic communications across networks to enhance inter-group communication and communication between performer and audiences. This performance system is using the haptic to communicate an element of a performer's emotional state through bespoke haptic mappings. In *Vibez*, we are looking to haptics as a means of rendering of emotion—something that is embodied. In this space, the haptic becomes more abstract. It has the potential to facilitate an intimate performative connection through an immersive and embodied experience.

To begin to understand the emotional state of a performer, we need to consider some way of translating metrics relating to their physical body into something machine-readable. Biometric sensors offer an affordable means to detect physical markers of interaction with an interface,

through this we can detect physiological symptoms of emotions such as stress and enjoyment.

In a previous ALGOBABEZ project, *BabeNodes*, we used sensors to detect markers of audience dancing to control aspects of the music. This included a Heart Rate sensor which audience members could attach to their fingers to trigger tempo changes and distance sensors which triggered samples. In this context, the heart rate sensor was most important in building a sense of connection with the audience, building a feedback loop between music and dancing, through bodies and physical interaction with technology. Beyond this, the use of technology situated in the audience, solidified the technological foundation of the performance, making it solid and touchable for the audience and not just ephemeral, complicated, ungraspable.

The Sacconi Quartet's work *HEARTFELT* explores touchable technology, combining biometrics with haptics, in doing so connecting the audience to the physiological processes of performance:

The question is whether this heart-exposing experiment will do what the quartet hope—namely get the audience closer to the physicality of their performance in a way that will reveal new musical dimensions, or rather, give an insight into the players' individual and collective stress levels and performance anxieties around the challenges of performing Beethoven (Service, 2015).

In *Vibez*, we are interested in how these concerns may affect us as distant collaborators. We are using a number of types of biometric sensing to build a broad picture of stress and concentration levels of performers: Heart Rate (HR), Heart Rate Variability (HRV), and Galvanic Skin Response (GSR). These biometric factors have been shown to relate to physiological states including stress (Taelman et al. 2009). In *Vibez* we are interested in how awareness of stress states may add to the audio information, struc-

turing how we perform, communicate with and respond to each other.

As performers we use algorithms to build, subvert, disrupt and dissolve process. When live coding we use this as a process for developing sonic structures, but beyond this we are interested in how we might explore interaction between collaborators with intrusive algorithms. Though we see biometric data as a possible avenue to extending communication where bodily presence is reduced, we also see that using this data as part of a performance system raises interesting issues around privacy. This aspect of performance is usually not shared, and performers are trained to counter the outward expression of stress during performance. We found it imperative to provide a possibility for the performer to subvert this process, so we implemented the simple mechanism of an 'honesty' slider. This allows the performer to increase or decrease the level of 'noise' on the biometric data stream. Part of our investigation includes interrogating the extent to which algorithmic noise impacts performer perception of presence and empathy built through biometric data streams, and whether it effects their level of comfort with publicly sharing this data.

2. System Design

Vibez is in the prototyping and development phase with completion of a refined system expected in the coming months. We have built and tested prototypes of the biometric sensor band and the haptics armband and are in the process of refining the data mapping through iterative testing. In this section, we describe how we implement the theoretical streams of our research in the system design, its constituent parts and the flow of data during performance.

The system is made up of several component software and hardware parts and a data flow structure that determines how they interact (See Fig. 2). The system includes: a biometric

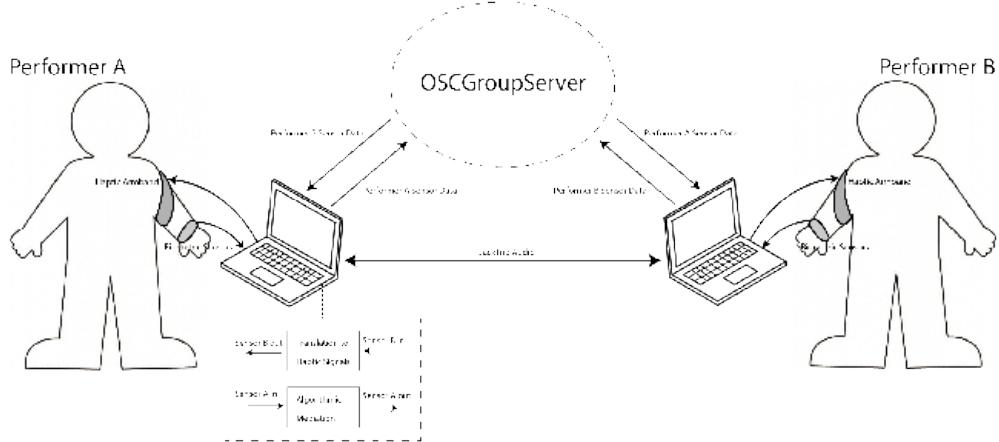


Figure 2. Overview of the system and data flow.

sensor band which attaches to the wrist; a haptic band, which attaches to the upper arm; a network server which manages the transfer of data from one location to another; a set of algorithms written in SuperCollider which control the data flow, mediation and haptic actuation; and a simple visualisation which communicates the system state to the audience.

3. Biometric Sensor Armband

The biometric sensor wrist band (see fig. 1) consists of a HR sensor (pulsesensor.com), a Grove GSR sensor and an accelerometer attached to an elastic wristband which fastens with Velcro. The sensors are connected to an Adafruit Feather. Though more accurate sensors are available, this setup was chosen over professional grade sensors because of the ease of integrating all sensors into a single band and the availability of Arduino libraries. Because the performers need to interact with the computer keyboard throughout the performance, the armband is designed to not restrict arm or hand movement and to be relatively unobtrusive. The sensors send a constant data stream to the mediating algorithms during the performance.

4. Haptic Armband

Haptic systems require several components including microcontrollers, drivers and the haptic actuators themselves. Due to the nature of our collaboration, the control signal is coming from a laptop. These would need to be received by a microcontroller, to communicate with a haptic driver and generate haptic waveforms from the controls. A haptic driver circumvents the current limitations of microcontrollers to provide higher quality vibration output. In turn, the drivers control motors, or haptic actuators that render the inputted information as vibrations for the user. The haptic armband incorporates two vibrating actuators controlled by bespoke driver chips which are multiplexed to a wireless Adafruit Feather.

The motors are driven by a DRV2605, which was selected for two main reasons: firstly, it interfaces with both ERM and LRA motor types, at a range of operating currents and voltages, which is advantageous for testing and comparison purposes; secondly, it affords a wider range of bespoke controls including an integrated library of haptic effects. One DRV2605 driver can only control one motor independently so a driver is required per motor. To address individual devices through Serial communication, an I2C multiplexer is required as each DRV2605 has the same, fixed I2C address. We have used

the TCA9548A multiplexer, which has eight bi-directional switches controllable through the I2C bus. This enables control of up to eight motors independently. The motors are encased in foam and embedded into a band worn on the wrist by the performer.

5. Network Infrastructure

The performance uses OSCGroups ‘a system for routing OSC messages between a group of collaborating users’ (Bencina 2013) to manage sending the data streams between performers. OSCGroups consists of a remotely accessible server and clients running on each connected machine, allowing us to use Open Sound Control to send data over the internet. The OscGroupClient library in SuperCollider, can then be used to set up responders to receive data from the server, as we would when playing on a LAN. Each computer sends the biometric data to the server using tags such as ‘\hr’ and ‘\gsr’. The OSC responders on each machine listen for messages received by the server with these tags allowing us to send data from one computer to another via the remote server. Managing the data flow from within SuperCollider facilitates easy integration of the sensors

and haptic actuators with our pre-existing performance system.

In the past year we have been experimenting with telematic setups for distributed Algorave performance practice. Live Coding systems such as Estuary (Ogborn et al. 2017) and Gibber (Roberts and Kuchera-Morin 2012) provide the possibility of long distance collaboration with local synchronisation, but are language specific and do not facilitate the integration of sensors and other hardware in the standard coding environment. For this reason we have been using audio streaming to facilitate collaboration, which supports continuation of our co-located performance practice with easy integration of our sensor system to enhance communication. We use JackTrip (Cáceres and Chafe 2010) to manage audio streaming, which on stable, high-bandwidth internet connections allows low latency streaming. We add latency locally in SuperCollider to offset any network latency to enable the output in the performance space to sound in time.

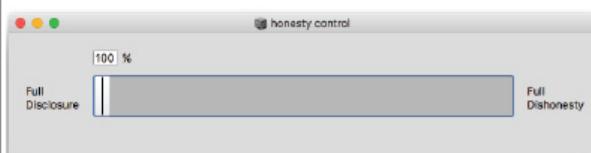


Figure 3. Example of visualisation showing heart rate, honesty level and overall mood of each performer (left). Honesty Control fader set to 100% honesty (right).

6. Interface

We programmed a slider control in SuperCollider (see fig. 3) which modulates the ‘honesty’ level of the outgoing biometric data. This simple interface was implemented to facilitate ease of use in demanding performance scenarios. The slider adds various levels of ‘noise’ to the biometric signal, from no noise at the ‘full disclosure’ end of the slider (this is the default setting) to entirely random data at the other extreme.

7. Visualisation

In order to communicate the biometric data and performer mediation to the audience during performance, we implemented a simple visualisation which represents these parameters through text and colour. The visualisation shows the overall mood of each performer as text. The honesty and heart rate values are also shown. We created gradients by mapping the mood to associated colours (outer side of gradient), and mapping the honesty values to a greyscale where white = 100% honesty and black = 100% noise (central side of gradient). Through this simple mapping audience members can easily perceive the performer emotional state and the amount of data mediation in play.

8. Application in Performance

In performances of *Vibez*, the two performers live code in SuperCollider in two different geographical locations, sharing audio via JackTrip. They each employ different approaches to live coding sounds, whilst Armitage uses SuperCollider to generate MIDI note, control and SysEx data that is sent to hardware synthesizers, Knotts writes software synths from scratch. During the performance, we each wear a biometric sensor wristband and a haptic armband. This allows us to feel vibration in relation to the activity levels, mood and heart rate of our collaborator.

9. Discussion

Vibez observationally addresses concerns pertaining to presence in telematic performance by extending inter-performance communication through data. This creates a physical connectedness through haptics and algorithmic mediation. We have discussed how biometric sensors can be useful in determining human emotional states, including stress, excitement and calm. Translating this data to the haptic allows it to be rendered as a form of heavily mediated touch. In this context, the haptic serves to implicate the body in the improvisational experience, bringing attention to the body in space and place. Considering the cognitive load inherent in live coding performance, connecting the tactile body allows new forms of communication that do not occlude the auditory or detract from the performer’s visual immersion in the coding environment. With this, the system embraces elements of uncertainty—algorithmic mediation explicitly acknowledges the technological aspects of the performance and how we inevitably lose detail and nuance in the translation of biological processes and sensing through digital tools (Cadoz et al. 2014). We added a performer controlled mediation to subvert the translation process as an expression of this imperfection and response to the ethical implications of unmediated personal data streaming.

Although we are yet to test the system in a real-life performance situation, and acknowledge this may have a significant impact on physiological signals detected by the biometric sensors, we conducted initial tests of the system and recount observations from this above. A further system evaluation that will enable us to understand the significance of the haptic communication is in planning stages and will consider the following: how does the body react to error/uncertainty? How does the performer respond differently when they feel the stress of another performer?

Conclusion

We propose that telematically activated haptic devices may provide an opportunity to develop a greater sense of presence between geographically distant collaborators. In addition, we claim that using physiological state as an input to the haptic feedback may aid with this empathy building by giving a small sense of the physical presence of the other performer. In this performance system, we explore this through the ALGOBABEZ method of disrupting spaces and processes and consider how algorithmic intervention can facilitate new modes of knowing in performance.

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PERFORMANCES

Círculo e Meio

An Audio-Visual Live Coding Performance Combining Choreographic Thinking and Algorithmic Improvisation

Joana Chicau¹
joanabcq@gmail.com

Renick Bell²
renick@gmail.com

¹Rotterdam, The Netherlands

²Tokyo, Japan

Abstract

The performance reflects how language boundaries are enacted through the computing environment and society, exploring how movement, gestures, discourses, and behaviours are choreographed and communicated through these apparatuses, and how our hybrid systems and transdisciplinary research co-construct each other. It is informed by recollection of sources that reference principles of non-linear composition, non-hegemonic time and space constructs, and techno-feminist understandings. It combines two connected digital interfaces. Using a shared choreographic vocabulary, the performers create meaning around the act and conditions of coding.

Choreographic and musical references

The authors have been collecting materials¹ which address the concept of the ‘circle’ as a spatio-temporal construct with considerable history. Notation systems convey notions of standardized measures, codes, gender, class, rituals, beliefs, ideologies, formation of habit and perception (Aureli, 2016), and their use determines the concrete ways in which we inhabit and produce physical and digital spaces (Aureli, 2016). As interfaces are “scripted” with ideologies (Tomás, 2016), the performers wanted to engage critically with the political significance of these references, questioning the (normative) power of abstractions (Feyerabend, 1999) and geometrical definitions as well as their power of transgression, commonality, consciousness, and freedom.

To illustrate the later, scores from various choreographers were analysed; for example, Eshkol-Wachman Movement Notation¹, which “utilizes a spherical system of coordinates, similar to latitude and longitude on a globe”, considering both human and non-human bodies as networks of actors with equal rights within a medi-asphere (EWMN, 2001).

In dance, the circle is regarded as “one of the oldest known dance formations it is a style of dance done in a circle or semicircle to musical accompaniment, such as rhythm instruments and singing” (Sachs, 1938). Anku describes the African concept of time as circular or spiral in nature and explains its manifestation in traditional African drumming practices (Anku, 2000). Many of those rhythms can be generated by the Euclidean rhythm algorithm and visually expressed as events along the circumference of a circle (Toussaint, 2004). Circles or semi-circles of drummers have been documented among many cultures over a longer time span than hippie social ritual, such as in (Greco, 2008) and (Williams, 2015). Drum circle etiquette echoes the ethical prescriptions of the

feminist approach the authors have adopted. (Hull, 2011; Hull, 2018)

A hybrid language and dual interface

The authors make use of two connected digital interfaces for live algorithmic composition. Bell uses Conductive, an audio system live coded in the programming language Haskell, and Chicau uses the web browser to code in JavaScript. The interfaces are connected through OSC tools enabling data-sharing and possibilities for each system to influence the other.

Following our conceptualization of the ‘círculo’, the choreographic thinking brings repetition and reversibility as central to the piece. The performance unfolds in a circular pattern. The code input written in the web browser will be revisited and activated in different moments, and unpredictable results will be displayed. The title of the piece can be translated as “a circle and a half”. This “half” is interpreted loosely to mean an incomplete circle.

Concretely, one or more complete cycles of a Euclidean rhythm are followed by an incomplete cycle, and up to three rhythm patterns are ud (both standard Euclidean rhythms and “circle and a half” rhythms). Percussion sounds were recorded and processed to emphasize the idea of drum circles and the universality of Euclidean rhythms, with processing to increase the range of expression, and a three-stage mapping from text to sonic characteristics was used to design additional sound atoms. The performance will be divided into moments in which one or both screens are active and may include physical movement in the performance space.²

¹ The inventory of choreographic and musical scores:
<http://circle.renickbell.net/index.html>

² The performance set up:
http://circle.renickbell.net/set_up.html



Figure 1. Chicau (top) will be activating her choreographic score written in web programming languages (HTML/CSS/JavaScript). Chicau will use the the browser console to write functions that draw on choreographic concepts. She will be using both local files and already existing interfaces, such as google search. Bell (bottom) will live code in Haskell, using functions from the Conductive library to compose, perform, and improvise the musical component of the performance to support the choreographic goals of the piece. He will be triggering sounds specifically designed for the performance as well as some sound processing through external hardware also connected to the live coding environment.

Figure 2: detail of shared vocabulary used for the interaction between the two systems. Chicau (left) will receive the messages from Renick which will be interpreted in JavaScript and trigger various visual outcomes in the webpage. Bell (right) will receive messages from Joana which will be translated to Haskell, and trigger different sound functions. Joana and Renick will be co-choreographing the piece.

External links and Media Assets:

The documentation of the project is delivered in an open-ended format, following Free/Libre Open Source (Floss) model. The source code for the project will be updated on github and in the form of an inventory/catalogue which further explains the conceptual dimension of the project.

Link to the performance code:
<https://github.com/JoBCB/circulo-meio>

Video recording /prototype:
<http://circle.renickbell.net/video.html>

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Fingerprints

Ryan Kirkbride¹

sc10rpk@leeds.ac.uk

Lucy Cheesman²

lucy.cheesman@gmail.com

Laurie Johnson¹

lauriej1316@gmail.com

¹ University of Leeds

² University of Sheffield

Abstract

Fingerprints is an improvised performance for collaborative live coding that explores ownership and identity within group creativity. It is performed by The Yorkshire Programming Ensemble (TYPE) and utilises a real-time concurrent multi-user text editor to facilitate meaningful creative exchanges in collaborative processes within the practice of live coding. The editor, Troop (Kirkbride 2017), allows multiple performers to share the same text buffer and write their own code while also interacting with code written by their co-performers. In fingerprints, each performer will work on code independently and create sound using “their own” musical algorithm before attempting to reshape their collaborators’ work. As this process continually repeats, the piece evolves and the performers are asked whether they can retain their own identities within a state of perpetual flux or if the communal process takes on a greater identity of its own.

Act: Study
Subject: History
Topic: _

Masato Kakinoki
m@kakinokimasato.com

EAVI, Goldsmiths, University of London /
CRISAP, LCC, University of the Arts London,
London, United Kingdom

Abstract

In this performance, the fixity and fluidity of history, digital materials and those of documenting and recording are explored by improvising the act of studying history, and improvising with the immediate recordings of the act. The recorded sounds of reading, writing, squiggling, drinking, eating and occasional mumbling are fluidified through the performer's physical manipulation. What the performer does can be regarded as learning, examining, organising, disorganising, manipulating or forging both certain history and the act of learning it. The nature and poetic sentiment of the act of learning are inherent elements behind the performance.

The trading history between England and Porto through wine and cod was studied in this performance instance.

Kakinoki is working on research-based art practice, particularly interested in the fields of food culture, sexual and romantic culture, and human history. He exposes the ongoing research process in the format of performance.

Keywords

Fluidity and Fixity
Physical Presence
Learning Performance
Improvisation
Food and Drink History
International Trade
Digital Audio
Audiovisual
Derivative TouchDesigner
Cycling '74 Max

Variações sobre Espaço #6

Filipe Lopes¹

filielopes@esmad.ipp.pt

Gilberto Bernardes²

bernardes7@gmail.com

Clara Cardoso³

clara.f.cardoso@gmail.com

¹ INET-md / uniMAD

² INESC TEC

³ MIOA, Bickerdike Allen Partners LLP

Abstract

We present Variações sobre Espaço #6, a mixed media work for saxophone and electronics that intersects music, digital technologies and architecture. The creative impetus supporting this composition is grounded in the interchange of the following two concepts: 1) the phenomenological exploration of the aural architecture (Blesse & Salter 2007) particularly the reverberation as a sonic effect (Augoyard & Torgue 2005) through music performance and 2) the real time sound analysis of both the performance and the reverberation (i.e. impulse responses) intervallic content — which ultimately leads to a generic control over consonance/dissonance (C/D). Their conceptual and morphological nature can be understood as sonic improvisations where the interaction of sound producing bodies (i.e. the saxophone) with the real (e.g. performance space) and the imaginary (i.e. computer) acoustic response of a space results in formal elements mirroring their physical surroundings.

formulae si:v

Marcin Pietruszewski
mpietrus@exseed.ed.ac.uk

University of Edinburgh

Abstract

The ‘formulae si:v’ is an experimental opera; a duo for synthetic voice and an algorithmic script for auditory scene formulation; an elemental synthetic laboratory where the sensible, the intelligible, the artificial, and the natural are animated and combined. Integrating a state of the art machine learning program, a novel hybrid sound and speech synthesis design, and an original spatialisation score, the work probes the experimental capacity of sound synthesis at the intersection between microsound, psychoacoustics and computational linguistics.

Brain Dead Ensemble

An Acoustically Networked Feedback Assemblage of Four

Alice Eldridge
alicee@sussex.ac.uk

Chris Kiefer
c.kiefer@sussex.ac.uk

Thor Magnusson
t.magnusson@sussex.ac.uk

Thanos Polymeneas Lontiris
a.polymeneas-lontiris@sussex.ac.uk

Emute Lab, University of Sussex,
Brighton, UK



Figure 1. The Brain Dead ensemble at the EmuteLab 0 performance (Brighton, UK, January 2018).

Abstract

The Brain Dead Ensemble are an acoustically networked feedback quartet/assemblage in which the structural, acoustic feedback pathways within and between “open” instruments create a fundamentally distributed musical agency. The current ensemble consists of two feedback cellos, a feedback bass and a Threnoscope, acoustically coupled to form a multi-instrument, multi-channel system - an expanded music interface.

The feedback cellos and bass are electro-acoustic-digital resonator instruments. Each instrument has pickups under each of its strings and one or more transducers built into the acoustic instrument body, inducing electromagnetically-controlled feedback which can be subject to digital processing. The classical model of a bowed instrument is inverted: the player no longer controls and excites the strings to produce sound, but

negotiates with an ongoing, lively, self-resonating instrument. The threnoscope is a software system created by ixi audio for drones, live coding and microtonal, spatialised composition. All the instruments are networked acoustically: the seven channels of the threnoscope are diffused to a quadraphonic PA plus the integral speakers of the string instruments.

The acoustic result of these feedback processes is characterised by a variety of sonic colours including airy microtonal micro-melodies, serene yet colourful drones, complex spectral gestures, and vast explosions surfacing gradually or unpredictably into screams. Performances are improvised; an emergent, negotiated form of performance which involves the steering and shaping of evolving, distributed, sonic energies rather than the instigation and exchange of discrete musical ideas. No one is in control, although everyone is playing.

Keywords

Hybrid instruments
Postdigital
Feedback
Contemporary chamber music
Drone
Noise
Spectralism
Assemblage
Cello
Double bass

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Music for HASGS

Henrique Portovedo
henriqueportovedo@gmail.com

CITAR - School of the Arts, Portuguese Catholic University, Oporto, Portugal

Abstract

This project is part of the research driven by the saxophonist and sound designer Henrique Portovedo, designated Multidimensionality of Contemporary Performance. Starting as an artistic exploratory project, the conception and development of the HASGS (Hybrid Augmented System of Gestural Symbiosis) for Saxophone became, as well, a research project including a group of composers and engineers. The project has been developed at Portuguese Catholic University, University of California Santa Barbara, ZKM Karlsruhe and McGill University Montreal with insights from researchers as Henrique Portovedo, Paulo Ferreira Lopes, Ricardo Mendes, Curtis Roads, Clarence Barlow, Marcelo Wanderley. The pieces for this performance were composed by Balandino di Donato, Giuseppe Silvi, Nicolas Canot and Tiago Ângelo. This performance will not only provide insights on the development of Augmented Instruments, but at the same time, it will provide data analysis for programmers and composers to prepare pieces for this specific augmented instrument. The pieces presented will be analysed according to new nota-

tional and compositional paradigms whitin HASGS as well as contribute to perceive the evolutionary trajectory of the instrument according to the repertoire.

Augmenting an acoustic instrument places some limitations on the designer's palette of feasible gestures because of the performance gestures and existing mechanical interface, which have been developed over centuries of acoustic practice. A fundamental question when augmenting an instrument is whether it should be playable in the existing way: to what degree, if any, will augmentation modify traditional techniques? The goal, according to our definition of "augmented", is to expand the gestural palette. The use of nonstandard performance gestures can also be exploited for augmentation and is, thus, a form of technique overloading. In our perspective, augmented instruments and systems should preserve, as much as possible, the technique that experienced musicians gain along several years of studying the acoustic instrument. The problem with augmented instruments is that they require, most of times, a new learning process of playing the instrument, some of them with a complex learning curve. Our system is prototyped in a perspective of retaining the quality of the performance practice gained over years of studying and practicing the acoustic instrument.

The phenomenon of interaction between instrumental and electroacoustic sounds became a fundamental point of interest of contemporary music. This project will bring a new augmented instrumental model as well as contribute with a large amount of repertoire making the bridge between acoustic and digital instrumental paradigms. A mission of the 20th Century art was to make the invisible visible; in the 21st century artists may become more concerned with finding ways to allow us to sense the invisible. The ration of the senses may shift, and new perceptual modes may be uncovered. As science develops greater sensitivity to life processes and art acquires new means of realization, artists may work more directly with forces and fields rather than simply representing them and engage more directly in their implementation rather than with their implication.

The Thing Breathed

Joe Watson

j.m.watson@sussex.ac.uk

Sussex University, Brighton, UK

Abstract

The Thing Breathed is a modular synthesis composition for live performance. It explores nested feedback networks instantiated in analogue synthesis, presenting a chaotic complexity that occludes attempts to fully understand the system. It is a ‘black box’ to its performer, who spends performance time searching for rare yet fruitful zones of sonic interest that have been discovered through rehearsal and experiment. As such the nature of the performance is one of risk and commitment, steering rather than commanding, performative rather than pre-programmed.

Keywords

Cybernetics
Self-organisation
Feedback
Analogue interfaces
Performativity

Introduction

The Thing Breathed is a modular synthesis composition for live performance. It was performed five times in 2015 at various locations in and around Brighton, UK. The piece has been dusted off for ICLI2018 because its artistic and scholarly concerns resonate with many of those of the conference, and, since the improvisatory nature of the performance means that each performance is unique, it is hoped that a fresh setting and an audience of critical but like-minded interface enthusiasts will breathe new life into the thing.

1. Artistic and scholarly context

Admittedly, we enter into a strange world, continually evolving but continually conserving all that has gone on, as fractal traces. It is, for all that a very beautiful world, at least insofar as I am able to glimpse it. (Pask 1992, 57)

The Thing Breathed is a performative¹ modular synthesis environment built around complex, nested feedback networks. The genesis of this work coincided with my first blush of excitement researching cybernetics, but also carried over concerns from the previous stage of PhD practice, centered on *musique concrète* and tape-music installation, such as alternatives to ubiquitous digital technologies, embodied cognition, gesture and ergonomics, and physical, resistant materiality. The initial modular synthesis work addressed a concept central to cybernetics, that of self-organising systems,² through attempts to build ‘self-generating’ patches, as they are known in the modular synthesis community: setups that ‘play themselves’, without the need for human intervention, while maintaining sonic interest, such as Douglas Leedy’s *Entropical Paradise*, documented and discussed at length in Strange (1983, 244-247).³ British cybernetician Gordon Pask defined self-organising systems thus: “any system with a behavior

that becomes more ordered (according to some vague criterion or other) is called a ‘self-organizing system’” (Pask 1964, 110). Early in his career he noted that “naturally occurring networks, of interest because they have a self-organizing character, are, for example, a marsh, a colony of micro-organisms, a research team, and a man” (Pask 1959, 232).

After initial experimental work in this area it became clear that a fully self-generating system was unsatisfactory, and a performer *would* be necessary, though intervention could be minimal at times. In practice, wholly autonomous self-generating patches tend not to be self-organising: once they are set in motion they do not exhibit an increase in order. Though ‘order’ (from some perspective or another) may well ebb and flow in such pieces, and this may be a significant part of the piece’s interest, over a sustained period order will tend to even out, and the piece will not demonstrate evolution or adaptation to a changing world. In general, the self-organising aspect of a self-generating patch will be in the initial ‘discovery’ stage, putting the system together, a long, often circuitous process whose goal-directed nature encourages evolution (though the desired state of ‘sustained sonic interest’ is necessarily subjective and goals are under-specified). In *The Thing Breathed* the performer is necessary to move between the zones of sonic interest, zones that are often hard to come across, but that burnt themselves into my musical memory as I conversed with the system. The search process – effected through twisting knobs, moving faders and listening – became the piece: how to move from one interesting area to another and form a satisfying structure, all the while subject to the contingency and scrutiny of a live audience.

Even though I put this system together and perform with it, patching cables and turning knobs,⁴ the locus of the multi-way interaction is a black box⁵ to me, and I cannot directly impose my

¹ See Karen Barad on performativity: “Unlike representationalism, which positions us above or outside the world we allegedly merely reflect on, a performative account insists on understanding thinking, observing, and theorizing as practices of engagement with, and as part of, the world in which we have our being” (Barad 2007, 133).

² “Self-organizing systems was perhaps the most visionary subfield of cybernetics research” (Cariani 2017, 121).

³ Strange calls such systems “self-playing dream ma-

chine[s]” (Strange 1983, 244).

⁴ ‘Wiggling’, as the denizens of Muff Wiggler, the pre-eminent modular synthesis forum, would say.

⁵ “The black box is a way of saying we cannot know what goes on inside any system, we have only our descriptions of behaviours we set up and observe: and when we find regularities, it is in the behaviours of the black box vis-à-vis our observation and interpretation as and when we interact with it” (Glanville, 2001b, 654).

will on the system; I cannot directly ‘write’ the result I desire. I have to work with it, coaxing fruitful zones of exploration. It means accepting the limitations of the equipment; going with the grain of the materials at hand rather than trying to subject the material medium to the will, the score, the plan, the program. In this way, the interaction feels more like a conversation, and we must learn each other’s tolerances and pre-dilections in order to reach some form of consensus. Of course, being the one who will be the final arbiter of consensus, I have an important element of control in the relationship, but if the questions asked are about the machine’s fitness for autonomous operation, then we have a chance, through sound, to explore control itself, and the nature of the devolution of control in human-machine interaction. These are notably cybernetic concerns, and the point is that they can only be addressed through a performative unfolding of the system, since the complex nature of the feedback network precludes analytical penetration, resists being separated out into constituent parts, and makes pre-programming an intricate, unpredictable balance of memory and contingency. In ongoing interaction one must allow the machine its agency, one must let it be as it becomes.

The Thing Breathed addresses areas which are currently, for the most part, addressed through conventional computation: A-life concerns like emergence, adaptation, and of course, liveliness itself; cybernetic concerns like boundaries of systems, signal flow, feedback, and of course, self-organisation. It is an interest in performative emergence through play with the world, and a desire for fluidity of boundaries in musical systems through complex feedback interaction, that leads to the use of analogue modular synthesis. Truly complex and fascinating zones of sounding behaviour can be reached through the interconnection of relatively few, simple modular elements, and in my interaction with the system I’m twisting knobs, patching cables, and often just listening. I find this tactile/audile ergonomics preferable to the interface of the computer, where listening is so often accompanied by look-

ing. I like that my modular systems don’t have a screen. Also, and crucially for me, as a musician creating performance systems, there is no lag as processing happens, because all processing is concurrent. There is no sequential ordering of constituent parts or events, there are no interrupt routines. There is a flow and a coming into being. Of course, the A/D⁶ - processing - D/A lag is a byproduct of one of digital audio’s huge strengths - if you can make recorded sound (almost) immediately available for manipulation, then you have a very powerful system for having a conversation with a processed historical version of your own sound making, and much excellent electro-acoustic music has been made in this vein. But if you are more interested in the bringing into being of sound, and a direct, concurrent interaction with that becoming, then this lag can present some serious problems. *The Thing Breathed* is a performative response to such issues.

6 Analogue to digital conversion.

2.Techical details and documentation

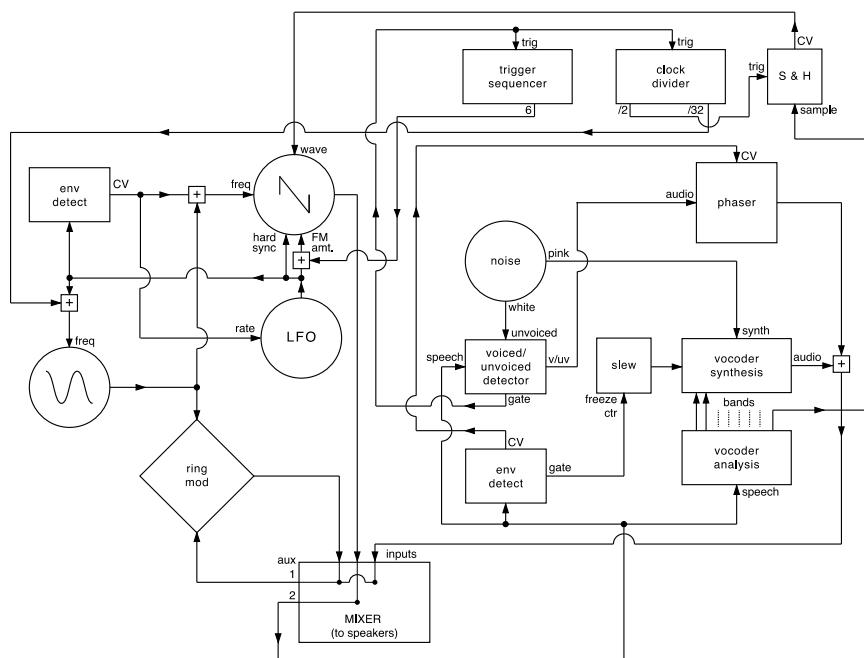


Figure 1. Schematic diagram of the modular system denoting functional blocks and signal flow

Documentation from two of the performances from 2015 can be found here:

Video: <https://www.youtube.com/watch?v=H8LlbtgdB5M>

Audio: <https://soundcloud.com/user-551299121/the-thing-breathed-church-of-modular>

Review and interview with the composer after the first performance: <http://aestheticsynthetic.com/interviews/joewatson/electronic-musicperformance/>

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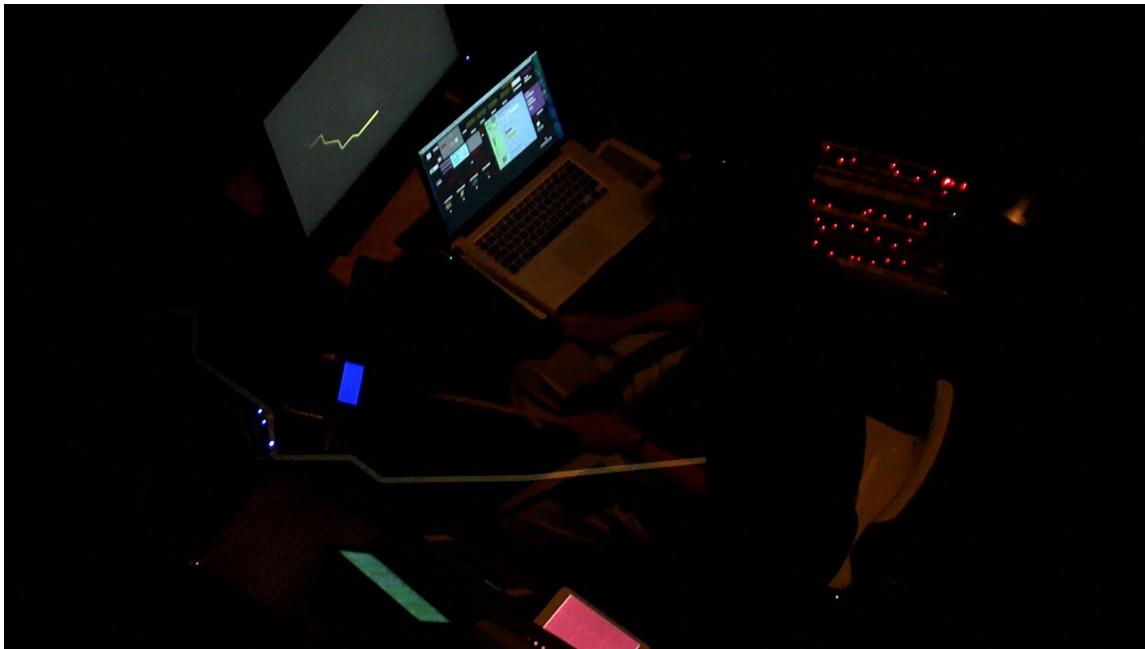
PIGS **Percussive Image Gestural System**

Amy Alexander

Curt Miller

Abstract

PIGS (Percussive Image Gestural System) is an instrument created by Amy Alexander for improvised visual performance with musicians. It focuses on layered visuals that are not bound to traditions of rectangular frames and “movie” structures — and on developing a performable instrument suited to improvisation. PIGS uses live gestural data as improvisational elements to create visual forms. Gestures can be used independently, or repeated with algorithmic variation through the use of drum interfaces to create visually rhythmic structures. To facilitate improvisation of video as a rhythmic “instrument,” PIGS incorporates a variety of percussive inter-

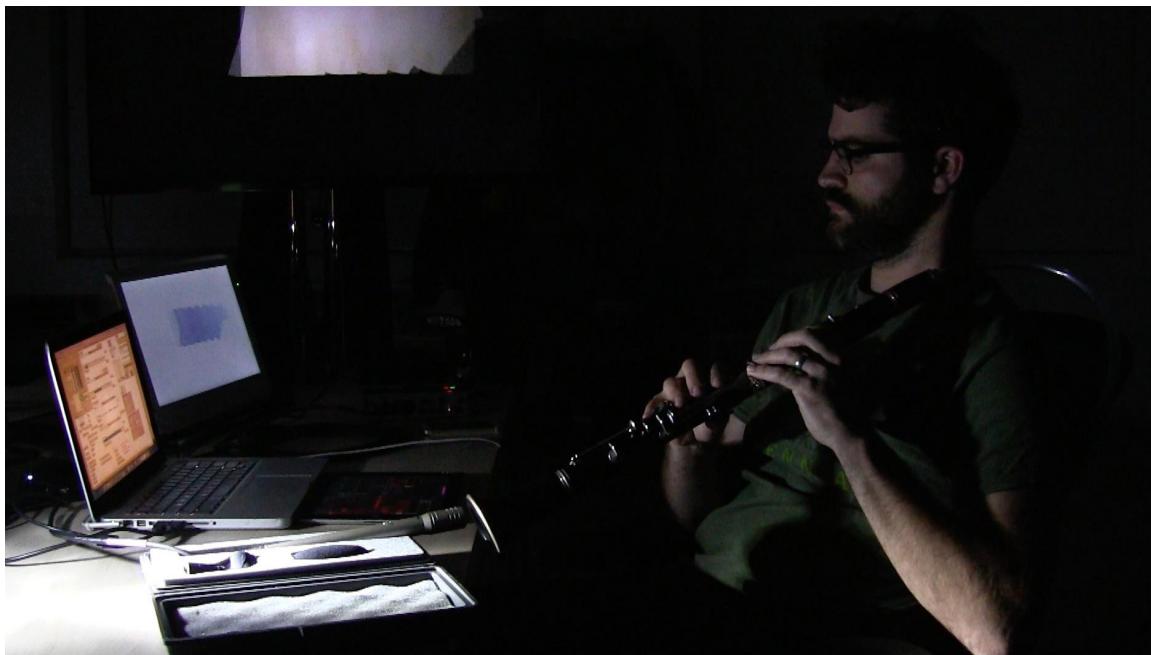


faces including MIDI drums, iPads, and Leap Motion. Currently Alexander collaborates with musician and sound artist Curt Miller, who has created a software instrument in parallel with PIGS in which he combines live clarinet with real-time processing of recorded source material.

PIGS aims to enable a performer to improvise visuals as they might on a musical instrument: in this case, to create fluid forms rather than rectangular, movie-like images, which seem to us anathema to perceptions of liveness for both performer and audience. So PIGS approach differs from that of many visual instruments in that it uses video less like an image and more like paint being applied performatively. This comparison is loose however, as the performative approach most resembles a set of guiros and drums: the video “paint” is scraped and struck

in various overlaid rhythms while the drums trigger drawings of varying durations. This arrangement of gestural and percussive interfaces facilitates performance of the layered, rhythmic structures.

Early and mid-twentieth-century direct-on-film animators like Len Lye, Evelyn Lambart and Norman McLaren drew directly on strips of film to create moving abstract forms. Other abstract filmmakers of that era, including Oskar Fischinger and Mary Ellen Bute, developed strategies for using repetition of forms and movement to create temporal and spatial visual rhythms on film. PIGS borrows from both of these traditions, applying them to live performance. But PIGS uses the time-based gesture itself, rather than the static form, as its source of repetition and visual rhythm.



Although using relatively traditional percussive interfaces promotes immediacy and improvisation, the process by which the PIGS instrument produces the resulting visuals is algorithmic. Each gestural stroke is displayed live but also functions as something of a sample, which can be replayed with modifications until replaced with another. Each gesture is composed of an array of points: each time these points are replayed they can be used to display new content, to combine with other data to form new patterns, (or for potentially any other arbitrary purpose.) Thus, repetitive structures are facilitated, as new material is continually produced via a process analogous to both “theme and variations” forms in music and looping structures in software design.

Miller’s software patch treats the playback of sound algorithmically as well, specifying parameters for the software to trace through sound files in defined textures, with undefined content allowing for both improvisational control and algorithmic variation. In addition to this multi-textured software layer, Miller improvises on clarinet and a feedback system using clarinet and talk box introducing the instrumental sound into the algorithmic layers and allowing for the electronic sound to feed back into the clarinet via the talk box. The resulting system has a flexibility that is geared toward the challenges of reciprocal improvisation in a mixed modal (audio and visual) collaborative ensemble.

Since PIGS is designed to be performed with arbitrary video material, Alexander has created a variety of

“compositions” for PIGS, often focusing on selections of various social media subcultures of self-made YouTube performers. She has recently developed an “algorithmic curator” option for PIGS, in which newly uploaded YouTube videos focusing on designated themes can be automatically “curated” shortly before the performance, using computer vision and other algorithms to find videos that meet specific characteristics. The algo-curator currently seeks videos that appear to be non-commercial personal narratives, which are normally difficult to find within YouTube. The performers then improvise using a time-based collage of personal global video of the hour -- a contemplation on whether the potential to realize Stan VanDerBeek’s 1966 utopian vision of a networked, global video “Culture: Intercom”¹ might lie within the detritus of contemporary social media.

¹ “CULTURE: Intercom and Expanded Cinema - Stan VanDerBeek.” http://www.stanvanderbeek.com/_PDF/CultureIntercom1,2,3_PDF_LORES.pdf. Accessed 20 Apr. 2018.

Noise Peddler

A Live Exploration of the Pedalboard as Performance Interface

Lee Westwood

L.D.Westwood@sussex.ac.uk

Danny Bright

D.G.P.W.Bright@sussex.ac.uk

University of Sussex, UK

Abstract

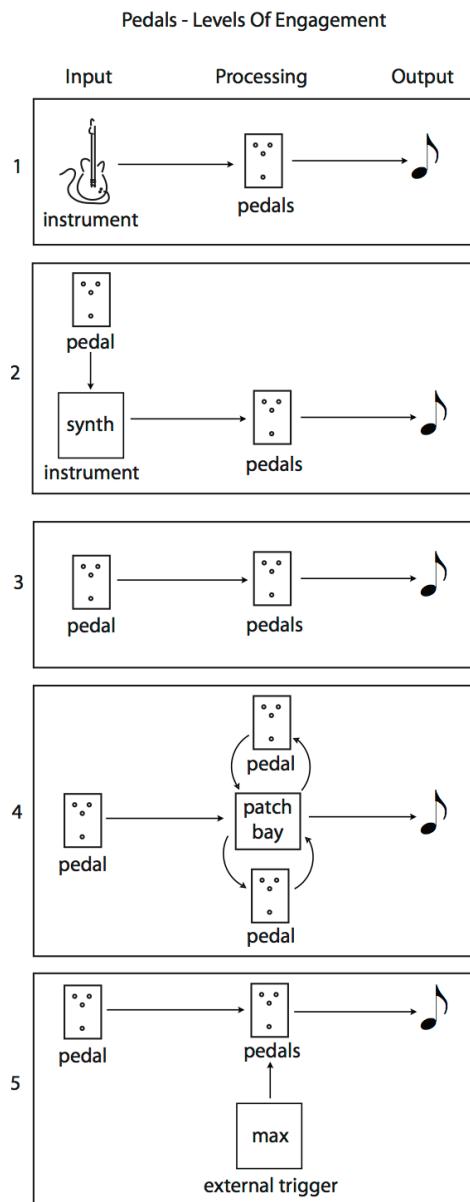
Noise Peddler is a part-composed, part-improvised performance for two people, two pedalboards, and four amplifiers involving the re-appropriation of guitar effects pedals to create independent musical interfaces capable of generating and manipulating their own sounds. The result is a visually symmetrical live performance that utilises dual stand-alone pedalboards, generative MIDI/CV control, and video projection, to explore the area between composition and free improvisation. The hybrid performance system employs a selection of cutting edge modern pedal technologies, alongside well-established analog circuits, and explores their potential as an independent interface, away from the guiding force of a traditional acoustic instrument.

The project's interfaces are constructed from a handpicked hybrid system of smaller, stand-alone modules originally intended for use with instrumental input signals, rather than a preconceived, integrated network. This hybrid system is expanded further through the addition of CV and MIDI parameter control, some of which is generative, via a custom Max patch. Each pedalboard generates two output

streams, which are directed into four guitar amplifiers, allowing the performers to create varied textures across a spectrum of simple-complex spatialised soundworlds.

The past decade has found expanding functionality blurring the boundary between pedals and modular synthesis, with CV in/out, MIDI control, effects/feedback loops, and programmable automation of parameters becoming commonplace amongst the more forward-thinking exponents. The proposed performance builds on a number of areas of current and historical practice – especially the intersection between popular and experimental electric guitar performance, and contemporary sound art/experimental performance. It seeks to explore what role the pedal, and pedalboard, plays within these areas of practice, and how it can be considered as a performance interface in its own right. The work draws influence from early proponents such as Jimi Hendrix, who developed and deployed what could be considered a performer/instrument/pedal/amplifier based cybernetic feedback system (van Veen, 2016: 76) to create soundworlds and textures beyond the capability of the instrument alone. In many cases these sonic textures were entirely dependent on the combination of the individual pedal circuits into a chain (for example, ‘Machine Gun’ from Band of Gypsies (Hendrix, 1970) at

3:59 and ‘Star Spangled Banner’ at Woodstock (Hendrix, 1970)). A more contemporary example is composer/performer Zeno Baldi (Baldi, 2017), whose work often utilises guitar pedals to create intricate sonic textures in both experimental performance settings and contemporary classical composition.



Although the pedalboard, and the use of guitar pedals, in experimental music is not uncommon, Noise Peddler seeks to investigate exactly what role the pedal, and pedalboard, can take by exploring the levels and modes of engagement that we can have with them as performers/composers (see figure 1). As such, it moves away from the first and most typical mode – where an input signal is modified by a chain of pedals - and instead will present a series of segments each exploring no-input pedalboard systems as performance interfaces. In doing so, it builds on previous work by the performers/composers that has involved pedal-dependent sonic materials and live manipulation - Swells, Shrieks & Judders (Westwood, 2017) - and part-composed, part-improvised compositions incorporating generative MIDI controlled analog pedals – Fracterruptions (Bright, 2017). This practice-based research engages with guitar pedals as the primary interface to performance, and seeks to explore the modern guitar pedalboard as a critical bridge between commercial

guitar technology, often sonically conservative guitar culture, and experimental performance, sound art, and contemporary electro-acoustic composition. In turn, it informs the development by the performers of a critical and contextual framework for considering the various roles guitar technology, and in particular the guitar pedal, plays in enabling sonic experimentation, and alternative modes of performance interface.

Keywords

Effects Pedals
Repurposing
Hybrid Systems
Performance
Composition
Improvisation
Noise
Generative Control
Electronics
Performance Systems
Electronic Performance
Control Voltage
MIDI
Guitar
Duo

Baldi, Zeno. 2017. *Solo set (Manchester)*, video available at: <https://vimeo.com/243905623> (Accessed 25/2/2018 20:26)

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A Method for Gestural Control of Augmented Harp Performance

Alexandra Tibbitts¹

alexandra.tibbitts@umontreal.ca

John Sullivan²

john.sullivan2@mail.mcgill.ca

Ólafur Bogason²

olafur.bogason@mail.mcgill.ca

Brice Gatinet²

brice.gatinet@mail.mcgill.ca

¹ University of Montréal, Montréal, Canada

² McGill University, Montréal, Canada

Abstract

Here we present an interdisciplinary collaboration and performance, featuring a gestural control system designed to augment harp performance. From a performers perspective, the developed interface system and prototype presented opportunities for real-time control and manipulation of the traditional instrument. Collaborators exchanged ideas and commentary, as well as problem-solved, in real-time. This was advantageous for direct and efficient regulation and implementation of the hardware and software into the artistic phase of this project and resulting composition. For the performer, the device needed to be lightweight, ergonomic, and user-friendly. In this performance, the device uses amplified harp, as well as voice of the player and electric tape, as sound-sources for computer-based audio effects and processing.

Keywords

Harp

Gesture controller

Performance

Electro-acoustic harp

Audio effects

Processing

Introduction

Performers play an essential role in the attractive and ergonomic design of digital musical interfaces (DMI). The genesis of this collaboration aimed to understand harpist's movements, using a motion-capture system provided by the Centre of Interdisciplinary Research in Music, Media and Technology (CIRMMT), as preliminary research for the design of an interface for gestural control. In this collaboration, the first author is the harpist and research assistant, the second and third authors are the main researcher and interface designers, and the fourth author is the composer. For the performer, it was necessary to design a wearable device that would not inhibit natural playing mobility and technique for performance. Another aim was to develop an interface system that could be accessible to musicians and composers with various backgrounds in an electro-acoustic setup.

The result was a lightweight and wireless controller with an interface system built in Max/MSP. Our system is adaptable for use with any instrument or movement based art form, affording opportunities for this system to be explored and implemented in systems beyond that presented here. The following presents a description of the composition and summarizes the artistic process, from an artist's perspective.

1. Description

Composition

...prends-moi, chaos, dans tes bras... is titled after a translated collection of Arabic poems written by Syrian poet, Adonis. At its core, the piece serves as a reflection on war-torn Syria and mounting tension affecting the Middle East and Europe, felt in recent years by the increasing numbers of refugee and asylum seekers. Two thematic elements are rooted in this composition: a narration of a Sumerian creation poem and a transcription of *Hurrian Hymn no.6* [Figure. 1] and a Mesopotamian song known as the first

written piece of music (ca. 1400 B.C.E.), discovered in the 1950's in the Ugarit, Syria.

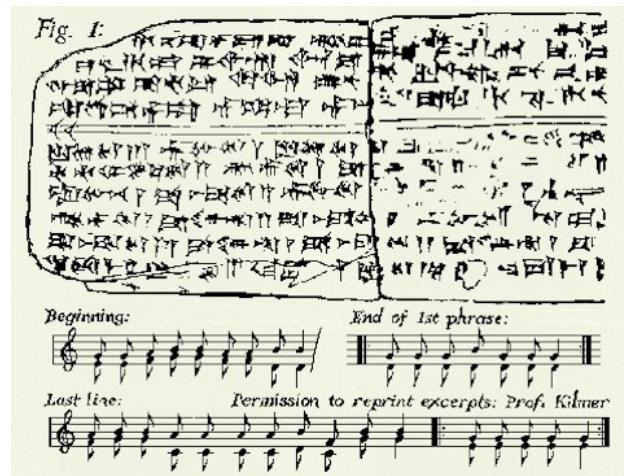


Figure 1. Transcription of Hurrian Hymn no.6.



Figure 2. Performance with harp and motion-controlled electronics.

The authors worked closely together to develop a piece that would artistically demonstrate the potential of augmenting harp performance. With over a decades experience in harp studies, it was of personal interest to the first author that the piece would focus on the marriage between musical gestures and the processing components of the device.

2. Setup

The work calls for amplified harp, gesture controller, voice microphone, foot-switch, and four speakers [Figure. 2]. Audio from the harp and voice are processed through several modules from GRM Tools. Processing parameters are mapped to the X, Y, and Z axes of the controller, allowing real-time manipulation of instrumental and ancillary gestures (Cadoz and Wanderley 2000). Parameters and effects are interchangeable based on a bank of presets configured in a Max patch, navigated by a MIDI pedal foot switch. MARG sensors (Bachman, et al. 2003) were integrated in the main hardware design for the device.

For the preliminary version of this prototype, collaborators took a simplified approach to mapping audio-processing parameters. Effects are applied to a desired axis (e.g. *pitch* controlling volume and *roll* controlling delay). With this approach, the performer could practice and master her technique of blending multiple effects during tight rehearsal sessions.

Rehearsals revealed efficient methods for utilizing the controller, with the left wrist and arm having the advantage of a large dynamic range of movement in comparison to the right. With this observation, parameters for the controller were focused on left arm mobility.

Future work would benefit in exploring gesture recognition and implementing machine learning into interface design. With this addition, a personalized gesture vocabulary could be developed and overtime incorporated in future use of this gesture controller.

Media link: Debut performance of “...prends-moi, chaos, dans tes bras...” April 2017, Montréal, Canada. <https://vimeo.com/291366942>

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CityStrings

Adriana Sá¹

adrianasa@clix.pt

John Klíma²

klima.de.sa@gmail.com

¹ University of Coimbra

² Noroff University College



Abstract

CityStrings is performed with an audio-visual instrument and a long wire stretched in space. The audio-visual instrument combines a custom zither (multi-string instrument) and AG#3, a 3D software that processes sound and image based on pitch analysis from the zither input. The wire - “magnetic wire” - is amplified via a transducer constructed from a coil of wire wound round a magnetic shaft. Both instruments allow for certain unpredictable sonic events, which conveys an understanding of expression. The role of the image is quite different: projected over the performers, it works as a reactive stage scene without distracting attention from the music.

Vibez

Joanne Armitage¹
j.l.armitage@leeds.ac.uk

Shelly Knotts²
knotts.shelly@gmail.com

¹ University of Leeds

² Monash University



Abstract

Vibez is a telehaptic performance by the live coding duo ALGOBABEZ. The work brings together strands of research in biometrics, haptics, telematic performance and algorithmic systems. The performers using sensors to track and send their biometric information (HR, HRV and GSR) to their geographically distant improvisation partner. The other performer receives this information as haptic messages via an armband and uses this to feel a sense of physical closeness with and empathy for their collaborator. The performers can choose to subvert the process by moving an ‘honesty’ slider up or down, randomising the data to various levels.

Yaxu Feedforward

Alex McLean
alex@slab.org

Deutsches Museum, Munich, Germany

Abstract

Feedforward is a text editor designed for the TidalCycles¹ live coding environment. The feedforward project began in February 2018 and is under active development. It forms the basis for experiments in pushing the limits of text-based live coding interfaces, including through in-line visual feedback, keyboard shortcuts into the transformation of pattern, and the live manipulation of edit history, both from past and present performances. This is a continuation of work begun with my first live coding interface ‘feedback.pl’ from 2003 until around 2009, when I first began work on TidalCycles. Feedback.pl supported live self-modification of code, in order to provide in-line visual feedback to the user. Feedforward is also heavily inspired by work of others in this area, including on the SuperCollider History Class by Alberto Campo et al,² of Charlie Roberts et. al on the Gibber family of live coding environments,³ and the work by Thor Magnusson on Ixi Lang.⁴ It also intends to draw from experiments in intelligence augmentation, most famously Douglas Engelbart in his 1968 ‘Mother of all demos’ and more recently the Dynamicland project.

¹ For information on TidalCycles please see <http://tidalcycles.org/>

² For information on the History class, see http://www.wertlos.org/~rohrhuber/articles/Purloined_Letters_and_Distributed_Persons.pdf

³ Gibber may be found at <http://gibber.cc/>

⁴ For information on Ixilang, see Magnusson, Thor (2011) ixilang: a SuperCollider parasite for live coding. In: International Computer Music Conference, 31 July – 5 August 2011, University of Huddersfield, UK.

The performance itself will consist of broken techno, where from-scratch improvisations are built, deconstructed and then looped and layered up. This will use the abilities of the Feedforward editor, which records timestamped keypresses, allowing past history to be brought back to life and manipulated live.

One wider aim of this piece is to challenge ‘from-scratch’ improvised live coding, and in particular its stance on anti-commodification. Inspired by the writing of Mark Fisher on red plenty, rather than throwing code away at the end of a performance in order to reject repeatability, the opposite approach is taken, of recording as much as possible, and immediately and automatically sharing it.

DOCTORAL SYMPOSIUM

Performative Sound Design

A Bio-signal Control Metaphor for Performative Sound Design

Luis Aly
up200203376@fe.up.pt

Rui Penha
gba@inesctec.pt

Gilberto Bernardes¹
bernardes7@gmail.com

INESC TEC, Porto, Portugal
University of Porto, Faculty of Engineering,
Portugal

¹ University of Aveiro, Portugal

Abstract

Sound design for performance art have long explored creative strategies based on improvisation which demands great invention and flexibility from the sound designer, which barely complies with the typical fixed media practices employed in the field. To organically bind sonic elements with the performance structure, we strive to design a sound-instrument capable of interfacing the stage performer's bio-signal with specific (sonic) constraints defined beforehand. By mediating bio-signal we intend to create control metaphors for a sound-instrument, which aims at expressive, dynamic, and interactive symbiosis between performative action and sound design.

Keywords

Performance studies
Sound design
Bio-signal
Human-computer Interaction

1. Objectives of research

Towards the definition and development of a collaborative framework for biofeedback sound design practice, our research agenda includes four main objectives: i) the definition of a computational interactive instrument capable of retrieving and sequencing sounds from large annotated audio collections based on the performer's psychophysiological measures; ii) a taxonomy of psychophysiological measures adapted to performative practices; iii) a mapping scheme between human psychophysiological activity and sound attributes; and iv) formal meta-composition method to explore the definition of musical sequences in real-time by recombining (structurally segmented and annotated) audio segments.

2. Related work

The multidisciplinary nature of this projects extends across four following domains of knowledge, for which we provide a short list of state-of-the-art references:

- *Cognitive science* studies that can support my research hypothesis on using bio-signal as a strategy to drive the generation of interactive artistic content (Damásio, 2000; Gallesse, Keysers, & Rizzolatti, 2004; Ortiz-Perez, Coghlan, Jaimovich, & Knapp, 2011).
- Studies on a *user centred taxonomy of psychophysiological measures* for use in interactive art in general (Bongers, 2002; Kivikangas et al., 2011; Nacke, Kalyn, Lough, & Mandryk, 2011; Nogueira, Torres, Rodrigues, Oliveira, & Nacke, 2016; Yannakakis, Martinez, & Garbarino, 2016).
- *Bio-signal driven musical/sound artistic practises* starting on 1960's (Donnarumma, 2016; Knapp & Cook, 2005; Lusted & Knapp, 1996; Ortiz, Grierson, & Tanaka, 2015; Rosenboom, 1977; Tanaka, 2009; Tome-Marques & Pennycook, 2014).
- Studies on the design of *digital musical instruments* and mapping strategies to relate action/ sound (Bernardes, Guedes, & Penny-

cook, 2012; Birnbaum, Fiebrink, Malloch, & Wanderley, 2005; Hunt, Wanderley, & Kirk, 2000; Knapp & Cook, 2005; Miranda & Wanderley, 2006; Tanaka, 2000, 2010).

3. Research methodology, contribution to the field and progress towards goals

Following the contextually-sensitive design principles and theories in (Wang & Hannafin, 2005), we will pursue a design-based research (DBR) methodology as a systematic, but flexible, collaborative and iterative practice with theatre and dance practitioners to develop and implement the core components of the research. Moreover, we will also rely on an art-based research (ABR) methodology that promotes the use of artistic practises as a primary strategy to understand the experience resulting from both the researcher and the artistic community involved in the study (McNiff, 2008). In greater detail, our methodological plan can be break down into the five following tasks:

1. To review sound design practices for performing arts, namely those with an open narratives;
2. To undertake an exhaustive assessment of existing biofeedback sensors, namely those processed by the OpenBCI brain-computer interface;
3. To design a sound-instrument which draws on meta-composition models to intelligently map multidimensional biofeedback data to sound narratives which organically bind with a live performance;
4. To perform a subjective evaluation of the meta-composition models and their applications in performing arts we are planning to conduct: i) questionnaires and direct observation in professional performing art production ii) direct observations and questionnaires to gauge the efficacy and efficiency of the proposed instrument.
5. To disseminate the results of our research by i) reporting the main contributions to the scientific and artistic community; ii) to plan

a series of live performances and public presentations where the instrument will be explored under constrained test situations; and, finally, iii) to fully develop the sound-instrument and make it available to sound designers, allowing it to integrate real-world performative scenarios outside controlled lab conditions.

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Supporting Live Craft Process in Digital Musical Instrument Design

Jack Armitage

j.d.k.armitage@qmul.ac.uk

Andrew McPherson

(supervisor)

a.mcpherson@qmul.ac.uk

Augmented Instruments Laboratory, Centre
for Digital Music, Queen Mary University of
London, London, United Kingdom

Abstract

Despite digital lutherie's goal of enabling liveness in performance, digital lutherie as a process often lacks liveness. The tools of digital lutherie, adapted from domains where liveness was neither feasible or important, can make craft process feel dull, blind and isolated. Understanding and supporting live craft process in digital lutherie is important for advancing and disseminating the art, and for improving digital luthiers' control over the liveness of their instruments. This requires a shift in focus from declarative and explicit knowledge of instruments, to the study of liveness, craft process and tacit knowledge in digital lutherie. This research aims to provide a foundation for this shift through integration of traditional and digital lutherie, and detailed comparison of digital luthier behaviour in different live crafting environments.

Keywords

Digital lutherie

Musical instruments

Interface design

Craft process

1.Purpose of the research and its importance to the field

To support the creation of digital musical instruments, academic communities have over the last six decades repurposed knowledge and methods from science, technology, engineering, mathematics and design. Declarative knowledge such as criteria and principles have been proposed to facilitate recognition of “what to look for” in digital instruments, and how to evaluate them. The procedural or imperative knowledge of how to actually make a great instrument is left to the designer to discover through the acquisition of tacit knowledge. Much like traditional lutherie, digital lutherie (Jordà 2005) remains an art form with craft process at its heart. Unlike traditional luthiers who have a richly embodied relationship with their craft, digital luthiers are often restricted to disembodied processes by digital media.

The purpose of this research is to situate traditional and digital lutherie together as craft processes with important similarities and differences, design and evaluate tools and methods to support live craft process in digital lutherie, and investigate ways digital luthiers can interpret and disseminate their craft process. This research is important to the field because digital lutherie can improve itself greatly through the study of and integration with traditional forms of lutherie, digital instrument making is an art form in want of specialised artistic tools and language for liveness, and there is no well understood procedure or infrastructure for disseminating digital lutherie craft process.

2.Background, related work and proposed approach

Examining digital lutherie as an art form is based on the foundation laid by Jordà (2005) and the insights of Buxton (1997) and Cook (2001). This is supported by philosophical investigations by Magnusson (2009), which are in turn supported by frameworks for tacit knowledge (Collins 2010) and embodiment (Clark 2015). Craft's

historical context is provided by Dormer (1997), its principles by Kettley (2012) and its contemporary methods by Beuchley & Perner-Wilson (2012). From these works, fundamental tensions in digital lutherie are extracted; top-down vs. bottom-up, declarative vs. imperative, explicit vs. tacit, symbolic vs. embodied, and logical vs. analogical. These tensions are examined in the context of digital lutherie crafting activities which are interpreted using design move analysis and linkography (Goldschmidt 2014).

3.Expected contributions

This work is expected to contribute foundations for a perspective on lutherie which integrates digital and traditional genres, insights into what kinds of interventions support live craft process in digital lutherie, and informed recommendations for the representation and dissemination of digital lutherie craft process in academic and popular culture.

4.Progress towards goals

Three studies have been completed thus far, with a study comparing two of those three currently in progress, and two subsequent studies anticipated (six in total). In Study 0 (published), interviews with violin luthiers about their craft process were thematically analysed and implications for digital lutherie frameworks, tools, methods and community infrastructure were discussed. In Study 1 (submitted, under review), digital luthiers were observed and analysed when given an ‘unfinished instrument’ to work with for one hour in groups using crafting materials. In Study 2 (completed, unpublished), digital luthiers were given the task from Study 1, using software instead of crafting materials. In Study 3 (in progress), Study 1 and Study 2 are being compared to derive design goals for digital lutherie crafting tools. In Study 4 (early planning stage), novel digital lutherie crafting tools focusing on facilitating liveness and bottom-up process will be designed and evaluated. Study 5 (anticipated) will iterate on Study 4.

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DMIs Design Fostering Authorship of Composers and Creativity of Performers

Raul Masu
raul.masu@m-iti.org

Madeira-ITI, Funchal, Portugal;
and FCT / UNL, Lisbon, Portugal

Abstract

My project aims to study the adoption of scores in mixed performances with DMIs and traditional instruments fostering performers' creativity while keeping the composer authorship over the piece. I intend to develop my research in the context of professional music performances and pedagogic scenarios. In this paper I introduce related works on DMI, touching the concepts of the composed instrument and composer-performer. I give an overview of existing literature that investigates relations between score and music technology, and I describe in detail the methods I intend to apply to achieve my goal. In general, my project relies on User-Centered design approach. In my research two artifacts – scores and DMIs – and three actors – composers, performer, teachers – are involved. All the actors and the artifacts are described. The conclusions of the paper present some work already done.

Keywords

Digital Musical Instruments
Novel Interfaces for Musical Expression
Human-Computer Interaction
User-Centred Design
Score
Music Performance

Introduction: Research Objective

My project aims to study the adoption of scores in interactive scenarios with Digital Musical Instruments (DMIs). My project particularly focuses on mixed performances with DMIs and traditional instruments. More in detail, the objective of such study is to provide performers with some degree of freedom, facilitating their expression of creativity when performing with or along DMIs, while maintaining the composer's authorship of the music. A secondary objective of the study is improving the development of creativity for students in pedagogic scenarios: in this case, music students will be the performers. Scores are fundamental in western musical practice. For this reason, an academic investigation over the adoption of scores can play an important role to facilitate mixed initiatives with classic instruments and DMIs.

1. Research Context and Related Works

In the last decades, music technology literature has explored the expressive potential of human-computer interactive performances. Since the birth of the NIME conference, the computer-music academic community started borrowing tools from HCI to evaluate new interactive music technology (Wanderley and Orio 2002): interactivity gradually became a central topic in computer music academic investigations. The concept of composed instrument was theorized for those tools whose design embeds the aesthetic of the music itself (Schnell and Battier 2002). This practice often overlapped the roles of composers, performers, and designers. For this reason, there is no need of scores, and scores are not widely studied from and HCI perspective. Few examples exists. For instance, score following algorithms are used in music performances where the electronic component follows the timing of human performers (Orio, Lemouton, and Schwarz 2003). With score following, the musicians have freedom in phrasing and timing, but the approaches to scores remain quite standard. Another approach is presented

by Magnusson, who considers live coding as a new interactive form of musical notation (Magnusson 2015), but does not really focuses on mixed performances with acoustic instruments. Recently, Gurevich presented the idea of using existing scores to inspire the design and the creation of new DMIs (Gurevich 2017).

2. Work Plan and Methodology

My research will rely on User-Centered Design approach (Abras, Maloney-Krichmar, and Preece 2004) organized in three main steps: 1) collection of requirements, 2) design and development, and 3) evaluation. The project involves three groups of users as actors in the design process: performers; composers; teachers. Performers are directly involved in the interaction with and alongside DMIs. This category include DMIs performers and classical instrumentalists, both professionals and students. Composers produce scores. Teachers have a crucial role even if they are not directly involved in the interaction. The first step of the design process will rely mainly on qualitative methods, quantitative questionnaires will also be used. The design/development phase will consist of a recursive loop of increasing fidelity prototyping. To guarantee the ecological validity of the evaluation, real concerts and classes will be adopted. In this phase observations and interviews will be conducted. The main outcomes of the design process will be a novel DMI and a framework concerning the adoption of scores with DMIs. The framework will be a theoretical work that provides composers with heuristics to infrastructure their compositional work within the interactive context, keeping into account the creativity of the performers.

3. Achieved Results

I started to work on the topic of my research using an autobiographical design approach, to investigate design issue related to the adoption of scores. In this phase, I am playing both the role of the designer/researcher and that of the composer. I developed Penguin, a system for

live scoring; I involved a performer in the design process (Masu, and Correia 2018). In parallel to the work with Penguin, I started to approach scores as a design object investigating the affordances and the constraints of such objects. Primary results have been achieved analyzing a composition for Cello and Chimney, a novel DMI (Masu, Correia, and Morreale 2018).

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Playful readings and deeper meanings

Terhi Marttila
terhi.marttila@gmail.com

University of Porto, Portugal

Abstract

I explore the specific case of interactive artworks which are predominantly based on the use of speech, text or language (ergodic literature) and which utilise this materiality to deliver a profound or somewhat serious message about a specific topic. Through case studies, a technology survey and a practical project, I look at both the history and current and future state of language as material for play in interactive arts.

Keywords

Speech
Text
Language
Interactive arts
Procedural rhetoric
Play

1.Purpose of the research and its importance to the field

There is nothing new in the creative use of speech, text and language in (interactive) arts, yet computers are becoming ever better at processing this type of material. This implies an imminent expansion in the possibilities of the materiality of language for artistic use. Language is a powerful medium with extensive capabilities for rhetoric. A digital, ergodic literature allows for interaction and play, and play can be quite engaging. The purpose of this research is to understand how artists can strike a balance between the construction of rhetoric and the creation of a space for play. It is an important area to study because technology trends will make language more accessible as a material.

2.Brief survey of background and related work

Ergodic literature implies that “*nontrivial effort is required to allow the reader to traverse the text*” (Aarseth 1997, 1). By contrast, nonergodic literature would require only “*eye movement and the periodic or arbitrary turning of pages*” (ibid.). Or in the words of Katherine Hayles: “*less an object than an event, the digital text emerges as a dance between artificial and human intelligences, machine and natural languages, as these evolve together through time*” (Hayles 2006, 187).

Such an interactive text or ergodic literature could be understood as procedural media, media in which meaning and representations are created through processes. Furthermore, “*the logics that drive our [systems of procedural representation] make claims about who we are, how our world functions and what we want it to become*” (Bogost 2007, 340). Although the concept is native to videogames, Bogost notes that “*procedural rhetoric [is] a domain much broader than that of videogames, encompassing any medium - computational or not - that accomplishes its inscription via processes*.” (Bogost 2007, 46).

But does media really “accomplish its inscription via processes” as Bogost claims it does? Sicart draws our attention to the fact that the notion of procedural rhetoric as a core design principle in the game design process implies that the players’ behaviour in the game can be predicted or even contained by the rules of the game (Sicart 2011). Furthermore, such a proceduralist perspective would assume that “*the meaning of the game, and of play, evolves from the way the game has been created and not how it is played*” (ibid.). However, for Sicart “*game systems can only partially contain meaning, because meaning is created through an activity that is contextual, appropriative, creative, disruptive and deeply personal*” (Sicart 2011, 87).

While meaning is created through appropriative play, the “*designers role is to open the gates for play in an object and with a purpose*” (Sicart 2014, 90). Thus the designer is needed for creating spaces for play, yet the design needs to allow space for this play occur. Indeed, this discrepancy was already pointed out by Aarseth in 1997: “*I feel it necessary to focus on broad, highly visible issues, such as the conflicts between the desires of users and the ambitions of creators.*” (Aarseth 1997, 183).

It is at this juicy divide that I position my task at hand. I want to build a deeper understanding of this interplay between design of rhetoric and play, specifically within the context of ergodic literature which deals with distinct issues, topics or ideologies.

3.Description of the proposed approach

I intend to answer my research question through a two-phase approach. In the first phase, I discuss relevant concepts and theories related to ergodic literature, conduct case studies of existing works and present a survey on current technologies related to speech, text and language. For the case studies, I choose pieces which grapple with a distinct issue or ideology. I try to understand how the experience has

been designed with the aim of placing a rhetoric based on procedural elements whilst also creating a space for play through the interactive elements. I try to understand whether the experience, as a whole, ends up being playful as well as successful in conveying the deeper message imbued in the piece.

In the second phase of my research, I apply the findings from the case study into my own work, attempting to create a work of ergodic literature which is at once both playful yet engages the user with its deeper meanings. Importantly, I utilise the possibilities afforded by the latest technologies to take a stab at creating a novel approach to playful reading.

4. Expected contributions

I survey this field to understand what has been done historically by artists, creating a selection of exemplary ergodic literature which can be categorised as communicating deeper meaning through a playful reading. A minor contribution is made as I look at what the technology landscape looks like today and in the near future from the perspective of speech, language and text and computers. I construct my own interactive piece which serves to exhibit the findings of the research process.

Finally, though the artistic project, this thesis contributes new knowledge about the experiences of migrant women.

5. Progress towards goals

I have completed one comprehensive case study which showed me that the approach of contrasting procedural rhetoric and the experience of play was of interest. I have conducted a preliminary technology survey which needs more depth. I need to distil my approach to the practical project and to be more specific about what technologies I want to play with. I need to understand exactly what aspects of migration (which is my topic of choice) I wish to problematise. I also need to conduct my first trial dialogue with a migrant woman in order to learn about the possibilities and limitations of dialogues as a means of collecting sentences for my project.

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Acoustic Ecology as tool for Environmental Awareness The ocean soundscape

Francisca Gonçalves
franciscarochagoncalves@gmail.com

FEUP, Porto, Portugal

Abstract

In a context in which the awareness of the impact of urban sound on our society is being raised, we are still facing the problem of increasing noise pollution. Moreover, according to studies in emerging fields such as soundscape ecology, animal sound communication has changed due to a soundscape transformation caused by increasing anthropogenic noise. This also applies to the underwater ecosystems: pile driving, shipping and renewable energies are some of the threats that we are facing today as they contribute strongly to underwater noise pollution. The recording of the underwater soundscapes can help us establishing a sound map to comprehend the development of this environment that is so important for the climatic conditions of this planet's health. Moreover, the study of oceanic sound dynamics can reveal useful information in terms of our planet's health. And not only that: by utilizing these underwater recordings in an artistic context, we can help raise awareness of acoustic problems marine life has to face today.

Keywords

Underwater noise
Acoustic ecology
Ocean soundscape

Introduction

Ocean is the pivotal factor determining the climatic conditions on the planet. The study of ocean sound dynamics can reveal useful information regarding our planet health. This research project intends to understand the ocean soundscapes and find out how the relationship between sound and nature can be a tool for designing immersive auditory spaces. The main goals of this investigation are to understand the ocean underwater soundscapes, how they are changing and evolving, to perceive how these changes are affected by the environment, to compare different areas, to study the anthropogenic impact on these soundscapes and to access what are the main contributions for sound pollution inside the ocean in our country.

1. Purpose of the research (and importance to the field)

According to studies in emerging fields such as soundscape ecology, we can observe how animal sound communication (bioacoustics) has been changing due to a soundscape transformation caused by increasing anthropogenic noise (Francis & Barber, 2013; Pijanowski et al., 2011). Bernie Krause describes the dilemma in his book: more than 50% of the material recorded over nearly five decades comes from sites so badly compromised by various forms of human intervention that the habitats are either altogether silent or the soundscapes can no longer be heard in any of their original forms (2015, 29).

The purpose of this research is to work directly with the ocean soundscapes in order to protect, understand and improve our knowledge on environmental topics, always on the lens for creating awareness to the society by sharing the results with the community through artistic approach and creative work. Soundscape recording, analysis and interpretation of data are also main parts of the project. The outcome will be not only establishing a library with the sound memory of the selected places or the development of a sound map of the Portuguese coast, but also

designing artistic interventions drawing on environmental field recordings and data sonification immersive sound projects. With an interdisciplinary approach, we may sensitize communities to be aware of our ocean underwater soundscapes environments, we can work in collaboration with other scientific fields of relevance to study the relationships between these soundscapes and the ocean health or ocean biology, bringing a wider access to the qualitative aspects of the ocean sound and how these soundscapes can influence our way to relate with the ocean itself.

2. Brief survey of background and related work

The Navy has long used sound to detect objects underwater (Hole et al, 2017). Sound is used by scientists, industries, navies, and others to communicate underwater, to monitor the ocean's moving water masses, to get images of the seafloor and structures beneath it, and to localize and track sources of sound in the ocean (Hole et al, 2017).

As Jennifer Miksis-Olds states, sounds from low-frequency sources like ships, seismic air-guns, and blue whales transmit 1000's of km in the deep ocean and can be combined to contribute to local soundscapes, making sound one of the most accessible tools for exploring the ocean (Miksis-Olds 2016). National Aeronautics and Space Administration (NASA) and The National Oceanic and Atmospheric Administration (NOAA) are both active researchers with cutting edge technologies for exploring and learning our environments. According to Tsang-Hin-Sum, investigating the variability of ambient sound in the oceans is the key for understanding many oceanic processes, such as surface wave interactions, wind, and climate change, as well as monitoring for seismic events and marine life (Tsang-Hin-Sun et al, 2015).

Miksis-Olds states that sound can be used to observe a variety of signals in marine ecosystems ranging from natural phenomena to anthropogenic activities indicative of global ocean use

and climate change. For a better understanding of global ocean noise, she examined changing acoustic conditions over the course of a year in the Pacific, Atlantic, and Indian Oceans. She got results that show differences between the soundscapes generated on opposite sides of an island that explain how the dominant ambient sound sources are influenced by regional physical, biological, and anthropogenic factors (2012).

Artists that develop experiences to challenge people's everyday awareness using technology and sound are my main inspiration works. Leah Barclay¹ explores the connection between art, the environment and the local communities. In her work *WIRA 2015*,² an interactive sound installation, she explores the cultural and biological diversity of river systems through an augmented reality sound walk. This installation is open for user's contribution with their own recorded soundscapes and was constantly evolving through the course of the exhibition. Matthew Burtner³ with his latest work *Music for Climate Science at Nasa 2017*⁴ pretends to discuss how music can contribute to climate science. Caitilin de Bérigny⁵ is an artist that creates awareness on environmental issues as theme in her work for the past decade. In her collaborative article "Tangible User Interface Design for Climate Change Education in Interactive Installation Art", she describes an interactive installation artwork, which incorporates tangible user interface objects and combines environmental science and multiple art forms to explore coral reef ecosystems that are threatened by the effects of climate change. She argues that the use of tangible user interface in an installation-art setting can help engage and inform the public about crucial environmental issues (de Bérigny, 2014). Also, in her work *Interantarctica*⁶, she draws attention to the climate change and offers a three-screen video installation where the viewer hears Antarctic compositions, created by other viewers in real-time interaction and presents scientific data through a multi-sensory experience (sound, sight, touch).

3. Description of the proposed approach

Starting from the issues already addressed in the context of the master's degree on how to improve our aural awareness, I question how we can use sound and soundscape compositions to establish a deeper emotional connection with natural elements that are alien to the urban environment. Field research is a way to engage and explore our environment through emerging media technologies, and art made possible to show creatively the results with new audiences. The creative interpretation of data demonstrates the power of art when paired with other fields. The idea of exploring and investigate the ocean, the ocean soundscapes, the acoustics, the impact of noise rising on the fauna will give me not only important data on the scientific approach but also on artistic point of view. The central theme of this investigation project is to study sea soundscapes to better understand the ocean sound dynamics with the aim to create environmental awareness in our society through art. Another focus of this research is also soundscape studies, especially in environmental data analysis with purposes for presenting data visualization and sonification works. The first part of the investigation will be the assessment of existent implemented hydrophones, a survey of investigation centres that work with the ocean and understand our sound policies in the sea. Using existent hydrophones in different parts of the ocean and proposing new key sites for recording sound we will have conditions and the possibility of developing a general sound map of our coast.

There are number of investigation centres in our country for possible partnerships in this project like the Interdisciplinary Centre of Marine and Environmental Research (CIIMAR), the Research Centre in Biodiversity and Genetic Resources (CIBIO), the Center for Environmental and Marine Studies (CESAM), MARINFO, STRONGMAR or Oceano Vivo Foundation just to name a few. The Pacific Marine Environmental Laboratory (PMEL) from NOAA, have an acous-

¹ <http://leahbarclay.com/>

² http://leahbarclay.com/portfolio_page/wira/

³ <http://matthewburtner.com/ecosono/>

⁴ <http://matthewburtner.com/music-for-climate-science-at-nasa/>

⁵ <http://www.caitilindeberigny.com/>

⁶ <http://www.caitilindeberigny.com/#/interantarctica/>

tics program for accessing the noise in the EUA. Learning from their framework we can also start collecting our own data nationally. SUB-ECO, a program funded by the Ministry of Defense of Portugal started a project that aims at reinforcing the capabilities of national underwater surveillance. After the local/ national assessment my goal is to make connections with several international organizations for an interdisciplinary approach. I am interested in using existing data as well as new data as raw material for data sonification works. The collaboration with the Underwater systems and Technology Laboratory in FEUP, where I am able to work with their team on sea expeditions, allowed me to record and monitor the sound activity in specific locations in our coast. Other data like salinity, temperature, pressure, turbidity or chlorophylla can also be used for data visualization and sonification tests. The data and material collected will be raw material for artistic practices.

4. Expected contributions

Our planet offers a wide distribution of fragile and endangered territories and disappearing soundscapes. I think it is important to deepen our knowledge to protect these locals, so we can preserve them in the future or, at least understand through interdisciplinary research what are the threats and concerns related to these places. Our country has a big extension of coast offering a variety of interesting locations to collect meaningful information and data related to the ocean. From a long time now researchers, scientists and now artists are relying on sound and on soundscapes to study and understand environments. Art or new media art are becoming tools for different approaches on scientific interpretation. With the evolution of technology, we can connect different fields like arts and science and interpret or evaluate environmental data using innovative forms of creativity of visualization. Art practice promotes the creative use of media and technology for creating awareness in the society. These forms of creative artworks with strong environmental messages also awake the public for our present problems. I feel moved by this to create

art that can bring awareness to the communities, to keep our oceans health and activate citizens to connect with these goals. The ocean represents to Portugal one of its greatest's natural and economical resources, so I feel that it is important to document the outcome of this investigation for the future. The expected results of this investigation project will be based on these three main branches: **Artistic / educational:** Creating awareness in the society through artistic practice, artistic expression as tool to engage audiences, immersive auditory spaces (Artworks, Installations, Sound art), educational workshops; **Noise pollution / ecology:** Elaborating a sound map of the Portuguese coast, analysis tools, database for public consultation, possible application on public health issues, intangible heritage, preservation of the sound memory; **Scientific:** Reflection on value and results in thesis format, publications (both in scientific support in conferences and colloquiums and in more informal formats for discussion and reflection).

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