COMPUTER MUSIC AND DIGITAL MEDIA ART THROUGH A WEB-BASED COLLABORATIVE INTERFACE

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Resumo

O presente documento apresenta uma investigação feita no contexto do Braga Media Arts, parte constituinte da rede de cidades criativas da UNESCO (UCCN). O objectivo e reflexão fundamental deste trabalho é dado na música por computador e na media arte a partir de interfaces colaborativas. Com um foco específico na performance artística e na interacção em sistemas digitais é proposto um ambiente audio-visual, Akson. Utilizando tecnologias web, o Akson foi inicialmente concebido como uma exploração do que poderia ser construído aproveitando a infraestrutura global da Internet, bem como a reprodução musical e visual em grande escala por vários dispositivos. É apresentada uma reflexão teórica da arte e da sua tecnologia enquanto veículo extensível da experiência, da pessoa e do sistema.

Palavras Chave: Música por Computador, Media Arte, Arte em Rede, Performance Artística

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Abstract

This document presents a research made in the context of Braga Media Arts, part of UNESCO's creative cities network (UCCN). The objective and fundamental reflection of this investigation is given in computer music and media art from collaborative interfaces. With a specific focus on artistic performance and interaction in digital systems, we propose an audio-visual environment, Akson. Using web technologies, Akson was initially conceived as an exploration of what could be built by leveraging global Internet's infrastructure as well as large-scale musical and visual reproduction across multiple devices. We present a theoretical reflection of art and its technology as an extensible vehicle of experience, person and system.

Keywords: Computer Music, Media Art, Networked Art, Artistic Performance

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There is no way I can objectively thank everyone involved in this little piece of text. It is with my heart that I hope they will find pieces of themselves in the course of my work.

During the reading you will find them. People who not only made this project with me, but also make me myself. The references that make me cry and laugh. The will that makes me write right now. For the artists, engineers and my incredibly strong family. It's because of them that my research exists. Just like me and my mind.

So I dedicate this dissertation to you. The person who is currently reading. For the time you decided to spend trying to understand a little bit more about me.

Luis Arandas

"There is no such thing as an avant-garde artist.
This is an idea fabricated by a lazy public and by the critics that hold them on a leash. The artist
is always part of his epoch, because his mission is to create this epoch."

Edgar Varèse 1965a, (Roads 2016)

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Abbreviations and Symbols

3D   *[Three Dimensions]*
ADSR   *[Attack Decay Sustain Release]*
AMD   *[Advanced Micro Devices]*
ANSI   *[American National Standards Institute]*
API   *[Application Programming Interface]*
AV   *[Audio-Visual]*
BEAST   *[Birmingham Electroacoustic Sound Theatre]*
BEER   *[Birmingham Ensemble for Electroacoustic Research]*
BMA   *[Braga Media Arts]*
CARA   *[Centro de Alto Rendimento Artístico]*
DAW   *[Digital Audio Workstation]*
DDR   *[Double Data Rate]*
DIP   *[Distributed Immersive Performance]*
DNS   *[Domain Name System]*
DOM   *[Document Object Model]*
DSMI   *[Distributed Synchronized Musical Instrument]*
DSP   *[Digital Signal Processing]*
ECC   *[Error-Correcting Code Memory]*
EMUI   *[Emotion UI]*
EQ   *[Equalization]*
ES   *[Embedded Systems]*
FFT   *[Fast Fourier Transform]*
FPS   *[Frames per Second]*
FOV   *[Field of View]*
GB   *[GigaByte]*
GHZ   *[GigaHertz]*
GL   *[Graphics Language]*
GLSL   *[OpenGL Shading Language]*
GUI   *[Graphical User Interface]*
HCI   *[Human-Computer Interaction]*
HD   *[High Definition]*
HDMI   *[High Definition Multimedia Interface]*
HTML   *[Hyper Text Markup Language]*
ICLI   *[International Conference on Live Interfaces]*
ICMC   *[International Computer Music Conference]*
INESC TEC   *[Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência]*
KHZ   *[KiloHertz]*
LFO   *[Low Frequency Oscillator]*

MB   *[MegaByte]*
MBPS   *[MegaBits per Second]*
MHZ   *[MegaHertz]*
MIDI   *[Musical Instrument Digital Interface]*
MIT   *[Massachusetts Institute of Technology]*
MP3   *[MPEG-1/2 Audio Layer 3]*
MPEG   *[Moving Picture Experts Group]*
MS   *[Milliseconds]*
NIME   *[New Interfaces for Musical Expression]*
NMP   *[Networked Music Performance]*
OGG   *[Container Format by the Xiph.Org Foundation]*
OJM   *[Orquestra de Jazz de Matosinhos]*
OS   *[Operating System]*
OSC   *[Open Sound Control]*
OSX   *[Macintosh Operating System X (Apple Computer, Inc.)]*
PA   *[Public Address System]*
RAM   *[Random Access Memory]*
TRS   *["Tip, Ring, Sleeve"Cable]*
TYPE   *[Yorkshire Programming Ensemble]*
UNESCO   *[United Nations Educational, Scientific and Cultural Organization]*
UCCN   *[UNESCO Creative Cities Network]*
VCS   *[Version Control System]*
VMM   *[Variable Markov Models]*
WAC   *Web Audio Conference*
WAV   *[WAVEform audio format]*
WI-FI   *[Wireless Fidelity]*
WWW   *[World Wide Web]*
XY   *[Coordinates of the Cartesian System]*
ZKM   *[Zentrum für Kunst und Medientechnologie]*

Chapter 1

Introduction

This dissertation transmits the development and experimentation of a collaborative audio-visual (AV) environment done in the context of Braga Media Arts[1], a recent creative city in the UNESCO's network (UCCN)[2].

In 2017, Braga[3] was officially designated as Creative City of UNESCO in the field of Media Arts. In the recent past the city pointed to an increasingly technological future, reinventing its economic fabric focusing on technology companies, digital communication studios, laboratories and research centers in the field of robotics, games, multimedia and media arts. Simultaneously a cultural ecosystem has gained form and expression, defining itself in a contemporary and transdisciplinary identity, situated in the intersection between new media and formal artistic expressions. The use of technologies in artistic practice has led many projects to transport Braga to a dimension of international recognition.

This research was done with a close relationship with its educational service, exploring the process of technological development and artistic experimentation of a proposed tool. Accompanied by historical and present references on networked interfaces, this document aims to show everything related to the project.

The digital interface presented was done using web technologies exploring networked interaction in the performing arts. All software and interface design was developed specifically for this research and the entire technical development process exists in the cloud with free access.

In this chapter we present the context and motivation that supported this research followed by the problems, hypotheses and objectives conveyed. Finally there is a description of the methodologies used and brief summary of the chapters comprised in the document.

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[1] Official Braga Media Arts website http://www.bragamediaarts.com/en/ [accessed 27/06/2019]

[2] Official UCCN website https://en.unesco.org/creative-cities/home [accessed 27/06/2019]

[3] Braga is a city and a municipality in the northwest of Portugal. It is the third-largest urban center in Portugal (after Lisbon and Porto).

1.1   Context and Motivation

The confluence of art and contemporary technology has always been a significant part of our work, both as artists and as critics. The consideration deposited in art and it's technology has led us to formalize opinions about human interaction and aesthetics that are fundamental bases of the work presented here.

The motivation of this work is rooted in influences from collaborative computer music to contemporary digital media art. Fundamentally we argue that systems like the one proposed are needed as artistic extension in the cloud, mainly as a way to do so.

All of the people involved in this research (minus some audience) had clear musical, artistic, and academic backgrounds. The search for an action that corresponds both to the ethics of art and to the technological development of instruments equally is undoubtedly what defined the concept of the formalized environment. This work is also product of references and artistic choices of the authors that they have maintained for some years before this investigation.

1.2   Project

The proposed project began with the establishment of a work flow that would allow a full year of software development without fail. A constant search for references in the course of the investigation was also maintained, always supported by the public artistic experiments.

Our aim as researchers and artists is to integrate the computational environment developed in the performing arts and as a distributed digital collaborative interface. In this way it is possible to create a bond that is consistent with development and outcome.

We develop and integrate in the cloud, an environment that can answer both the main research questions and our conceptual requirements. We are committed to developing it with web technologies creating interfaces for multiple devices. These technologies were chosen to allow digital multimodality both in the development of it as a tool and as an AV generation system.

1.3   Problem(s), Hypotheses and Objectives of Research

Considering the massive worldwide development of web technologies, networked collaborative interfaces and digital AV generation, we define the various parameters of research.

We can formulate our problem considering the following:

- We have already extended our senses and our nerves by the various media (McLuhan, 1964)

- The interactive capabilities opened up by computer networks allow for shared creativity, from textual or telematic real-time improvisations to globally constituted group projects, with distance no barrier to collaboration (Dixon, 2007)

- New web standards such as Web Audio and Web GL introduce the capability for web browsers to duplicate many of the features in computer music tools (McKinney, 2014)

- By default, the interface is a system or device through which unrelated entities can interact (Sá, 2010)

Problem

- How can we implement and validate a web-based AV tool for collaborative interaction?

Hypothesis check

- Can we, through the use of web-based technologies:

  - Develop a collaborative environment for AV networked interaction?

  - Use the internet as a vehicle for interaction between artists with potentially global distances around the world?

  - How can a multi user system for artistic creation mediate, and thereby enhance, the interaction between agents with distinct creative proficiencies?

  - How can a digital collaborative AV system contribute for artistic creation through the use of web-based technologies?

  - Validate the developed tool in public experiments using cloud tools?

Objectives

The main objective of this research is to develop a networked AV collaborative environment with web technologies

Understand the role of a multi-user digital system as a mediation agent in computer music and AV performance.

The proposal and validation of this tool should be implemented in a context of the Educative Service of Braga Media Arts.

1.4   Research Methodology

In this sub-chapter we present the methodology and research design used.

When this research was integrated in the context of Braga Media Arts, the objectives explained earlier were very clear, keeping the research questions defined during the work process. We, as researchers, have carried out a thorough review of the conceptual and technological literature that in turn extended to the end of the investigation. A balance of possible outcomes and similar projects/methodologies for art creation was always performed.

The development process of the proposed environment (see chapter 3) was carried out with respect to *practice-led research* and *research-led practice*[4] (Smith, Dean 2009; Candy, 2006) methods and covering also the fundamental practices of *artistic research*[5] (Busch, 2009; Liamputtong & Rumbold, 2008) as an academic mode of production.

After having a work flow defined and practicable in the scope of the research time scale we believed that the continuous technical development parallel to the artistic/theoretical research was the method to be adopted (*computer-led practice*).

1.5   Dissertation Structure

This dissertation is organized in 5 chapters followed by the appendix, attachment and references.

- The first chapter

  – In the first chapter we explore the foundations of this research, the type of project, the motivations, the resolution, the hypotheses and problems.

- The second chapter

  – A review of the fundamental literature is made to instantiate our research in history, always accompanied with contemporary references. We present a sub chapter with recent works entitled *state of the art*. In here several important works made recently that are an important reference for this investigation are cited.

- The third chapter

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[4]A type of research that leads primarily to new understandings about practice. Is concerned with the nature of practice and leads to new knowledge that has operational significance for that practice (Candy, 2006)

[5]Fundamentally defined by art that understands itself as research, in that scientific processes or conclusions become the instrument of art and are used in the artworks. This refers to a particular phenomenon in contemporary art, in particular in institutional-critique, whereby research is considered a part of the artistic process and is carried out by the artist herself. In this case, art is in fact a form of knowledge (Busch, 2009)

- – The third chapter is an extensive presentation and review on the proposed digital environment, Akson. A detailed documentation is provided of the technologies used, how they were made and the concept that defines it as a digital environment.

- The fourth chapter

  – In the fourth chapter are explained in detail the public experiments done with the proposed environment during the investigation. The relationship they have with technical development, also with an evaluation of the material used (hardware and conditions) and the participants of each public work.

- The fifth chapter

  – In chapter five a conclusion is drawn from all the research done. Future work is proposed, objectives and difficulties are listed.

Chapter 2

Contemporary and Historical Practice

2.1 Literature Review

In this section of the chapter a necessary exposition is made of the various areas and works related to research and the state of the art.

2.1.1 Introduction

This literature review will try to contextualize important milestones of computer music, collaborative interfaces and digital media art in time. This action arose not only from the need to support the technological contribution of this dissertation to the academy, but also to make a valuable theoretical essay.

Within this chapter will mention works, artists and technologies used in the field of audio-visual interaction, their relationship as digital networked media and also will be covered digital frameworks and environments that allow the artist to do so. Some of the examples raised in this text will have a clear connection with artistic performance and possibly an ontological approach to the extension of both the human body and the artistic gesture in the use of collaborative digital instruments. The usage of web technologies, their own evolution and insertion in the artwork as medium will be studied contextually in contemporary digital art forwarding the presentation of the digital system proposed in this dissertation in the next chapter.

2.1.2 Computer Music Performance

As digital technologies changed the world of music and music performance, a world seen as a listener and as a performer (Morandi, 2017), it is common for the artist to use the maximum exponent of technological power for artistic composition and performance, the computer. With that change, it is easy for us to understand that with new computer technologies we also have new modes of artistic expression (Broadhurst, 2007).

When we revisit the past and we analyse experiences such as *9 evenings: Theatre and Engineering* (Oppenheimer, 2011) and, for instance, Atau Tanaka in Etablissement Phonographiques de L'Est (EPS), Paris (1993) (Joaquim, 2015), we understand that computational technology was already completely embedded in artistic performance. As it was done in multiple artistic vanguards (Mathews 1963).

Figure 2.1: Photo named "*Cage. Variations*" found in Arnolfini. An article about *9 evenings: Theater and Engineering*.

But when we talk about new technologies, and we situate that in the past, we start to see patterns and mark differences. The laptop from today is completely different from the laptop from the year 2000 or 2005. And inheriting by these premises we also understand that when the performance does not only contain music, we can always use the same system to process the artwork, even if not only in the digital domain. An example to that might be when the musician or the composer might also want to express himself visually or add different media in the same piece (Noto, 2009).

Today, it's possible to do using the same computational structure, easily. The artist can merge all technologies together, from digital complex data structures to the most unorthodox type of analog control. But of course music is music, and when the artist tries to expresses himself through all these different media we call that media art.

We can always appropriate the fact that everything can be transformed, transmutable and have various formats at the same time in the computational domain. A constant stream of data that we give meaning as we go. It's also interesting to acknowledge how people that work in the vanguard of performing art with great emphasis on computer music and visual art as Robert Henke (2018) look at composition and performance nowadays disrupting the computer as a separate tool and embedding it completely in their thought (Henke, 2016) on *Computer Music is Dead*.

Trying not to go out of scope, this dissertation places it's focus on post-digital revolution technologies, from 1990 until today (Reilly 2013). We can point the focus to being not so much on computational revolution but more on the possibilities it has as a performing art, material for performing art, and how we can understand it as musicians and artists in general.

A good example that is changing dramatically the role on composition and performance for an artist is the profound alteration that is constantly happening in graphical user interfaces (GUI) throughout the years. Understanding the difference that exists now on human-computer interaction (HCI) such as the revolutionized conception of how do I see a computer and its operation (Sá, 2010). A new version of experience generation.

2.1.3 New Media and Computer Music

All of the variables related to decision making that exist in artistic creation, specially when talking about digital music and digital media performance, are key points to discuss different outcomes of the artwork. I'd like to build a relationship focused on what we consider to be main examples of digital music technologies, starting from the earliest interactive computer systems such as *Groove* by Max Mathews (ATT Bell Labs 1969, 1970) and *A computer aid for Musicians* by the National Research Council of Canada (Pennycook, 1985) and making a bridge with common contemporary technologies.

This evolution brought us new methods on how to address problems relative to the user environments in real-time interaction and can be transposed to a performative problem. Those new methods allow us to make professional music using only digital technologies with a great level of abstraction from computer's binary data and actually have a result almost indistinguishable from acoustic performance (Roads, 2016).

We can find examples of that in programming tools like Csound[1] (Senna, 2017), Max/MSP[2] (Zicarelli, 2002), Pure-Data[3] (Puckette, 2007) and SuperCollider[4] (McCartney, 2002). These frameworks allow the user to focus primarily in the artistic expression, with a much more easy,

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[1]CSound main website https://csound.com/ [accessed 27/06/2019]
[2]Max/MSP main website https://cycling74.com/ [accessed 27/06/2019]
[3]Pure-Data main website https://puredata.info/ [accessed 27/06/2019]
[4]SuperCollider main website https://supercollider.github.io/ [accessed 27/06/2019]

quick and solid work flow.

Using these tools the artist can expect results that can mimic analog instruments with a good degree of certainty (Henke, 2018), from conventional music production to contemporary music performance. It might also be worth mentioning that with new tools and systems also appear new plugins and methods of interfacing these tools and systems. Good examples of this will be libpd (Brinkmann, et al 2011), a library that wraps Pure-Data as an embeddable audio library. Maximilian (Grierson, 2011), a free, open-source and MIT licensed C++ audio synthesis library built on top of RtAudio (Scavone, 2002). The Minim library (Mills et al., 2010), an open-source audio library built on top of Java Audio API and of course The Synthesis Toolkit (Cook & Scavone 1999).

All of this allows the artist to have various ways of reaching his goal and have an approach to interactive or node-based programming different than conventional computer science. From placing elements in time just like a DAW or allowing the artist to make artworks on stage (more examples can be found on Algorithmic Composition). Examples of that are ALPHA v1.0 by Julien Bayle[5], where the artist structures real-time audio-visual content, and also the work of Boris Divider[6] in Data+Perform where the artist talks about his performance as a *"treatment of data and it's graphical representation with the mixing of generative and reactive elements"*.
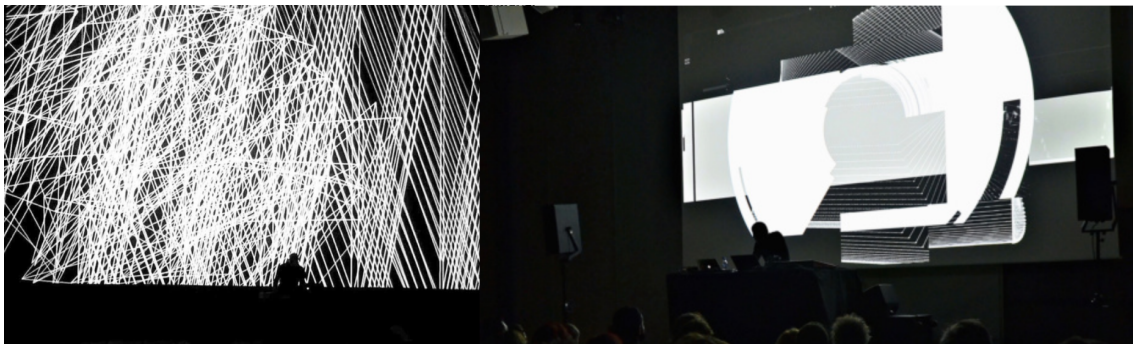
Figure 2.2: Courtesy of the Authors. On the left a picture of Julien Bayle performing ALPHA v1.0 in Montréal and on the right a picture of Boris Divider on Data+Perform live performance.

These examples rely on digital systems developed by the artists in their performing environment of choice. They build their own network and algorithms specific to the artwork. The performances are also a fixed experience that the artists present when they are in concert halls. With the growing possibilities and technologies appearing in the domain of the audiovisual arts also fostered by the massive research focus in intelligent interfaces, the practice in itself can be singularly adapted.

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[5]Julien Bayle's main website http://julienbayle.net [accessed 27/06/2019]

[6]Boris Divider's main website www.borisdivider.com/ [accessed 27/06/2019]

2.1.4   New Media and Computer Graphics

Always contributing to the drastic change in the creative processes with technological advances (Broad and Grierson, 2016) and having in mind that visual art might have a role to play in computer music performance, we form up a review on today's digital computer graphics.

In the preface of the book Cyclo. Id (2011) published by Ryoji Ikeda alongside with Carsten Nicolai (Alva Noto) we can read in the preface that the artists declare that they have *"abandoned the idea that the image acts only as a functional accompanist to sound and instead subordinated the audio element for our desire of the image"* (Ikeda and Noto 2011) (Carvalho, 2018). On this position before artistic practice we can see the graphical image having a different role to play inside the AV performance, not specifically an income or outcome to music but the original compositional matter.
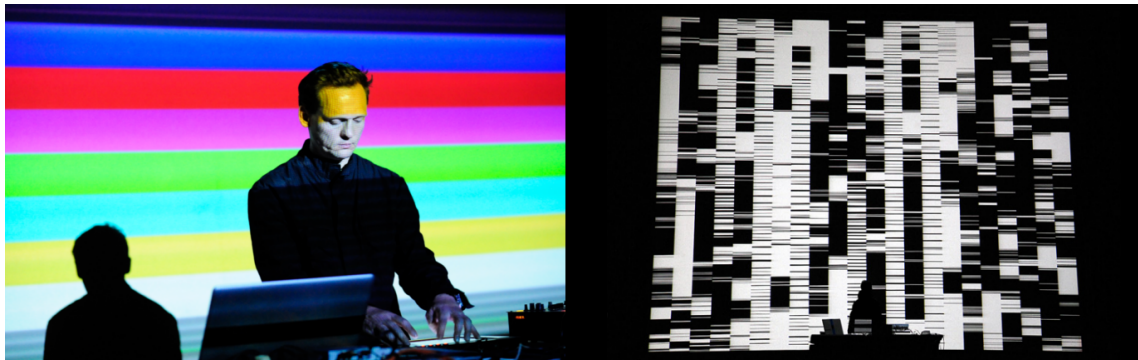
Figure 2.3: On the left picture taken from Sónar 2018 official website of Carsten Nicolai (Alva Noto) performing and on the right picture taken from Ryoji Ikeda's official website of the artwork *text pattern*.

Interesting work can also be found in the field of synaesthesia[7] and AV relationships. The work of Kandinsky on color/music (Kandinsky, 1947) and the Quayola's sonic visualizers (Quayola, 2011a) are a big reference to take in account.

Regarding the possibilities artists have on content generation, just like music there are several ways of making video or digital graphics with or without real-time interaction in artistic performance. Environments like Processing (Fry & Reas, 2001), OpenFrameworks (Lieberman, Watson, & Castro, 2005) (Gomes, 2014) a project started at MIT Media Lab conceived in 2001, or Cinder (Gómez, Colubri & Charalambos, 2016; Bell et al., 2012) a software that also has a good environment for the artist to program digital graphics and sound with the availability to use in their projects for any use (commercial or otherwise).

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[7]Synaesthesia - Neurological Condition on Wikipedia https://en.wikipedia.org/wiki/Synesthesia [accessed 27/06/2019]

The massive development happening worldwide on the field of interactive graphics is astonishing and has great possibilities. Also, the development of visual computing nowadays has a big coherence with the type of hardware and API's people have access to, the widespread availability of programmable graphics processing units (GPU's) and shading languages such as GLSL (Rost et al., 2009) makes visual art easier to develop. Some media artists also use and exploit gaming programming systems, such as Unity[8], Unreal Engine[9] or Godot[10].

2.1.5   Networked Systems and Performance

As humans, we create structures and networks for almost every type of collaborative behavior, and NMP has benefited from over three decades of development (McKinney, 2016). Examples of that can be the experiments of the San Francisco Bay Area network band pioneers and of course the development of the internet. Introduction of protocols like Open Sound Control (OSC) (Wright, 2002) for multi-purpose communication present good ways of extending those networks.

There is also relevant work on the field of collaboration and networking that presents taxonomies and extended research that help us structure a better relationship with the past. Such examples are *Displaced Soundscapes - Computer Supported Cooperative Work for Musical Applications* (Barbosa, 2003) and *Internet Music: An Introduction* (Hugill, 2005). And to don't lose definition, the term network music can quickly become opaque and without meaning. For that I would like to bring the book *Networking Foundations* (Ciccarelly & Faulkner, 2004) where a network is defined as a system that allows communication to occur between two people or machines (McKinney, 2016).

When we talk about networked digital systems we are also thrown to the big infrastructure of those systems, and there is a problem raised by Bridle (2018) that studies the opacity of that computation. As digital systems take place inside the machine, hidden inside buildings and big structures that propagate themselves as long as wires and WI-FI enables, there is a barrier from the user. And even when we disrupt that barrier, it remains beyond the comprehension of most. The aggregation of complex systems in contemporary networked applications means that no single person ever sees the whole picture (Bridle, 2018).

That is a problem to human interpersonal behaviour and brings us multiple sociological paradigms (e.g. automation bias) (Parasuraman & Manzey 2010), but might not be a problem in performatic interaction. The outcome of the piece is multiple times the most important thing, and if there is a clear trade of information in the main path of communication (*path* defined as sender-receiver link) with a controlled amount of noise (Shannon, 1948) that might be a problem solved (both for the public and performers). To the communication and to the embodiment. The

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[8]Unity main website https://unity.com/ [accessed 27/06/2019]

[9]Unreal Engine main website https://www.unrealengine.com/ [accessed 27/06/2019]

[10]Godot main website https://godotengine.org/ [accessed 27/06/2019]

point that defines *controlled communication* as a scale is based on the model defined by Claude Shannon (1948).
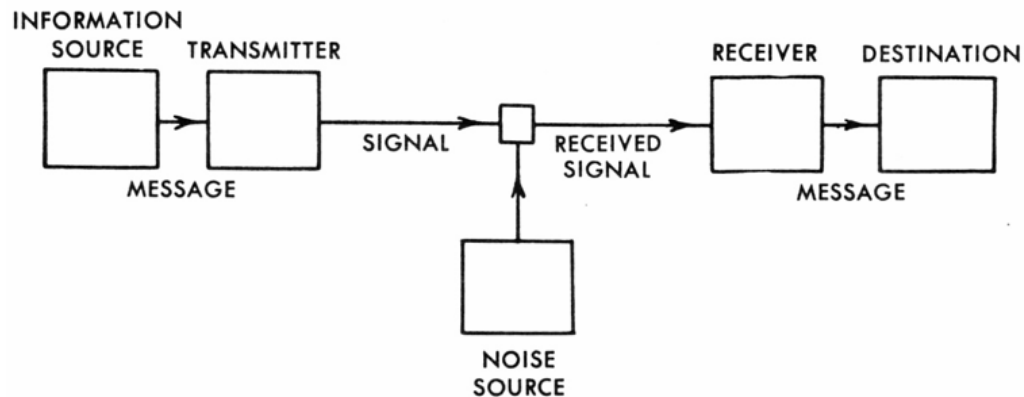
Figure 2.4: Picture of the schematic diagram of a general communication system. Claude Shannon on *The Mathematical Theory of Communication.*

Nowadays, from the simplest social media user to the most complex serious information structure, we rely on an incredibly big communication field. That field by default, tries to erase this noise source and leaves us space to develop creative ideas and ways of experimenting it in new ways. These new ways of expressing can sometimes take place in an interactive distributed computer system for real-time music made by multiple users (Brown, 2007).

To differentiate the models for collaborative behaviour as types, we have to split systems by data communication architectures. These networked models for collaborative actions might be divided mainly in *Centralized Network Models*, *Decentralized Network Models*, and *Distributed Network Models* (Hernst, Gurle, & Petit, 2000; Pulkka, 1995).

These different ways of building software and flows of information also bring different ways of exploring it, as medium or the art itself (Blanton, 2019; McLuhan, 1967). And as there are new ways of exploring it, new ideas and systems come to life.

A good example of musical performance is the iconic work *Dialtones (A Telesymphony)* (Bédat, 2002), a concert whose sounds are wholly produced through the carefully choreographed ringing of the audience's own mobile phones, presented at Ars Electronica Festival (2001) and at the Swiss National Exposition (2002). In contrast to that model of interaction we have the The Birmingham Ensemble for Electroacoustic Research (BEER) performing at the Network Music Festival in 2014 with the three members sitting at a table. Surrounded by the audience contrasting

Figure 2.5: Courtesy of RAND Corporation. Network Models proposed by Paul Baran in 1964. Image found in document RM-3420-PR.

the effort to show that the music is played in real-time, this performance explores a minimalist interaction with the computer (Akkermann, 2016).

Figure 2.6: Courtesy of the Authors. On the left a picture of *Telesymphony* performance and on the right a picture of BEER performing in Network Music Festival (2014) in Birmingham.

Complex networking schemes allow for the sharing of performance data between musicians, however, the connection between the music and the listeners – both ensemble participants and audience members can be diffuse and unfocused (Diakopoulos, 2012), that's why I bring two different examples of performative interaction.

It's also important to notice techniques like live-coding (Colins et al., 2004) that are commonly used nowadays in meetings such as *algoraves* (Collins & McLean, 2014; Collins et al., 2003). In here, we can see an evolution from bands like The Hub with *state of the art* live-coding. The Hub is a band from 1980's that used San Francisco bay area as a fertile ground for composition experimenting with microcomputers as a musical instrument automata (Brown, 2002), also

growing from the League of Automatic Composers (Boutwell, 2009). A good reference can be Alexandra Cardenas, currently based in Berlin and also part of the live-coding scene in Mexico City (Alex, 2013).

Figure 2.7: A picture of The League of Automatic Composers performing in San Francisco 1981 (McKinney, 2016; Brown, 2002)

The live coding performances require flexible tools for real-time musical structuring and the tool itself (the coding environment) must not be a hindrance while performing. Just like a classical instrument, the artist needs to have clear control over the engine. Seeking an agile and quick deployment of the content, the artist needs to use frameworks that allow that. Not only for live-coding, but also for rapid prototyping. There are examples like ChucK[11] (Wang & Cook, 2003), TidalCycles[12] (McLean & Wiggins, 2010), Sonic Pi[13] (Aaron & Blackwell 2013), Impromptu[14] (Sorensen, 2005) and Fluxus[15] (Magnusson, 2014). These allow the fast generation of audio and/or graphics.

Some of these frameworks, tools, and artworks exist thanks to the needs of the artist that created them, which is something that happens a lot in digital systems. And sometimes, when making a review of existing music and audio-visual programs we can observe that some aspects of

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[11]ChucK official website https://chuck.cs.princeton.edu [accessed 27/06/2019]

[12]TidalCycles official website https://tidalcycles.org/index.php/Welcome [accessed 27/06/2019]

[13]Sonic Pi official website https://sonic-pi.net/ [accessed 27/06/2019]

[14]Impromptu official website http://impromptu.moso.com.au [accessed 27/06/2019]

[15]Fluxus official website https://www.pawfal.org/fluxus/ [accessed 27/06/2019]

artistic expression especially on electro-acoustic composition are not addressed by standard music programs (Thiebaut et al., 2008). That might be, or not, a problem.

2.1.6   Instruments using Web Technologies

By leveraging the internet as a live software ecosystem, this chapter will examine how such technology can best reach artists, and live up to its potential to fundamentally change creative practice in the field. As a starting point compared to the days of today we have the long distance concerts by telephone.
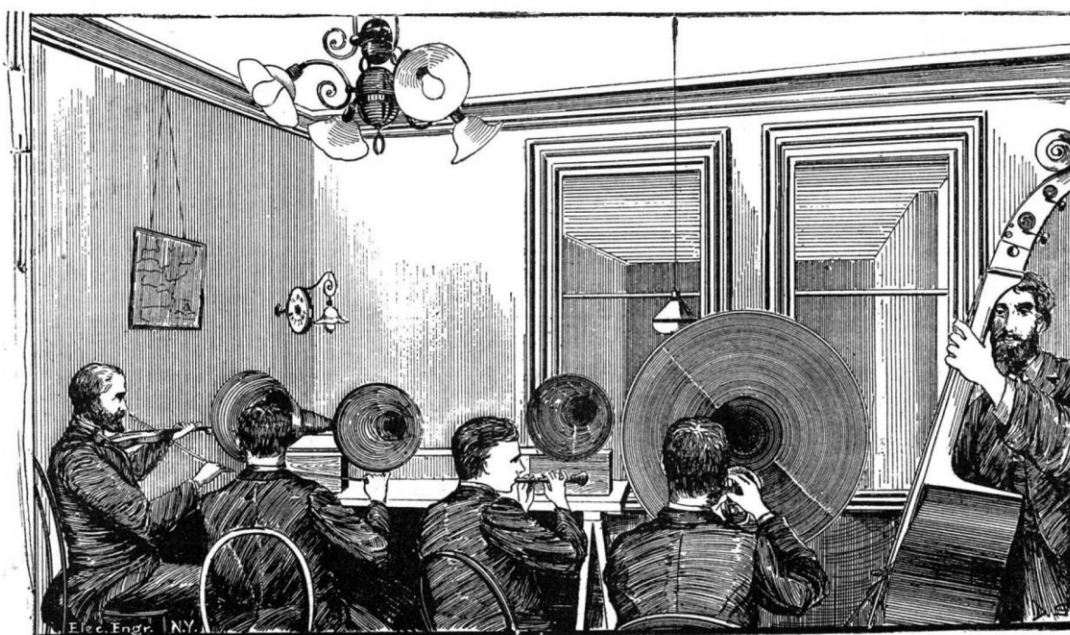
Figure 2.8: Picture found on article *Long Distance Telephone Concerts* by Scientific American, February 28, 1891, page 130. Performers in New York and audience in Newton Massachusetts.

Creating platforms where the newest techniques can be used by artists as part of their day-to-day job is a point of innovation that happens all over the world. Using browser-based tools is one of them.

There are some similarities on the research happening now and the first experiments of musical performance using internet connections. For instance, audio streaming for collaboration was a big topic of research in University of Southern California (1993) (Schooler & Touch, 1993), nowadays with big advances in broadband speed. A couple of years later, in June 13, 2002 the University of McGill and Stanford help the first transcontinental jam session utilizing high quality audio and video which later led the University of Southern California develop their own technologies for what they called Distributed Immersive Performance (DIP) (Chew et al., 2004).

Approaching composition as plural behaviour, we have an important milestone in collective creation systems with the piece of software FMOL. In 1997 the Catalan theater company *La Fura dels Baus* commissioned the experimental artist Sergi Jordà to develop an online collective music creation system (Barbosa, 2006; Barbosa, 2003). The artist could connect to this project and find a web-based database which allow the user to upload pieces to the server for later modification. This project later included the play *F@ust 3.0*, inspired on Goethe's work.
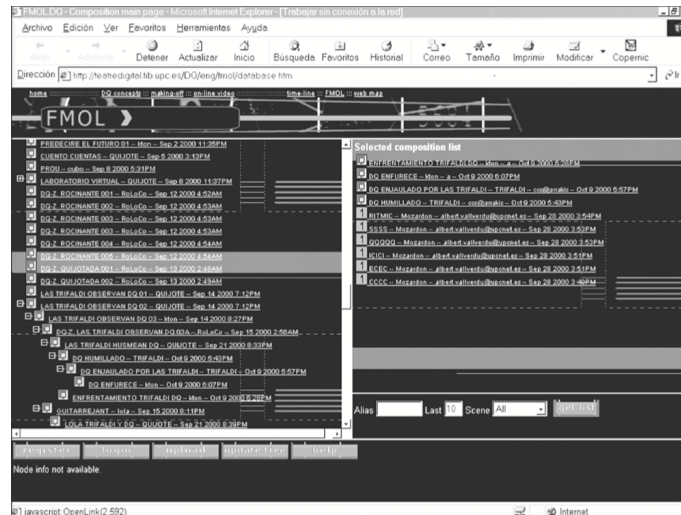
Figure 2.9: Courtesy of Alvaro Barbosa. A screenshot of FMOL software. A web-based tree-structured database. © Sergi Jordà

Nowadays, we have interfaces embedded in the browsers that allow us to control all kinds of computational tasks through many different API's in or out of the WWW. Recent developments also allow users to make their own libraries and development in powerful languages like JavaScript (JS) (Flanagan, 2002) and it is important for audio-visual artists that work on browser-based technologies to understand the structure of both the Web Audio API (Favory & Serra 2018; Smus, 2013) for audio development and the WebGL API (Parisi, 2012) for graphics and interactivity. //

Just as the Internet offers huge potential as a shared musical performance space (Jin, 2015), it also has other great applications for the arts. That can be found in examples like music production on cloud tools (Morandi, 2017), automatic audio mastering (Najduchowski, 2018) and collaborative code editing (Fiala, Yee-Kind & Grierson, 2016). Which is the example of Soundtrap[16], LandR[17] and CodePen[18]. Some of these tools found across the internet may not be done specifically to and for artists, and not at all correlated with artistic performance. But might be interesting to study as a potential use case.

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[16]Soundtrap main website https://www.soundtrap.com/ [accessed 27/06/2019]

[17]LandR main website www.landr.com/ [accessed 27/06/2019]

[18]CodePen main website https://codepen.io/ [accessed 27/06/2019]

2.1.7   Intermedia and Digital Interfaces

There is a lot of interesting work from artists all over the world trying to merge technologies together, and there is also a great desire to extend the human senses in art.

Artists of course also explore that field, and one way of doing that is to merge technologies together and messing around with different feelings. An example of that might be the work of Neil Harbisson (2013), audiovisual artist and president of the Cyborg Foundation[19] who implanted a sensor in his brain to perceive colors using their frequency range and transmitting it to his brain (Bryant, 2013), this allows the artist to "hear" colors. This intervention in his body was considered one of the most shocking post-human transformations of all times alongside the extreme performances of Yoko Ono and Marina Abramović (Jones, 2013).

The artist Stelarc, pseudonym of Stelios Arcadiou, might also be worth mentioning as one of the most important artists trying to push the boundaries of human perception and capabilities, known for his transformation of the ear in his arm, performances like the "Third Hand" in his body (Paolo & Kirk, 1995) and for texts like *"From Zombie to Cyborg Bodies - Extra Ear, Exoskeleton and Avatars"*.

These extensions are just like the multimodality of an instrument and it's propagation, sometimes through different media. It's a barrier that is designed by each medium broken when necessary, from technological methods to the human body. Using the iconic phrase by McLuhan (1964) *"We have already extended our senses and our nerves by the various media"* we all understand the intentions of these analogies.

Coming back to the audiovisual domain, sensory associations between color and music are found across many cultures as well. One of the earliest is the Pythagorean quest to assign a particular color to each musical note, but in more recent times we have more people involved in synaesthetic experiences like Charles Baudelaire, Wassily Kandinsky, Sergei Eisenstein, and Richard Feynman (Ione & Tyler 2003).

We know of Kandinsky's interest in *"colored hearing"*, and also Nina Kandinsky, his wife, wrote that he passionately loved colors from early childhood and claimed to distinguish a particular smell and musical sound for each color, a common synesthetic trait (Kandinsky, 1947, p.9).

These analogies are also a bridge to the word media art and new media art, whatever that means. The structures that are built take advantage of one media as extension of another. The terms *transmedia*[20] and *crossmedia* are important on this matter but in regarding this particular example *intermedia* might be more accurate. We have to realize the importance of the term *intermedia*, brought to us by the composer and poet Dick Higgins, also part of the group Fluxus (Smith, 1998). The expression says that when two or more discrete media fuse conceptually, they become *intermedia*, they then difference from mixed media, being inseparable from the essence of the work of art (Longhi, 2002; Higgins, 1984:138).

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[19]Cyborg Foundation main website https://www.cyborgfoundation.com [accessed 27/06/2019]

[20]
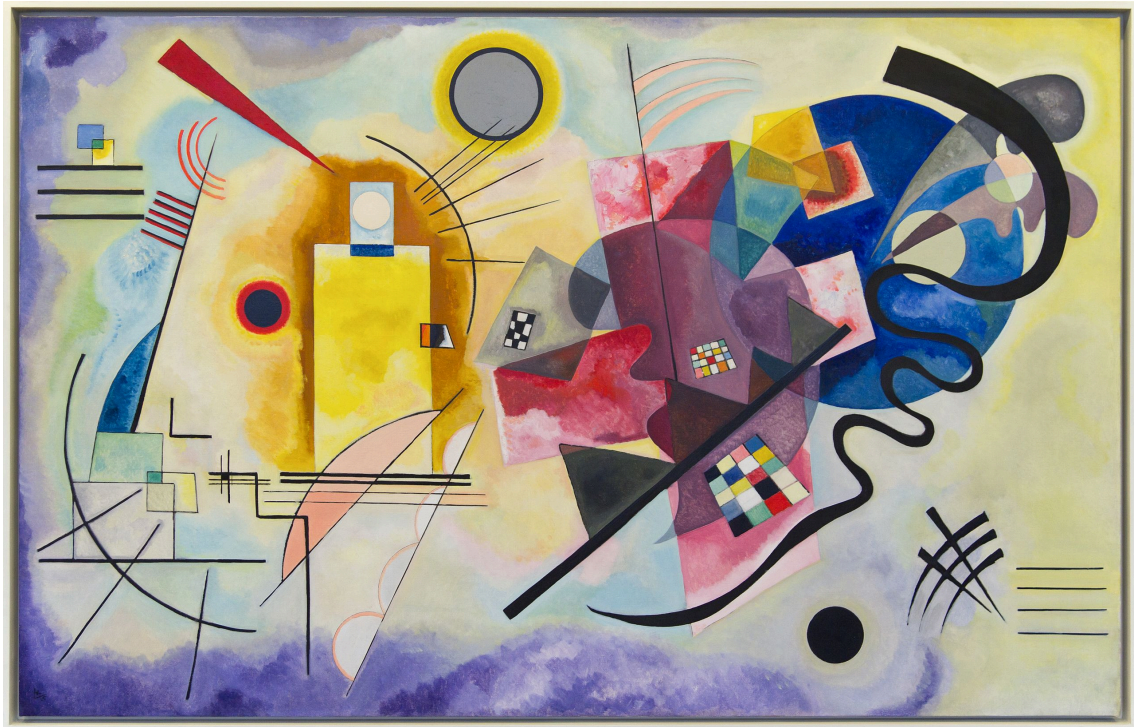
Figure 2.10: Kandinsky's Yellow-Red-Blue (1925) is from his period of totally non-representational works, but this particular painting seems evocative of the concept of a person experiencing vivid 'synesthetic' imagery. Oil on canvas, Musée National d'Art Moderne, Centre Georges Pompidou. Reprinted with permission: Réunion des Musées Nationaux/Art Resource, NY. 2003 Artists Rights Society (ARS), New York/ ADAGP, Paris. Amy Ione and Christopher Tyler on Neurohistory and the Arts.

2.1.8 Contemporary Media Art

As quoted in the first chapter, this research is carried out in the context of Braga Media Arts, having a very close relation with media art practice.

Created in 2004, the UNESCO Creative Cities Network (UCCN) promotes cooperation with and among cities that have identified creativity as a strategic factor for sustainable urban development. With the growth of this network, UNESCO aims to place creativity and cultural industries at the heart of the cities development plans and to promote an active cooperation between them[21].

Since its foundation, Braga has been in the avant-garde of its different contemporary scenarios, wether it was under the roman empire or during the sumptuous baroque period. With each challenge, the city has become richer in diversity and more curious about near future.[22].

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[21]Citation of the UCCN page on Braga Media Arts Website http://www.bragamediaarts.com/en/uccn/ [accessed 27/06/2019]

[22]Citation from Braga Media Arts official Website http://www.bragamediaarts.com/en [accessed 27/06/2019]

2.1.8.1 Media Arts Definition

There are many definitions of Media Arts. For Braga Media Arts we start with the concept of Media Arts as an integration of new technologies into artistic and creative practice, as well as in social exchange and innovation. This includes disciplines such as video games, digital animation, digital and interactive art, sound art, film and digital video, digital television and the use of technology in the performing arts[23].

2.1.8.2 Educational Department Goals

New technologies have revolutionized the world of artistic creation, extending it to new artists and, above all, new arts. In some cases democratizing while in others isolating. The Braga Media Arts Educational Service takes this space between creation, Media Arts and the community. Relying on new technologies, it encourages the consumption of art, performance, creation and development of tools and knowledge. The goals should be achieved through a transversal programming that serves the community using media as the basis of development[24]. As a connection link to other media art cities around the world, Braga Media Arts alongside gnration[25] gallery has hosted artists worldwide referenced like Ryoichi Kurokawa[26], Lucas Paris[27] and Nonotak[28].

Figure 2.11: Image with both the official logo of Braga Media Arts (left) and the official logo from UNESCO's UCCN (right).

2.1.8.3 Towards Media Arts Practice

Wunschmaschine und welterfindung which alludes to two specific aspects of technology is one example for this matter. It reflects in aspects of technology, more specifically to both its visionary potential as an object onto which to project fantasies and desires, having the power to invent the world (Büscher et al., 1999). Also, in 1997, Felderer (*Eine Geschichte der Technikvisionen*) states that technology-based visions are to be seen as mnemotechnical structures that allow to think the unimaginable, to project an image to the never-before-seen... *"Technology as content*

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[23]BMA public definition on Media Art practice.

[24]Public objectives of BMA Educational Service as a diffuser of artistic activity.

[25]gnration main website http://www.gnration.pt [accessed 27/06/2019]

[26]Ryoichi Kurokawa main website http://www.ryoichikurokawa.com [accessed 27/06/2019]

[27]Lucas Paris main website http://lucasparis.ca [accessed 27/06/2019]

[28]Nonotak main website https://www.nonotak.com accessed 27/06/2019]

and medium is in this sense a continuous transgression of boundaries."

As points of reference and diffusion of artists and art we have several centers and global events that can be cited. With a quick step back in history we have (*la biennale di venezia*), cited here as one of the biggest examples of new media art practice. We can find works of artists in this venue like Marcel Duchamp, Brian Eno and the canadian David Rokeby. Also, a privileged point of encounter is the Ars Electronica festival in Linz, Austria (Manovich, 2003). Ars Electronica came about in 1979 as a renewed version of the Bruckner Festival, an event devoted to contemporary music accompanied by an academic symposium (Quaranta, 2016; Leopoldseder, Schöpf % Stocker, 2004). The European Media Arts Festival[29] is also a big reference alongside with the Print Screen Festival[30]. On the east we also have the Microwave Festival (started in 1996), a big reference on worldwide new media art. Both in Germany we have the Transmediale[31] festival and ZKM (*Zentrum für Kunst und Medientechnologie*) a cultural institution in Karlsruhe. On this matter, the PhD *Artificial Aesthetics: Creative Practices in Computational Art and Design* (2016) by Miguel Carvalhais and the book *Beyond New Media Art* (2013) by Domenico Quaranta are both great references on literature.

"What is the need of new media as a separate domain if the computer is being integrated in all existing art forms anyway? For instance, theatre itself becomes one digital trajectory, from concept, production, stage design, light, music to promotion and ticket sales. It doesn't need the specific new media arts insights. The same could be said about performance, dance and film" *(Lovink, 2007)*

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[29]European Media Arts Festival main website https://www.emaf.de/de/index.html [accessed 27/06/2019]

[30]Print Screen Festival main website https://www.english.printscreenfestival.com [accessed 27/06/2019]

[31]Transmediale main website https://transmediale.de [accessed 27/06/2019]

2.2   State of the Art

This section will explore and present recent examples of works that influence and are also a current reference to the state of the art of this research. A singular distinction/explanation will be made of both works and creators alongside it's academic references. All these examples exist in the context of the academy, published in international theses, articles or conferences.

- Shoggoth

Network advances have fostered a unique approach to live electronic music that facilitates collaboration in a field where solo performance is perhaps more common. Furthermore, the interdependencies, presentations, locations, and structures of these groups introduce new variables with regards to the perception of liveness and embodiment for both performers and audiences (Follmer, 2005). For embodiment in electronic music performance is worth looking at Shoggoth, a software for performing network music in a 3D graphics environment by Chad McKinney (2016) on the thesis *Collaboration and Embodiment in Networked Music Interfaces for Live Performance* done at the University of Sussex for the degree of PhD. This framework allows real–time group performance with members distributed over potentially global distances and was presented in the Network Music Festival (2013). The Shoggoth network implementation uses OSC (Wright, 2002) and messaging with OSCpack (Bencina, 2013) for communication. Also part of this PhD is presented a framework for live coding that uses browser technologies and allows real-time collaboration, Lich.js (McKinney, 2014). This JS abstraction was created to achieve several goals including quick collaboration, graphics and audio live coding.
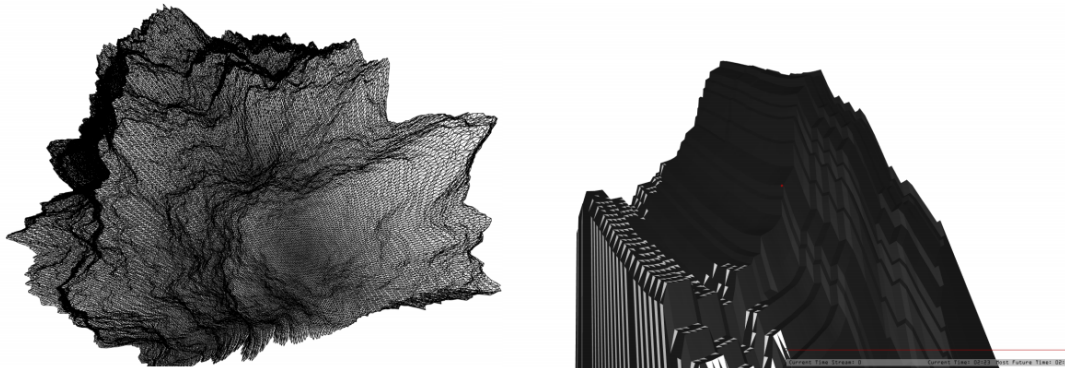
Figure 2.12: Two screenshots of possible shapes that Shoggoth can graphically generate. These were found on Chad McKinney's PhD document (2016)

- GroupLoop

Presenting a work that explores the internet and the browser as a carrier medium, offering collaborative experiences in instrument design, we reference *GroupLoop*. A browser-based, collaborative audio feedback control system for musical performance done in MIT media lab (Ramsay & Paradiso, 2015).

This work uses the internet as a carrier medium to connect the various users allowing each one a singular audio stream collaborating in complex feedback loops. Users are able to shape the feedback sounds real-time by adjusting sonic properties and explore multiple channel interactions.This work was presented at NIME 2015 as a collaborative musical instrument using browser based technologies and debutted in a live performance by three trained musicians.
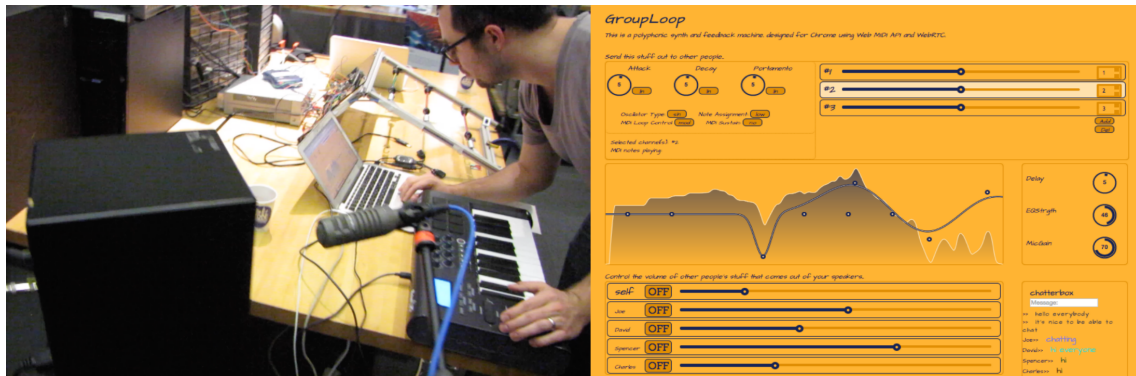
Figure 2.13: Picture on the left is a photograph of a performance in MIT media lab using GroupLoop on the right a print screen of the web interface found online.

- Fingerprints

Fingerprints is an improvised performance presented at the International Conference on Live Interfaces 2018 (Kirkbride, Cheesman & Johnson 2018). It was performed by the Yorkshide Programming Ensemble (TYPE) and uses a real-time concurrent multi-user text editor. While performing, the artists were able to share the same text buffer and write their own code while also interacting with code written by their co-performers. The text editor was presented in SMC 2017 (Kirkbride, 2017), and is configured to use the TidalCycles, FoxDot[32], and, most recently, SuperCollider live coding languages.
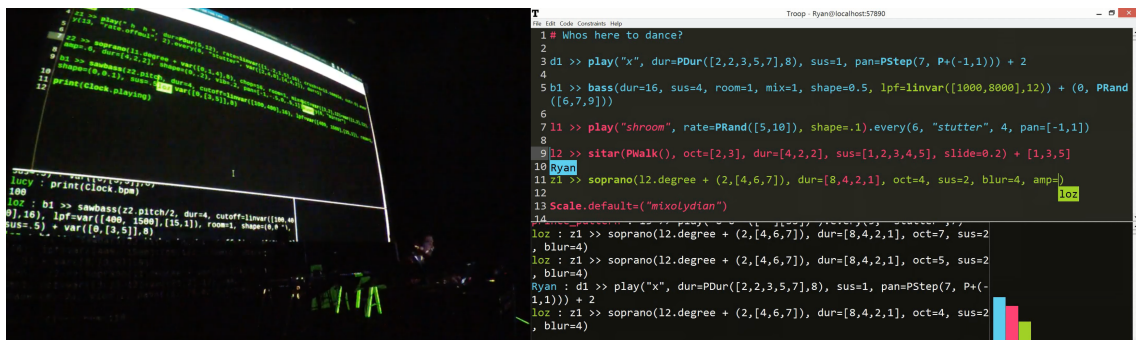
Figure 2.14: Picture on the left photograph of the performance Fingerprints in Passos Manuel (Porto) in ICLI 2018. On the right a print screen of the editor used, Troop.

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[32]FoxDot main website https://foxdot.org [accessed 27/06/2019]

- Waveguide

Waveguide is an AV performance by Andrew Blanton that uses the internet as a resonant body for drums. By sending data from drums to a server and back through the audience's cell phones in real time, the work uses the array of cell phone speakers to create an immersive AV environment. Each phone of the audience acts as an individual small speaker, screen, and interactive environment, allowing for real time dispersed audience interaction with the work as it is performed (Blanton, 2019). Waveguide was presented in Soundwave ((7)) Architecture, a part of "Augmented Environments" on September 3rd, 2016 at Gray Area Theater (Blanton, 2016). Also at the previous LAST Festival on March 23rd, 2018 Andrew presented his work Waveguide as part of his presentation *"Sound in the Machine"*.

Andrew works at the exploration of sound and software, maintaining a very strong relationship with classical music as a drummer. His current work focuses on the emergent potential between cross-disciplinary arts and technology, building sound and visual environments through software development, and building scientifically accurate representations complex data sets as visual and sound compositions.

Figure 2.15: On the left picture of the performance by Andrew Blanton on Soundwave and on the right a picture of the graphical content displayed on the screen throughout the performance.

- MalLo

MalLo is a distributed, synchronized instrument for music performance that explores the potential of the internet as a music listener, predicting a musician's action before it is completed. It was presented at NIME 2015 and the article demonstrates an interesting system architecture the authors used to mitigate the internet latency (Jin, Finkelstein & Fiebrink, 2015). To reduce the risk of sudden, severe congestion delaying receipt of the prediction, the authors have constructed a multipath forwarding system that uses a series of servers throughout the internet, hosted on Amazon EC2[33] and other commercial hosting companies. These servers are placed in multiple strategic geographic locations so as to create diverse routes through the Internet.

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[33]Amazon EC2 main website https://aws.amazon.com/ec2/ [accessed 27/06/2019]
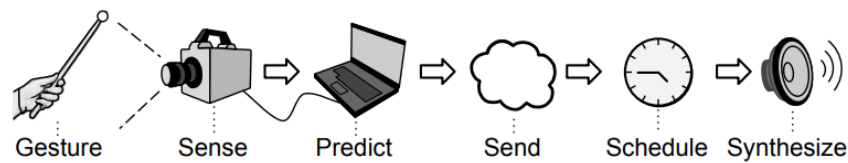
Figure 2.16: An example of a distributed, synchronized musical instrument (DSMI). The instrument is composed of various parts that exist in different locations. It uses prediction in order to synthesize the same audio in each location at the same moment. It capitalizes on the predictable path of a percussion mallet in order to accomplish this goal.

- Yig

Yig is presented as a real-time network music performance environment by Chad Mckinney and Nick Collins at SMC 2012 in Copenhagen. This system, being designed for real-time performance, some design decisions seek to streamline actions necessary to create and manipulate sound while preserving depth and flexibility. This offers multiple audio render contexts and possibilities and Yig also explores the relationships between sound and user action with a GUI (Correia, 2013; Mckinney & Collins 2012) that has some similarities with the ReacTable (Jordà et al., 2007). Yig was performed in places like ICMC (September 14th, 2012 in Slovenia) and in the Network Music Festival (January 28th, 2012).
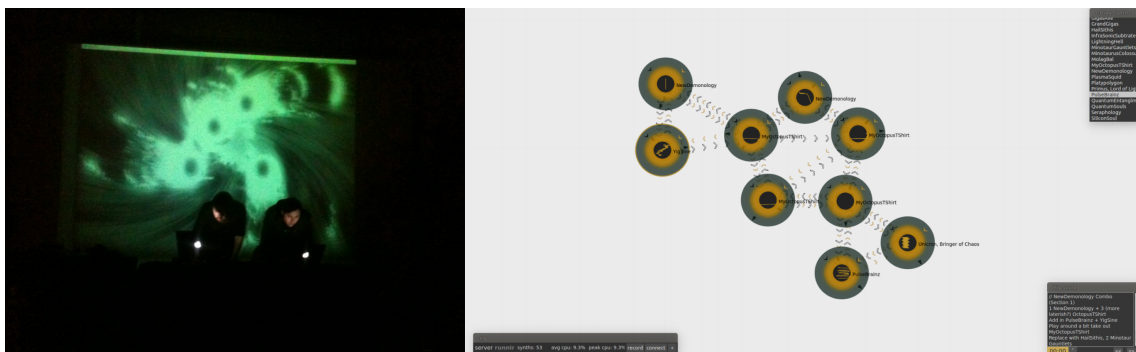
Figure 2.17: Picture on the left is a performance at the 2012 Network Music Festival in Birmingham (UK) with Yig and on the right is a screenshot of the software's GUI.

- *cellular*

cellular is the name of a performance for soprano saxophone, vibraphone, live electronics and the audience members' smartphones. This artwork was commissioned by the INESC-TEC institute and explores large numbers of distributed interfaces on live performance. The first goal was also to serve as a test case for the *a.bel* platform, a project that explores real-time interaction of the audience as agents of participation using portable devices. This work was presented in Casa da Música (Porto, 2015) and in Berklee College of Music (Boston, 2015). The première included

pieces from Rui Penha, Neil Leonard, José Alberto Gomes, and Carlos Guedes. *a.bel* was also published in the International Conference on Live Interfaces as a novel mobile application for audio networking (2015).

Figure 2.18: On the left is a photograph of one of the performers at the concert presented at Casa da Música and on the right is a photograph of the public interacting via mobile at the concert held at Berklee.

- Monad

Monad is presented at NIME 2016 as a novel multimedia system for networked musical collaboration that can be shared by multiple participants to collaborate remotely on a musical performance. In this work audiovisual aesthetics and network architectures are explored to ease the problems of delay, data loss and and reduced agency of users. (Çakmak, Çamci, & Forbes, 2016). Participants draw and manipulate virtual objects, resulting in animation and sound. The system works in a server-client relationship, where all players are clients and the server holds the virtual object data which the clients interact with.

Figure 2.19: Picture on the left is a public performance of Monad with remote players in Istanbul, Vancouver and Berlin. On the right a screenshot of the software's GUI.

- SMARTPHONY.IO

At WAC 2016 in Georgia Tech was presented a concert for two violins, one cello and an audience of smartphones. The performance involved audience participation with their mobile

devices organized, reproducing different noises, samples, and synthesized sounds from random locations in the hall. This performance is a solid example of what can be accomplished with a node.js server, instantiating various sound generators and propagating in the vector of connected users using mobile phones as playback machines. This performance was also presented at the Herzen University and Cross Art festival (2015), both in St. Petersburg, Russia. This artwork has clear relationships with *Telesymphony* by Golan Levin and his mode of performative interaction. The cellphones of the public were also remotely controlled by Andrey Bundin.
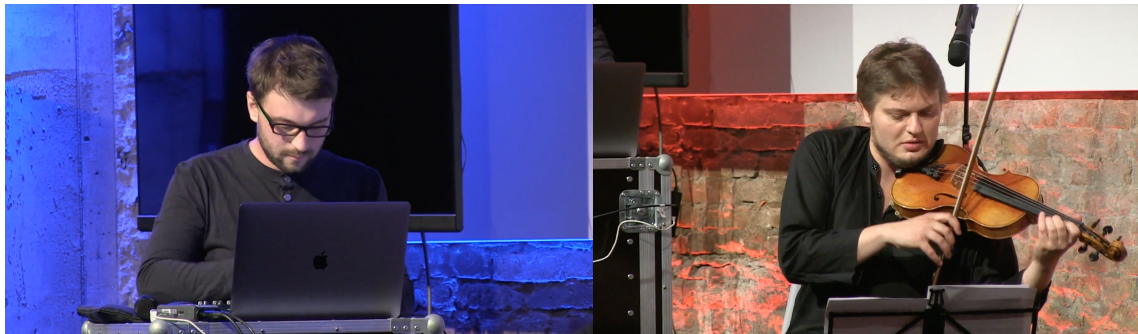
Figure 2.20: Two pictures of the *Concert for Smartphones and Orchestra* in Georgia Tech (2016) during Web Audio Conference (WAC). On the left Andrey Bundin on electronics and on the right as violin, Alexey Kotchetkov.

As said earlier, the internet is a place where people tend to work on a lot of different ideas collaboratively (sometimes singularly), and we can find incredible examples of instruments development sometimes never done in the academic context that actually can be a reference. That is the example of works like Simulacra[34], the Chrome Experiments Lab[35], the Multi-player Piano[36], and Blockdust[37]. There are also projects that fit in this section but don't particularly use the web nor web technnologies. Projects like *Tempest* (Vigroux & Schmitt, 2012); *STM Duality* (Sanz & Barandun, 2015) and *Imposition* (Schwarz & Edisonnoside 2012) (Carvalho, 2018).

To use technology as a new mean of artistic expression is very important, evolution for the individual by the individual. (Stelarc, 2011).

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[34]Official repository of the author https://github.com/ChadMcKinney/Yig [accessed 27/06/2019]

[35]Official website for Chrome Experiments lab https://experiments.withgoogle.com/collection/chrome [accessed 27/06/2019]

[36]Official website for the Multi-player Piano http://www.multiplayerpiano.com [accessed 27/06/2019]

[37]Official website for Blockdust https://blokdust.com [accessed 27/06/2019]

2.3   Conclusion

On the basis of this extensive text, and with this group of references raised, sometimes different in many aspects, a practical part will be performed using some of the characteristics found across all of them.

Structuring relationships on collaborative networked systems and AV interaction, we present Akson, a digital environment as product of this research. We will document and explain the whole process of conceptual and technical development on the next chapter of this document.

With an approach following the guidelines of practice-led research (Liamputtong & Rumbold, 2008), we create a strong bond with artistic performance, making experiments during the research period. The outcome of all the references raised in this document as literature and as contemporary practice on the field are what we consider to be the foundations of Akson.

Chapter 3

Akson Environment

Akson ('æk,son) is the digital environment presented in this research, and this chapter presents it's conceptual and technical development in detail. The following sections are made in order to demonstrate the entire process of evolution with an intensive explanation of the potentialities, their references and the interface.
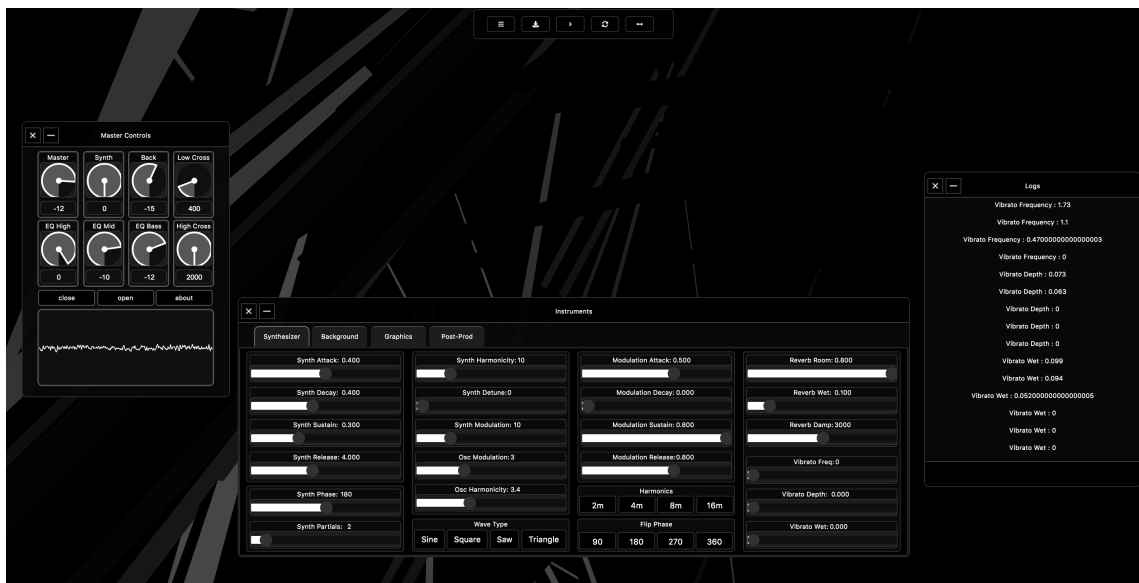
Figure 3.1: Print Screen of Akson took by the authors.

3.1   Overview

To start to explain the whole existence of Akson, it might be a good practice to define one of the biggest conceptual reasons it has, as an environment. Akson is a bridge, a linking current between people, between devices and between audio/graphics. Akson is also called so due to the cerebral organization of the Axons. If we look at the neural architecture of a human brain and

try to understand the structure that neurons create, we realize that the Axon is the medium that a neuron uses to establish contact with another neuron (Arbib & Aleksander, 1995).

The nervous tissue (or neural) is composed of nerve cells (neurons), supported by cells in the glia. Neurons are the cells essential for brain activity. In our brains there are billions of these neurons organized in local circuits, which in turn constitute subcortical regions. Neurons have three important components: a Cell Body, Dendrites, and the Axon. Neurons are interconnected in circuits where there is the equivalent of conductive wires (axon fibers of neurons) and connectors (synapses, the points at which axons contact the dendrites of other neurons) (Damásio, 1994).

The way the Akson structure is originally thought, is a bit like brain activity, and not just an analogy to the Axons as connection links. The bundles of axons traverse the brain substance in the white mass, connecting different regions of the cerebral cortex. Some regions are local, between regions of the cortex separated by small millimeters, while other connections bind regions that are far apart, such as, for example, cortical regions from one of the cerebral hemispheres to cortical regions of the other (Purves et al, 2004; Damásio, 1994).

This is fundamentally how we should look at Akson in terms of scale and network structure. The neurons exist in the network of the brain, that by itself exists in the network of the body, that exists in the network of the society. Akson also exists as a network, in the network of the Web that by itself interfaces with other networks across the world. It also creates smaller structures with people that are currently in the same interaction model (see section 3.7), between devices and between audio/graphics.
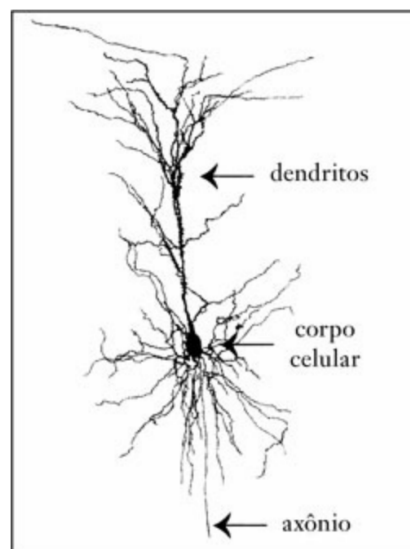
Figure 3.2: Courtesy of Publicações Europa-América. Image in *O Erro de Descartes* by António Damásio. Diagram of a neuron with it's principal components: Cell Body, Axon and Dendrites.

This analogy to the human body and the structures in which it is submerged is undoubtedly one of the most important concepts that defines Akson. It is also a possible way of interpreting it as an interface and/or for other types of intersection between different media, spaces and people.

3.2   Akson and Web Technologies

Akson technologies rely on the Web and it's programming interfaces, allowing every device that can connect to the internet to use the system. It has server-side programming to define different modes of interaction (interpersonal and singular), and front-end for Audio and Graphics generation/playback. This way it's possible to have general control capacity between users (artists or audience) and establish interaction methods inside the network.

In the beginning of this research the code started to be allocated in the Heroku[1] infrastructure, a cloud application platform that has similar properties to the Amazon AWS[2] cloud computing services. And the version control of the code was done through GitHub[3], a common software development platform. These interfaces have cross integration to make it easy to deploy digital systems. On the next figure we have a diagram that shows the work-flow adopted for the code development in this research.
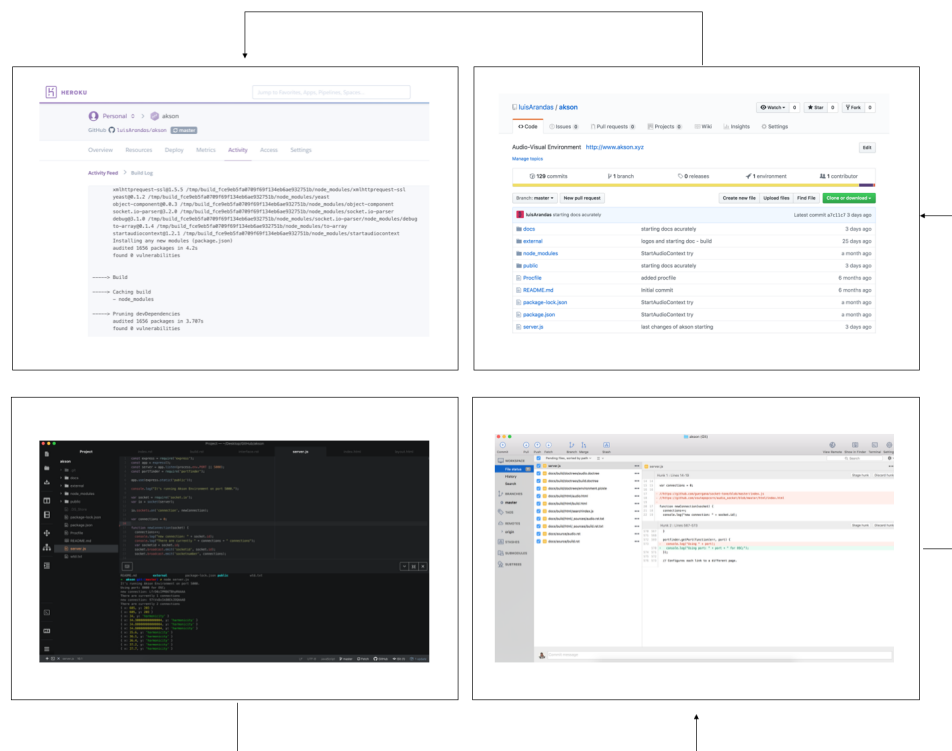
Figure 3.3: Starting on an open source code editor Atom (bottom-left) and then uploading it to the cloud through SourceTree (bottom-right) an open-source Git GUI software. When the system is fully updated we have the GitHub interface of the Akson repository with all the code commits that by itself interfaces directly with Heroku pipeline.

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[1]https://www.heroku.com/home [accessed 27/06/2019]

[2]https://aws.amazon.com [accessed 27/06/2019]

[3]https://github.com [accessed 27/06/2019]

Cloud services that offer Unix machines for people to use, normally interface with several programming languages and/or libraries. In this research, we use node.js[4] (Teixeira, 2012; Tilkov & Vinoski, 2010) for backend programming. This is a JS runtime built on Chrome's V8 JS engine. A Google's open source high-performance JS and WebAssembly engine, written in C++ (Gray, 2009). node.js libraries were managed through npm[5] (Wittern, Suter & Rajagopalan, 2016), static file serving through express[6] (Bush & Linden, 2016; Holmes, 2015) and the connections between users were managed through socket.io[7] (Cadenhead, 2015; Rai, 2013; McCaw, 2011), a library for real-time web applications that enables two-way communication between web clients and servers. With the server handling the connections and the behaviour of client pages, it was then possible to start developing the AV system on top of the Web Audio API (Roberts, Wakefield & Wright, 2013; Wyse & Subramanian, 2013) and the WebGL API (Parisi, 2012; Marion & Jomier, 2012). A better description of the AV engine will be done in the next points of the chapter.

There are online resources that support the assessment and understanding of this research. The main code (with the progress placed in time) can be found on *https://github.com/luisArandas/akson*. Documentation regarding the code can be found on *https://akson.readthedocs.io/en/latest/index.html* (an open-source and free documentation platform). And sound tracks from the public experiments done with Akson (see chapter 4) can be found on *https://luisarandas.bandcamp.com/album/akson-environment*.
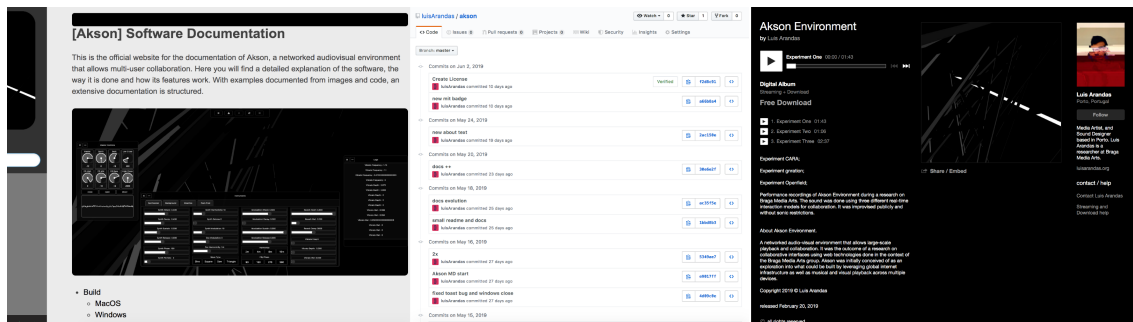
Figure 3.4: On the left, screenshot of the offical readthedocs website. On the middle, screenshot of the *commits* tab in GitHub. On the right a screenshot of Akson's bandcamp with music from public experiments.

3.3   Audio Engine

As previously mentioned (section 3.2), the sound system is built from the Web Audio API. This is a high-level Web API for processing and synthesizing audio in web applications. It involves handling audio operations within an audio context, and has modular routing. It is designed carefully to allow a powerful and versatile way for controlling audio on the Web (Kleimola &

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[4]https://nodejs.org/en/ [accessed 27/06/2019]

[5]https://www.npmjs.com [accessed 27/06/2019]

[6]https://expressjs.com [accessed 27/06/2019]

[7]https://socket.io [accessed 27/06/2019]

Larkin, 2015; Smus, 2013). Technically, the Akson sound system is made using native JS (Flanagan, 2002) and the library tone.js (Mann, 2015). In these libraries are constructed the two main divisions in the sound system. The Synthesizer (Lead) and an Auto-Filtered Noise generator (Background). These have individual controls on their methods/functions as abstracted classes of the system. There is also the possibility to define the notes the current Synthesizer is going to play, and detailed explanation on the interface will be made in section 3.6.

3.4   Graphics Engine

The graphics system is built from WebGL (section 3.2), an API used to create 3D graphics in a Web browser. Based on OpenGL ES 2.0, WebGL uses the OpenGL shading language, GLSL, and offers the familiarity of the standard OpenGL API (Angel & Shreiner, 2011). Because it runs in the HTML5 Canvas element, WebGL has full integration with all DOM interfaces (Anyuru, 2012).

Akson has four technically arranged scenes as objects. They have multiple AV properties unique to each other, allowing interaction with the instrument's methods without requiring a GUI. As the user uses the capabilities of the interface, they are allocated dynamically in the space of the web page. The graphics system uses native JS and the three.js (Dirksen, 2013) library. A project that creates a lightweight 3D graphics library with a default WebGL renderer.

3.5   Instruments of Akson

The Akson is originally designed having four main divisions as a group of instrumental potentials. As cited in section 3.3 there are two main divisions in the sound system (Lead and Background), one called Graphics (to control mainly methods in the various graphic scenes) and another called Post-Prod which has general AV controls in the environment. The various distributed methods belonging to each part can be accessed by the Instruments panel found in section 3.6.3.2.

The division of Akson's experience into these four parts is also explored in the various modes of interaction (see section 3.7).

3.6   Interface

To experience Akson, the user does not need to deal with code or understand how the technologies described in this document work in the first place. One can access the current host by typing in a browser *www.akson.xyz* or download the last standalone version from GitHub tab *releases*. The cited DNS serves the current server used in Heroku. It is recommended to use Chromium-based browsers, the main target of this project. Chromium[8] is an open-source web browser project

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[8]Chromium main website https://www.chromium.org [accessed 27/06/2019]

in which Google Chrome bases its source code.

As mentioned in section 3.4, Akson is divided into four scenes (fig. 3.5). These allow interaction by the computer mouse and/or touch screen, exploring different sound properties/methods of the system. Sonically, the first and fourth scenes (counting in figure 3.5 from left to right) explore methods relative mainly to Lead, and the second and third explore mainly to Background.

Figure 3.5: Screenshots of the four graphical scenes of Akson in their default state.

In the following sections the relationship between graphical interaction and sonic feedback will be explored in depth. These relationships are also broken down by a custom GUI that can be found when the user connects by Desktop (section 3.6.1). Also, WebGL is a DOM API, which means that it can be used from any DOM-compatible language: JS, Java, or—if you embed WebKit into an application on a Mac — Objective C (Thiemann, 2005).

- Interaction on the First Scene

    - Here the user is able to play notes on the main Synthesizer (see section 3.6.3.2) by clicking the instantiated geometries. When Akson begins, objects are instantiated and it's possible to formalize interaction through raytracing[9]. This allows AV feedback from a custom perspective. The instanciated geometries change color on click (for all users).

- Interaction on the Second Scene

    - The second scene lets you control Background properties in the form of rotation of the contained geometry. This scene creates a custom dodecahedron with vertices scattered across space that by itself controls multiple instances of the Background domain of Akson. A more detailed explanation on the methods can be found in fig. 3.9.

- Interaction on the Third Scene

    - The third scene creates a new instance of geometries that occupy the whole field of the web page. These geometries can be controlled by the XY position of the mouse/touchpad and also control methods of the Background domain. By moving through the web page the user can have a dynamic view of the object.

- Interaction on the Fourth Scene

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[9]three.js Raytracing/Raycaster documentation https://threejs.org/docs/api/en/core/Raycaster [accessed 27/06/2019]

– The fourth scene has a run look similar to the first but with a different aesthetic and controlling different methods of the Lead. Here the master synthesizer is played by playing notes when there is human interaction. The instantiated geometries may be in *wireframe* mode, and the colors may also be different. These visual aesthetic choices then have repercussions on the type of sound played.

Regarding AV relationships. As the behavior of these systems may be tied to different factors, a perspective on interaction is not solely focused on action-reaction patterns, but on the overall variable behavior of the work, in each occurrence and in response to interaction (Ribas, 2013). These relationships are also explored collaboratively among users who share Akson, a more detailed explanation in modes of interaction can be found in the section 3.7.

3.6.1 Desktop

Akson is an audio-visual instrument that allows interaction on the browser screen directly with the graphics generated, but also has a more conventional GUI composed of dials, sliders and buttons (section 3.6.3). This GUI is found on computers (both Desktop and Laptop) and can be enabled/disabled from the space bar on the keyboard (keyboard functions in detail can be found in section 3.6.3.5). Warranties are not guaranteed to work on tablets (both iOS and Android) due to the volatility of machine types (in size and specs) but it is always possible to call the virtual keyboard.

In the next sections we explore the various types of interfaces created for Akson, how they can be used and what they contain. There is a main bar at the top of the window, there are interfaces in Dialog[10] format and Modal[11] format. They are built using the Nexus open-source project (Allison, 2011) that has a set of nexusUI JavaScript objects (Allison, Oh & Taylor, 2013) demonstrating many dynamic functions that can be done within the canvas object inheriting from HTML5 DOM. Akson has 64 sliders, 109 buttons, 8 dials and bidirectional socket connections for all of them.

3.6.2 Mobile

On mobile phones, Akson exists in a specific way and a bit different from computers. It removes all GUI, allowing only the interaction with the scenes through the touch screens. Whenever the server recognizes an input, it questions what kind of interface it is. If it stays on the type of interface recognized as mobile phone, then Akson will run this way.

Devices of this kind also allow you to interact with scenes and play content. There is also an adopted characteristic made to allow a large-scale controlled experience. If there is a device in the

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[10]Dialog definition on Computer Hope https://www.computerhope.com/jargon/d/dialogbo.htm [accessed 27/06/2019]

[11]Modal definition on Computer Hope https://www.computerhope.com/jargon/m/modal-window.htm [accessed 27/06/2019]

Desktop/Laptop category (see section 3.6.1) changing the scene, the mobile phones also change. In this way, it is possible to interact remotely (without GUI and without AV content streaming) with large quantities of mobile phones with potentially large distances and to reproduce content in a coherent way. It also allows us to think of them as resonant machines in space (Blanton, 2019; Henriques, 2015) as a distributed array of speakers.
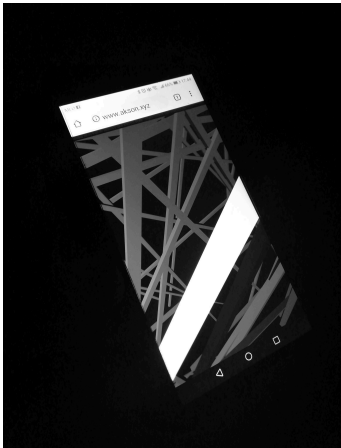
The figure on the left is a photograph of a Huawei P10-Lite mobile phone connected to Akson. It is an Android smart phone with a screen of 5.2 inches and a resolution of 1920x1080 pixels. With hardware from 8 Core to 1.9 GHZ and running the EMUI 8.0 system. The figure shows the default state of Akson on mobile devices.

3.6.3   Graphical User Interface

Apart from all the automatically generated graphical/sonic content and the potentialities in the interaction of the scenes, the graphic interface will be fully explained in this section. It is divided by sectors and they are illustrated with images, tables and text separated by subsections.

3.6.3.1   Master Dialog

The Master Dialog. It has effect on the main out of the browser sound/graphics system. Connected to the AudioDestinationNode[12], it provides useful conveniences such as the ability to set the volume and mute/stop the entire application. This dialog has 8 dials, 3 buttons and an oscilloscope.

On the figure 3.6 we can see (on the left) a print screen of a Master Dialog and (on the middle and right) the System dialog (opened by the *About* button). This brings up a window with information about the system where Akson is running, and explains the various models of interaction in the network (section 3.7). The information we can get from the system are functions from the *navigator* and *window* JS objects and we can compare network information and AV properties of the machine currently playing. The various interaction models are explained with references to Todd Winkler's book *Composing Interactive Music* (1998).

On the bottom of the figure we have the various widgets listed and their actions. The dialog windows of Akson are minimizable, closable and are draggable, to give freedom to the user. The

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[12]https://developer.mozilla.org/en-US/docs/Web/API/AudioDestinationNode [accessed 27/06/2019]

oscilloscope used is a JS widget that has an FFT size of 2048 and connects to the AudioNode[13] capturing the current AudioContext[14] (check section 3.3).

Nr.	Name	Result	Widget	Range	Step
1	Master	Akson main Audio Volume	Dial	-50, 0	0.1
2	Synth	Synthesizer (Lead) Volume	Dial	-30, 0	0.1
3	Back	Filtered-Noise (Background) Volume	Dial	-40, 4	0.1
4	EQ High	Gain applied to a High EQ Band	Dial	-50, 5	0.1
5	EQ Mid	Gain applied to a Mid EQ Band	Dial	-50, 5	0.1
6	EQ Bass	Gain applied to a Bass EQ Band	Dial	-50, 5	0.1
7	Low Cross	Low Crossover Frequency of the Master	Dial	20, 2000	1
8	High Cross	High Crossover Frequency of the Master	Dial	20, 2000	1
9	Close	Close AV scene	Button	-	-
10	Open	Open AV scene	Button	-	-
11	About	Triggers the System dialog	Button	-	-

Figure 3.6: Picture of the Master Dialog (top-left), the System Dialog (top-center and top-right) and a table with the various widgets and methods (bottom).

3.6.3.2 Instruments Dialog

As quoted in section *Instruments of Akson*, the various instrument methods are accessed in the Instruments Dialog. Here we have 64 sliders and 96 buttons, all with numeric display of the modified quantity and nomenclature. The Synthesizer tab has 21 sliders and 12 buttons (fig. 3.8). The Background tab has 17 sliders and 26 buttons (fig. 3.9). The Graphics tab has 20 sliders (Fig 3.10). The Post-Prod tab has 6 sliders, 58 buttons and 3 meters. (fig. 3.11).

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[13]https://developer.mozilla.org/pt-PT/docs/Web/API/AudioNode [accessed 27/06/2019]

[14]https://developer.mozilla.org/pt-BR/docs/Web/API/AudioContext [accessed 27/06/2019]

- Synthesizer Tab

  – The Synthesizer tab is the default when it opens. Here the Lead is controlled, the main properties of the instantiated class (Synthesizer with 6 voices) and the effects (Reverb and Vibrato). It is also possible to change the wave type, the phase in degrees (functionality created to hit several users together) and harmonics. Below the panel in the figure we can see the various properties and groups of methods. Here we have the result of the widget when used, the class (so it's easier to use the code), range, name, step and GUI type.

- Background Tab

  – The Background tab has the properties to control the Filtered Noise (Background) source. Here we have methods that allow us to use the noise source as an instrument applying common synthesis models found in digital applications. There are methods like *Frequency Time*, *Rolloff*, *Filter Wave Type* and various attributes of the applied filters (Reverb and Phaser). The graphic on the bottom has the same information provision as in the Synthesizer tab.

- Graphics Tab

  – In the Graphics tab we find several methods of graphic control on the scene. Akson creates a three-dimensional field when the rendering process begins (page start up) and for this creates a virtual camera and lights to focus on the geometries. The four scenes are each a 3D object with its independent controls belonging to a 3D scene that encompasses them all. In this panel we find controls for each light system in each scene like scaling methods, camera control, zoom factors and frustum aspect ratio.

- Post-Prod Tab

  – The Post-Prod tab has general controls (both visual and sonic) that operate on a global scale in Akson. This is where we find visual Shaders, four pieces of code for graphics post-processing (on figure 3.7 we can see its use in the same scene as a way of comparison). There is no sonic relationship with shading processing, it is a feature that is isolated from sound and music generation. We have also a custom scale/note engine for the Synthesizer (ordered synthesizer note groups), and Camera Offsets (useful for multi-monitor/multi-machine and/or graphical effect). These controls offer a more global power throughout Akson's AV generation affecting the environment. There is also a group of buttons that offer AV presets and three meters that have graphic information about FPS, MS and MB as performance memory (out of the *performance* JS object). On the scales object (upper right corner of the panel) we have buttons for each note (from C2 to B5), the *Clean* button and the *Scale* button. The *Clean* button will refresh the array used to draw notes to the synthesizer, and the *Scale* button (top panel

in fig. 3.10) opens a modal with various scales used in the world (bottom graphic on fig. 3.11). The scales were originally all set in C to facilitate a start pattern.
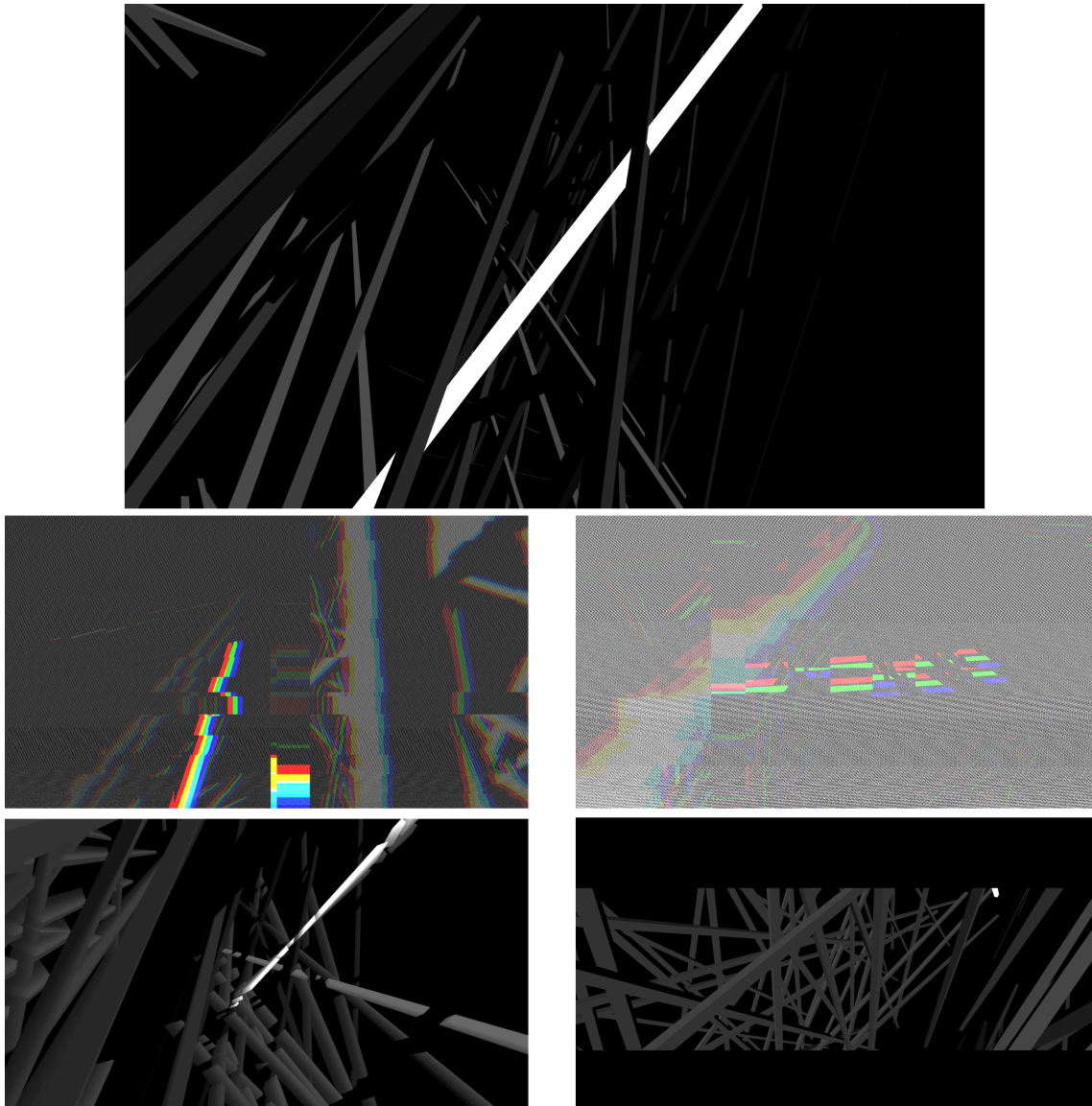
Figure 3.7: In this figure we have 5 Akson print-screens. On the first (top) we have the default visualization of Akson. On the next 4 we have the shaders used in this work. They are instances of the *EffectComposer* and multiple *Pass* objects. On the middle row we have the *GlitchPass* shader with two modes of intensity (on the instruments panel called *Glitch* and *Noise*). On the bottom row we have on the left the *afterimagePass*, a method of graphic processing that creates kind of visual entrainment sometimes compared with reverb. And on the right column we have the *Vignette* effect that adds two black tabs to the main scene camera.

3.6.3.3   Logs Dialog

The Logs Dialog was one of the first dialogs to be made in Akson and is open at the same time as the Instruments and Master dialog. It exists as an inter-user action viewer and does not allow interaction.

This object is used to visualize whenever any part of the interface is used, printing its name with the recorded value. It also has a note viewer (triggered notes of the synthesizer), global input and output controller, and also lets you know when someone connected to Akson switches interaction state (to allow multiple people to share the same mode knowing they are not alone). A screen shot of Logs can be found in fig. 3.12 middle left corner.

3.6.3.4   Top Bar

The upper bar of the Akson serves to aid in the interaction of the instrument. It's possible to use their functions by clicking the buttons or by the keyboard (section 3.6.3.5). There are 5 buttons on the bar and this is not draggable or closable (being always possible to disable the GUI). Based on the numbering of fig. 3.12, button 1 opens a Modal with a text about Akson, and its context . Button 2 opens the *Save Settings* dialog. Button 3 changes scene. Button 4 refreshes the environment, and button 5 opens the modal of interaction models (section 3.7, fig. 3.13).

The *Save Settings* dialog has Media Record[15] functions and consists of 5 buttons. It is divided into two boxes called *Save Frame* and *Save Audio*. The first one has 3 buttons, the *New Page* (opens a new tab with a camera capture), *Save to Disk* (downloads a capture from the camera) and *Save 360* (it does a 360 capture from the same camera). The second has two, *Start Audio* (just like a record button on a DAW) and *Stop Audio* (to end the recording that is running). There is also an Audio tag that works natively in browsers as an object that reads and downloads files (works with MP3, WAV, and OGG). The downloads happen exactly when the user clicks the button

3.6.3.5   Keyboard

The main functions of Akson and the most important features can be called by the keyboard. In this way it is possible to formalize the interaction with Akson in computers quickly. The various letters are arranged in fig. 3.14 and are intended for *QWERTY* keyboards, although in this document a diagram is provided with the various key codes and functions used. Thus it is possible to adjust the code to any machine.

3.7   Interaction Models

Interaction models are undoubtedly one the most important things of this investigation and of Akson. Since one of the main focuses in this whole process is in collaborative interfaces, modes of interaction are undoubtedly the fundamental point for collaboration. The way artists interact, how

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[15]Media Record Mozilla website https://developer.mozilla.org/en-US/docs/Web/API/MediaRecorder [accessed 27/06/2019]

the audience interacts (between each other and between artists) is explored in depth in the way that Akson happens and especially with the public experiments done throughout the investigation (chapter 4). In this section we will explore the three modes presented in this research, the way they are technically done and why they were chosen. Mainly supported by Todd Winkler (1998), and on his book *Composing Interactive Music*.

Akson uses web technologies, and in the first place exists in its infrastructure. This choice was made at the beginning of the research, not because it would not be possible to execute it in other efficient ways in native frameworks but to take advantage of the inherent characteristics of the internet (Stallabrass, 2010; Tribe & Jana, 2009; Stallabrass, 2003). This large, constantly evolving global network presents features clearly explored in this work as collaborative potential and as an AV extension. Thanks to the millions of access points, the simple use of a browser and the communication protocols existing in literally all the machines created in the last 10 years enable all of that.

Akson presents 3 models of interaction which are made as communication structures between users. The *descenter* mode (subsection 3.7.1). The *streamed* mode (subsection 3.7.2). And the The *allocate* mode (subsection 3.7.3). There is also the possibility to choose the *alone* mode which is the absence of interaction (stops all incoming connections and ends the collaboration).

3.7.1 First Model - *descenter*

descenter is Akson's default interaction model when the user connects. This method lets the user stream the synthesizer through every device being able to control all the other attributes of the instrument just by himself. This method is based on *The Improvisation Model*, paradigm of the *Jazz Combo* (Winkler, 1998. p.25). On the fig. 3.15 we have a diagram that shows how the modes of interaction happen between users. There is a common block called "information" which is basically an exchange of information between people by the server using the Logs dialog (see section 3.6.3.3). This way we always have graphical feedback of other people using Akson regardless of the mode.

This was the first mode to be developed. It allows a collaborative and at the same time singular experience. The only musical content that is common between instances are the notes of the synthesizer. We also have graphical display of the user actions on the geometries.

> *"We are honored to be in somebody's computer. You are very close to a person when you are on his desktop. I think the computer is a device to get into someone's mind."* (Paesmans, 1995)

3.7.2 Second Model - *streamed*

The *streamed* interaction state allows everyone to be a master. Every tiny change in the interface will stream to every user that also shares this state, and it is possible to create large-scale AV

structures. This method is based on *The Conductor Model*, paradigm of the *Symphony Orchestra* (Winkler, 1998. p.23).

The development of this mode of interaction resulted from feedback obtained after the public performance done with the *descenter* mode. After a reflection on the feedback of the participants (chapter 4, section 4.1), and supported by academic references this mode was developed. It is a model of interaction that allows everyone to do everything on everyone. In the diagram in fig. 3.15 we have the "Akson Environment" block to exchange information. This means that all the functionality inherent to Akson can be streamed bidirectionally, targeting to all people in the same mode (an example of that is the Master dialog (3.6.3.1), not explored in the *descenter* mode). Using this method it is also possible for anyone to be a single source for coordinating machines, even if they are alone in Akson. It is possible to be a conductor of all the connected machines.

> *"Concerning live performance, designers must not only consider awareness and communication between the musicians, but also their relationship with the audience." (Fencott, 2012)*

3.7.3   Third Model - *allocate*

The *allocate* mode relies on the choice of the user on what to control. This method splits the instrument in four parts (see section 3.6.3.2), and the user chooses one. This method is based on *The Chamber Music Model*, paradigm of the *String Quartet* (Winkler, 1998. p.25) and allows you to instantiate a group of people in different parts of the environment.

This method was born from feedback obtained in the interactive installation realized in the gnration (see chapter 4) and by reflection/necessity based on historical references that presented the laptop performance as classical instrumental collaboration (e.g. The Hub[16] and BEER[17] ensemble).

This way of interacting adopts a procedural model of assigning tasks in a group to several agents creating a performance with several artists influencing each other. When this interaction model is chosen, a dynamic selection process is started in Akson. A dialog with the name "Allocate System" (fig. 3.12 top) appears and you can choose one of the four instruments (section 3.6.3.2). It is possible to control one of the four at a time and the other users that share the same state (*allocate*) are arranged by the other 3. The tabs found in the Instruments tab are disabled so it is not possible for the user to control parts not belonging to their state.

> *"When laptop performance interfaces move beyond simple one-to-one mappings, they present unique ensemble challenges, particularly in terms of the synchronization and sharing of musical material. Specialized improvisation environments for specific performances (e.g. Trueman 2008) or ensembles (e.g. Rebelo and Renaud 2006) can help*

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[16]Bandcamp of Artifact Recordings https://artifactrecordings.bandcamp.com/album/the-hub-art-1002-1989 [accessed 27/06/2019]

[17]BEAST main website http://www.beast.bham.ac.uk/offspring/beer/ [accessed 27/06/2019]

groups to negotiate these challenges and structure their collaboration." (Freeman &
Van Troyer, 2011)

3.8 Code, Construction and Implementation

The whole process of Akson's technological evolution since the beginning of the research was documented from the outset. All the steps taken (commits and uploads to the servers) are recorded so that everyone can see how it evolved in time. It is possible to create comparisons with the decisions taken and to relate them to the experiments throughout the thesis process. GitHub has features as VCS that allow you to revert files back to the previous state (anytime on the research period). On the main Akson repository website *https://github.com/luisArandas/akson* you can navigate to the Code tab *https://github.com/luisArandas/akson/commits/master* and navigate the repository in time or compare the new Akson states.

Of course in computer programming some steps are taken just to solve logical problems that arise when we set a goal. These steps were taken in order to achieve a bigger challenge in the overall structure of the system, often building the features that today make Akson.

On fig. 3.16 we show a diagram of the Akson repository file tree and the folder communication flow. Starting on the Procfile (top figure), the Unix server is told to execute *node server.js*, and then the server is started. From here a *public* folder is instantiated with the *index.js* file that will read the remaining files and bridge dependencies. In the lower left corner we have the layout of the folders and files seen from the root directory and to the right the various file provisions in each folder (*docs*, *public*, *external* and *node modules*). With this set, we integrate Akson's GitHub through Webhooks (Morgan, 2018) to dynamically change the server in the United States.

3.9 Conclusion

In this chapter it's done an extensive journey to the concept, development and techniques used in the proposed environment, Akson. Here we demonstrate it's features, how they work and how they were done. It presents a finished AV environment and its evolutionary process also related to the public experiments of which it was targeted (chapter 4). There is a detailed description of the interface and the actions it has as a tool, with great emphasis on the references that influence the way of thinking that led Akson to be done.

The design of a new tool is a virtualization of many actions (Bardon & Malmborg, 1997). When someone designs a tool, instead of focusing on the action s/he focuses on something much more general. What Akson represents and means is subject of an explanation at the beginning of the chapter. It's demonstrated that the problem to be solved is greater than simply the development

of a collaborative system, of a networked system, and even greater than just building this system. It is a creator of networks. A networked environment within networks, creating networks. As an instrument and as a transmutable environment. The analogy to the organizational patterns in the human brain and the extension of the human gesture in the digital world is mentioned as main concept of its existence.

It's also done a full review of the underlying technologies used in this process. The exploration of opportunities provided by the cloud and how that was what originated the easy resolution of the interaction methods used. All the features of Akson, frameworks and libraries used are also explained.

Most of all, this chapter serves to understand the various ways of using Akson, how it works and what it represents. It divides the central components of the system in the various sections and subsections, creating pointers between them.

Nr.	Name	Result	Widget	Range	Step	Class
1	Synth Attack	Control Synthesizer Attack	Slider	0.01, 0.8	0.01	Synthesizer
2	Synth Decay	Control Synthesizer Decay	Slider	0, 1	0.01	Synthesizer
3	Synth Sustain	Control Synthesizer Sustain	Slider	0, 1	0.01	Synthesizer
4	Synth Release	Control Synthesizer Release	Slider	0, 50	0.1	Synthesizer
5	Synth Phase	Rotate Synthesizer Phase	Slider	0, 360	1	Synthesizer
6	Synth Partials	Add Synthesizer Harmonics	Slider	0, 32	1	Synthesizer
7	Synth Harmonicity	Harmonicity of the 6 Voices	Slider	0, 50	0.1	Synthesizer
8	Synth Detune	Detune main Oscillation	Slider	0, 5000	0.1	Synthesizer
9	Synth Modulation	Overall Modulation	Slider	0, 50	0.1	Synthesizer
10	Osc Modulation	Core Oscillator Modulation	Slider	0, 10	0.01	Synthesizer
11	Osc Harmonicity	Core Oscillator Harmonicity	Slider	0, 10	0.01	Synthesizer
12	Wave Type	Type Wave of main Oscillation	Button	-	Sine, Square, Saw, Triangle	Synthesizer
13	Modulation Attack	Modulation Envelope Attack	Slider	0.01, 0.8	0.01	Synthesizer
14	Modulation Decay	Modulation Envelope Decay	Slider	0.01, 0.8	0.01	Synthesizer
15	Modulation Sustain	Modulation Envelope Sustain	Slider	0.01, 0.8	0.01	Synthesizer
16	Modulation Release	Modulation Envelope Release	Slider	0.01, 0.8	0.01	Synthesizer
17	Harmonics	Harmonic at Power of 2	Button	-	2, 4, 8, 16	Synthesizer
18	Flip Phase	Flip Phase in Pi	Button	-	90, 180, 270, 360	Synthesizer

Nr.	Name	Result	Widget	Range	Step	Class
1	Reverb Room	Room property of Reverb on Lead	Slider	0.01, 0.8	0.01	Reverb
2	Reverb Wet	Wet property of Reverb on Lead	Slider	0.01, 0.8	0.01	Reverb
3	Reverb Damp	Damp property of Reverb on Lead	Slider	2000, 4000	0.1	Reverb
4	Vibrato Freq	Frequency property of Vibrato on Lead	Slider	0, 15	0.1	Vibrato
5	Vibrato Depth	Depth property of Vibrato on Lead	Slider	0, 1	0.01	Vibrato
6	Vibrato Wet	Wet property of Vibrato on Lead	Slider	0, 1	0.01	Vibrato

Figure 3.8: Screenshot of the *Synthesizer* panel followed by two tables with the various widgets functions and methods.

Figure 3.9: Screenshot of the *Background* panel followed by two tables with the various widgets functions and methods.

Nr.	Name	Result	Widget	Range	Step	Class
1	AutoFilter Freq	Rate of the AutoFilter LFO	Slider	500, 5000	0.1	AutoFilter
2	AutoFilter BaseFreq	Lower Value of the LFOs Oscillation	Slider	100, 1000	0.01	AutoFilter
3	AutoFilter Octaves	Number of Octaves above BaseFreq		-2.5, 8	0.01	AutoFilter
4	AutoFilter Q	Q of the band Filter	Slider	0, 10	0.01	AutoFilter
5	AutoFilter Wet	How much of Affected will pass Through	Slider	0, 1	0.01	AutoFilter
6	Autofilter Depth	Range of the Filter Modulating	Slider	0, 1	0.01	AutoFilter
7	Noise Playback Rate	Playback Rate of the Noise	Slider	0.5, 35	0.01	Noise
8	Noise Min	Minimum Frequency Number	Slider	100, 1000	0.1	Noise
9	Noise Max	Maximum Frequency Number	Slider	1000, 15000	0.1	Noise
10	Noise Filter Gain	Gain of Filter on Noise Source	Slider	-99, 5	0.01	AutoFilter
11	Noise Wave Type	Wave Type of Noise Generator	Button	-	White, Brown, Pink	Noise
12	AutoFilter Rolloff	Rolloff of Filter on Noise Source	Button	-	-12, -24, -48, -96	AutoFilter
13	AutoFilter Wave	Wave Type of AutoFilter	Button	-	Sine, Square, Saw, Triangle	AutoFilter
14	Noise Frequency Time	Frequency of Noise Overall Oscillation	Button	-	2m, 4m, 8m, 16m, 32m, 2n, 4n, 8n, 16n, 32n, 2t, 4t, 8t, 16t, 32t	Noise

Nr.	Name	Result	Widget	Range	Step	Class
1	Reverb Wet	How much of affected signal on Noise Source (Reverb)	Slider	0, 1	0.01	Reverb
2	Reverb RoomSize	Correlates to the Decay Time of Reverb	Slider	0, 1	0.01	Reverb
3	Phaser Frequency	Speed of the Phasing on Noise Source	Slider	0, 1	0.01	Reverb
4	Phaser Wet	How much of affected signal on Noise Source (Phaser)	Slider	0, 1	0.01	Phaser
5	Phaser Q	Quality factor of the Filters	Slider	0, 50	0.01	Phaser
6	Phaser Octave	Octaves of the Phaser Effect	Slider	0, 10	0.01	Phaser
7	Phaser Base Frequency	Base Frequency of the Filter	Slider	0, 1000	1	Phaser

Nr.	Name	Result	Widget	Range	Step	Class
1	Light Scene One	Amount of Light Emission on First Scene	Slider	0, 5	0.0001	Scene One Object
2	Light Scene Two	Amount of Light Emission on Second Scene	Slider	0, 6	0.0001	Scene Two Object
3	Light Scene Three	Amount of Light Emission on Third Scene	Slider	0, 5	0.0001	Scene Three Object
4	Light Scene Four	Amount of Light Emission on Fourth Scene	Slider	0, 6	0.0001	Scene Four Object
5	Camera Aspect	Camera Frustum Aspect Ratio	Slider	0, 5	0.01	Camera
6	Camera Zoom	Sets the Zoom Factor of Camera	Slider	0, 2	0.01	Camera
7	Camera FOV	Camera Frustum Vertical FOV (from bottom to top of view in degrees)	Slider	-170, 170	1	Camera
8	Camera Near	Camera Frustum Near Plane	Slider	1, 2000	1	Camera
9	Scene One X	Scene One Object X Scale	Slider	0.35, 3	0.0001	Scene One Object
10	Scene One Y	Scene One Object Y Scale	Slider	0.35, 3	0.0001	Scene One Object
11	Scene One Z	Scene One Object Z Scale	Slider	0.35, 3	0.0001	Scene One Object
12	Scene Two X	Scene Two Object X Scale	Slider	0.35, 3	0.0001	Scene Two Object
13	Scene Two Y	Scene Two Object Y Scale	Slider	0.35, 3	0.0001	Scene Two Object
14	Scene Two Z	Scene Two Object Z Scale	Slider	0.35, 3	0.0001	Scene Two Object
15	Scene Three X	Scene Three Object X Scale	Slider	0.35, 3	0.0001	Scene Three Object
16	Scene Three Y	Scene Three Object Y Scale	Slider	0.35, 3	0.0001	Scene Three Object
17	Scene Three Z	Scene Three Object Z Scale	Slider	0.35, 3	0.0001	Scene Three Object
18	Scene Four X	Scene Four Object X Scale	Slider	0.35, 3	0.0001	Scene Four Object
19	Scene Four Y	Scene Four Object Y Scale	Slider	0.35, 3	0.0001	Scene Four Object
20	Scene Four Z	Scene Four Object Z Scale	Slider	0.35, 3	0.0001	Scene Four Object

Figure 3.10: Screenshot of the *Graphics* panel followed by one table with the various widgets functions and methods.

Nr.	Name	Result	Widget	Range	Step	Class
1	Set View OffSet X1	Sets an Offset in a Larger Frustum	Slider	0, 5000	1,00	Camera
2	Set View OffSet X2	Sets an Offset in a Larger Frustum	Slider	0, 5000	1,00	Camera
3	Set View OffSet X3	Sets an Offset in a Larger Frustum	Slider	0, 5	0.01	Camera
4	Set View OffSet X4	Sets an Offset in a Larger Frustum	Slider	0, 5	0.01	Camera
5	Set View OffSet X5	Sets an Offset in a Larger Frustum	Slider	-5, 5	0.01	Camera
6	Set View OffSet X6	Sets an Offset in a Larger Frustum	Slider	-5, 5	0.01	Camera
7	Instrument Presets	AV Presets	Button	-	1, 2, 3, 4, 5	Multiple
8	Shaders	Post-Processing Shaders on the Scene	Button	-	Default, Glitch, Noise, Reverb, Vignette	Renderer
9	Scale [Notes]	Changes current Scale playing in the Synthesizer. Default is C Pentatonic Major	Button	-	C2, C#2, D2, D#2, E2, F2, F#2, G2, G#2, A2, A#2, B2, C3, C#3, D3, D#3, E3, F3, F#3, G3, G#3, A3, A#3, B3, C4, C#4, D4, D#4, E4, F4, F#4, G4, G#4, A4, A#4 B4, C5, C#5, D5, D#5, E5, F5, F#5, G5, G#5, A5, A#5, B5	ScalePlaying
10	Scale [Clean]	Removes all Notes from the Playing Scale	Button	-	Clean	ScalePlaying
11	Scale [Scale]	Triggers a Modal with various Scales used across the World	Button	-	Scale	ScalePlaying

Scale Modal		
Scale	Function	Notes
C Major Pentatonic	cMajorPentatonic()	C2, D2, E2, G2, A2, C3, D3, E3, G3, A3, C4, D4, E4, G4, A4, C5, D5, E5, G5, A5
C Minor Pentatonic	cMinorPentatonic()	C2, D#2, F2, G2, A#2, C3, D#3, F3, G3, A#3, C4, D#4, F4, G4, A#4, C5, D#5, F5, G5, A#5
C Major	cMajor()	C2, D2, E2, F2, G2, A2, B2, C3, D3, E3, F3, G3, A3, B3, C4, D4, E4, F4, G4, A4, B4, C5, D5, E5, F5, G5, A5, B5
C Minor	cMinor()	C2, D2, D#2, F2, G2, G#2, A#2, C3, D3, D#3, F3, G3, G#3, A#3, C4, D4, D#4, F4, G4, G#4, A#4, C5, D5, D#5, F5, G5, G#5, A#5
C Harmonic Minor	cHarmonicMinor()	C2, D2, D#2, F2, G2, G#2, B2, C3, D3, D#3, F3, G3, G#3, B3, C4, D4, D#4, F4, G4, G#4, B4, C5, D5, D#5, F5, G5, G#5, B5
C Melodic Minor	cMelodicMinor()	C2, D2, D#2, F2, G2, A2, B2, C3, D3, D#3, F3, G3, A3, B3, C4, D4, D#4, F4, G4, A4, B4, C5, D5, D#5, F5, G5, A5, B5
C Adonai Malakh	cAdonaiMalakh()	C2, C#2, D2, D#2, F2, G2, A2, A#2, C3, C#3, D3, D#3, F3, G3, A3, A#3, C4, C#4, D4, D#4, F4, G4, A4, A#4, C5, C#5, D5, D#5, F5, G5, A5, A#5
C Hungarian Major	cHungarianMajor()	C2, D#2, E2, F#2, G2, A2, A#2, C3, D#3, E3, F#3, G3, A3, A#3, C4, D#4, E4, F#4, G4, A4, A#4, C5, D#5, E5, F#5, G5, A5, A#5
C Hirajoshi Japan	cHirajoshiJapan()	C2, D2, D#2, G2, G#2, C3, D3, D#3, G3, G#3, C4, D4, D#4, G4, G#4, C5, D5, D#5, G5, G#5
C Ionian	cIonian()	C2, D2, E2, F2, G2, A2, B2, C3, D3, E3, F3, G3, A3, B3, C4, D4, E4, F4, G4, A4, B4, C5, D5, E5, F5, G5, A5, B5
C Locrian	cLocrian()	C2, C#2, D#2, F2, F#2, G#2, A#2, C3, C#3, D#3, F3, F#3, G#3, A#3, C4, C#4, D#4, F4, F#4, G#4, A#4, C5, C#5, D#5, F5, F#5, G#5, A#5

Figure 3.11: Screenshot of the *Post-Prod* panel followed by two tables with the various widgets functions and methods.

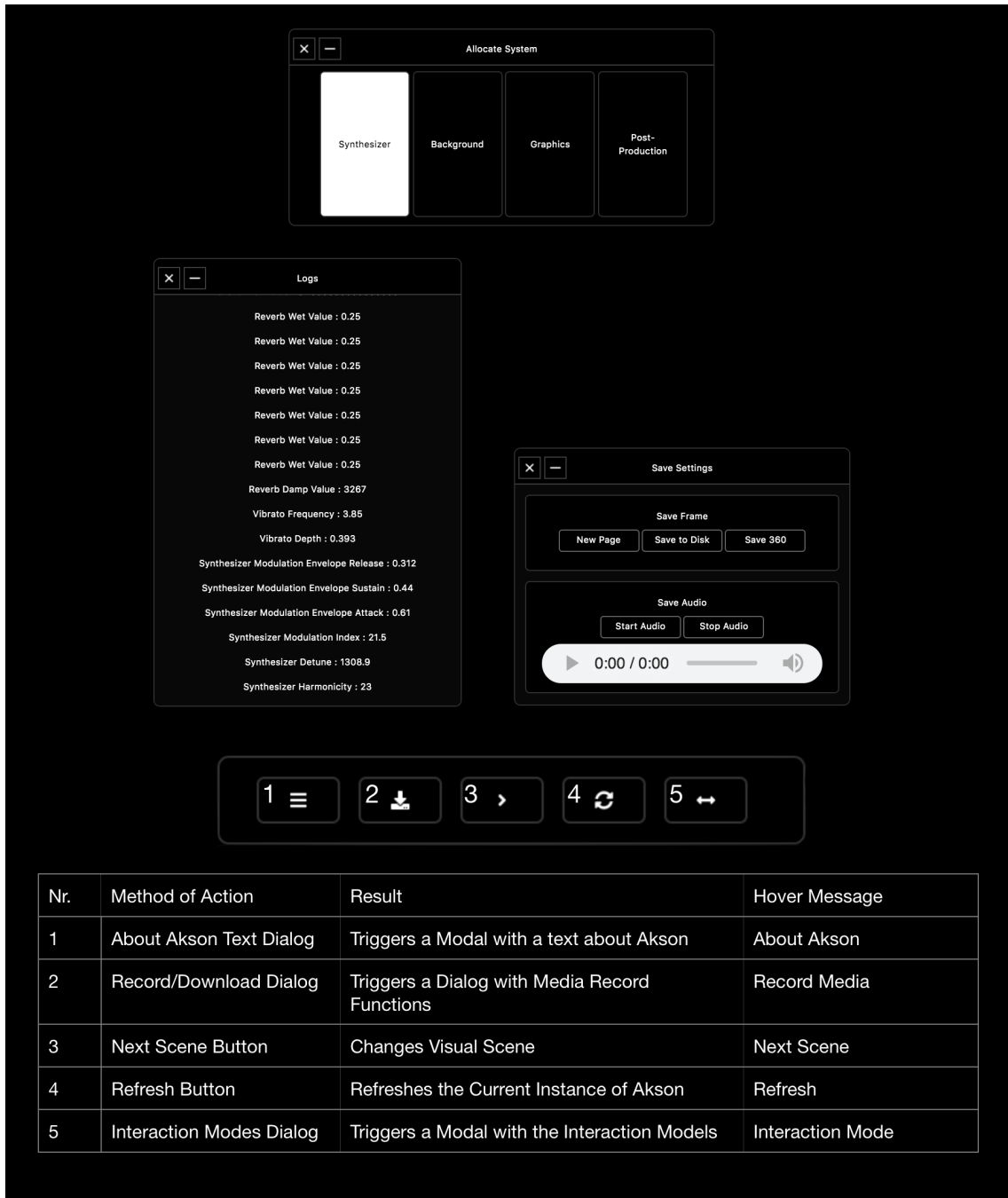| Nr.	Method of Action	Result	Hover Message
1	About Akson Text Dialog	Triggers a Modal with a text about Akson	About Akson
2	Record/Download Dialog	Triggers a Dialog with Media Record Functions	Record Media
3	Next Scene Button	Changes Visual Scene	Next Scene
4	Refresh Button	Refreshes the Current Instance of Akson	Refresh
5	Interaction Modes Dialog	Triggers a Modal with the Interaction Models	Interaction Mode

Figure 3.12: Screenshots of the Allocate dialog (top), the Logs dialog (middle-left), the *Save Settings* dialog (middle-right) and the Top bar with a panel containing methods of action.
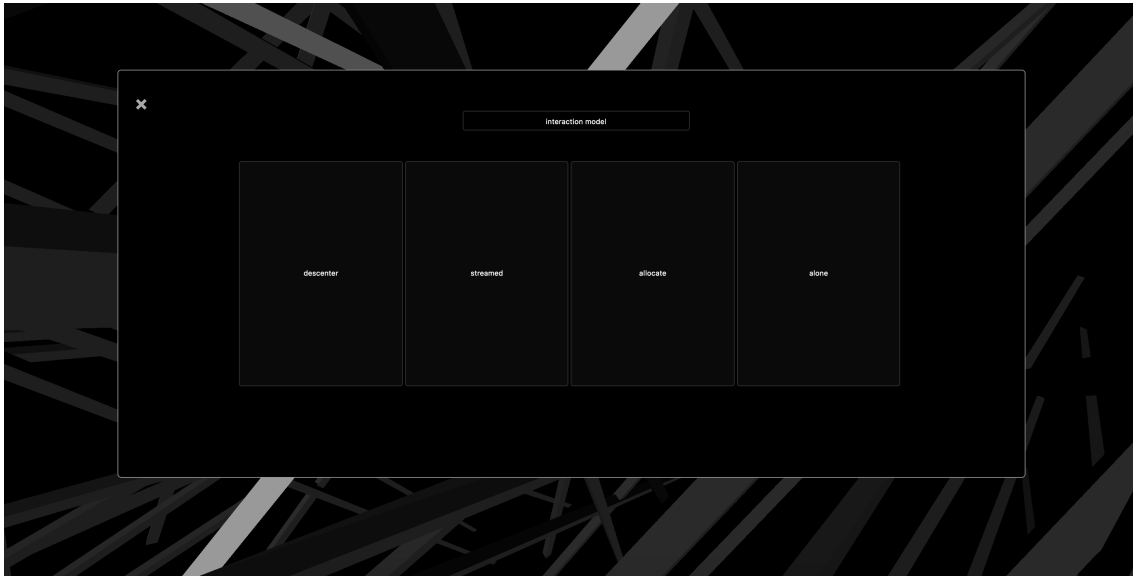
Figure 3.13: Screenshot of the modes of interaction modal triggered by the Top bar.

Nr.	Method of Action	Keycode Event	Functions
1	Remove current Scale (Synthesizer)	192	removeScale();
2	Change Scales (Synthesizer)	49, 50, 51, 52, 53, 54, 55, 56, 57, 48, 222	class ScalePlaying
3	Change Scene (Graphics)	81, 87, 69, 82	scene.add(3D_Object);
4	Top Bar methods (Graphical Interface)	89, 85, 73, 79, 80	topBar();
5	Akson default Presets (Post-Processing)	65, 83, 68, 70, 71	postPresets();
6	Modes of Interaction	72, 74, 75, 76	changeState();
7	Stop and Resume Graphics and Audio	90, 88	onoffScene();
8	Graphical Shaders (Post-Processing)	67, 86, 66, 78, 77	shaderButtons();
9	*About* dialog trigger	189	aboutDevice();
10	Graphical User Interface (GUI) Trigger	32	triggerGUI();

Figure 3.14: Keyboard map (*QWERTY*) with a panel containing methods of action, Keycode Events and the functions found in the code.
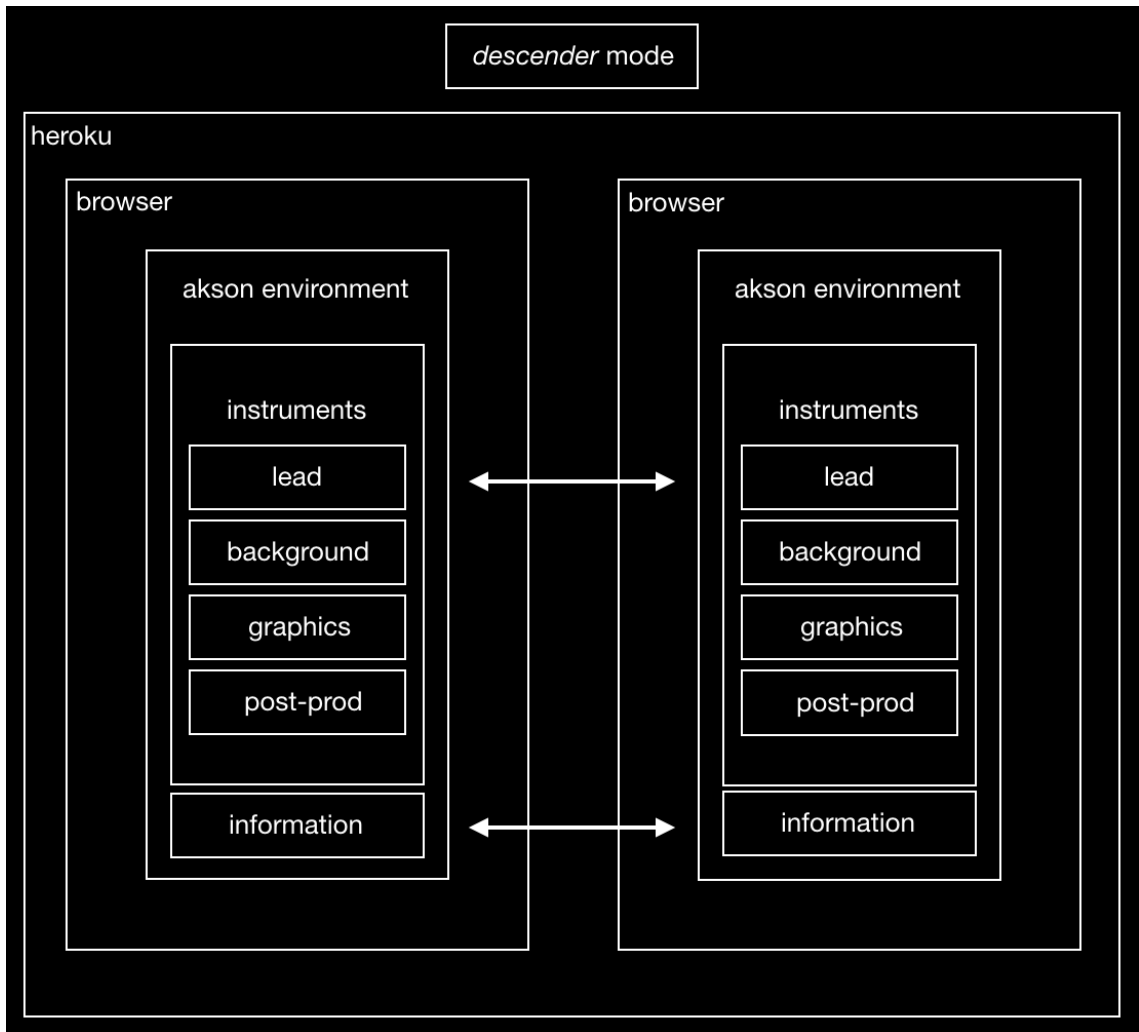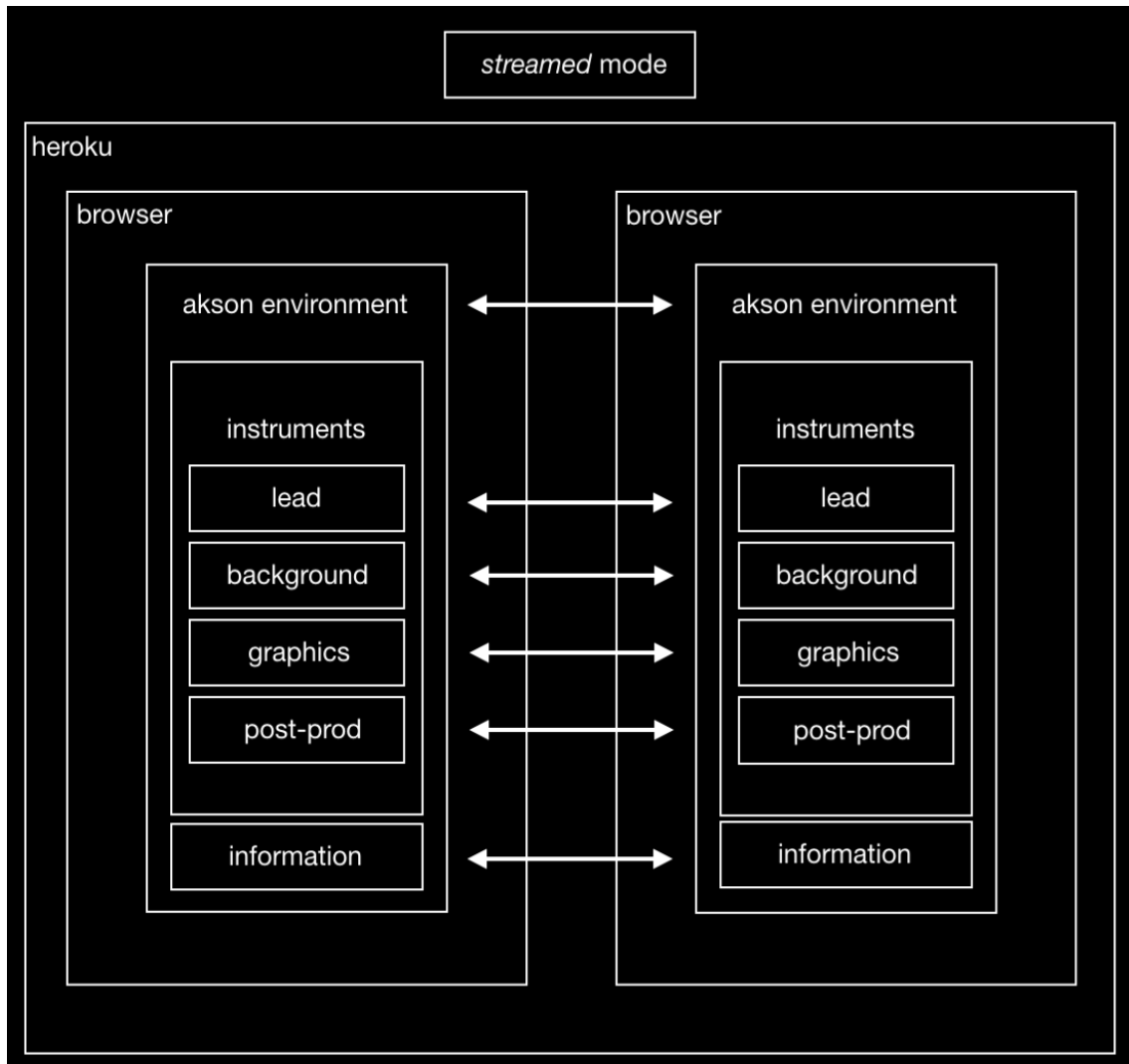
Figure 3.15: Diagram of Akson's *descenter* model.

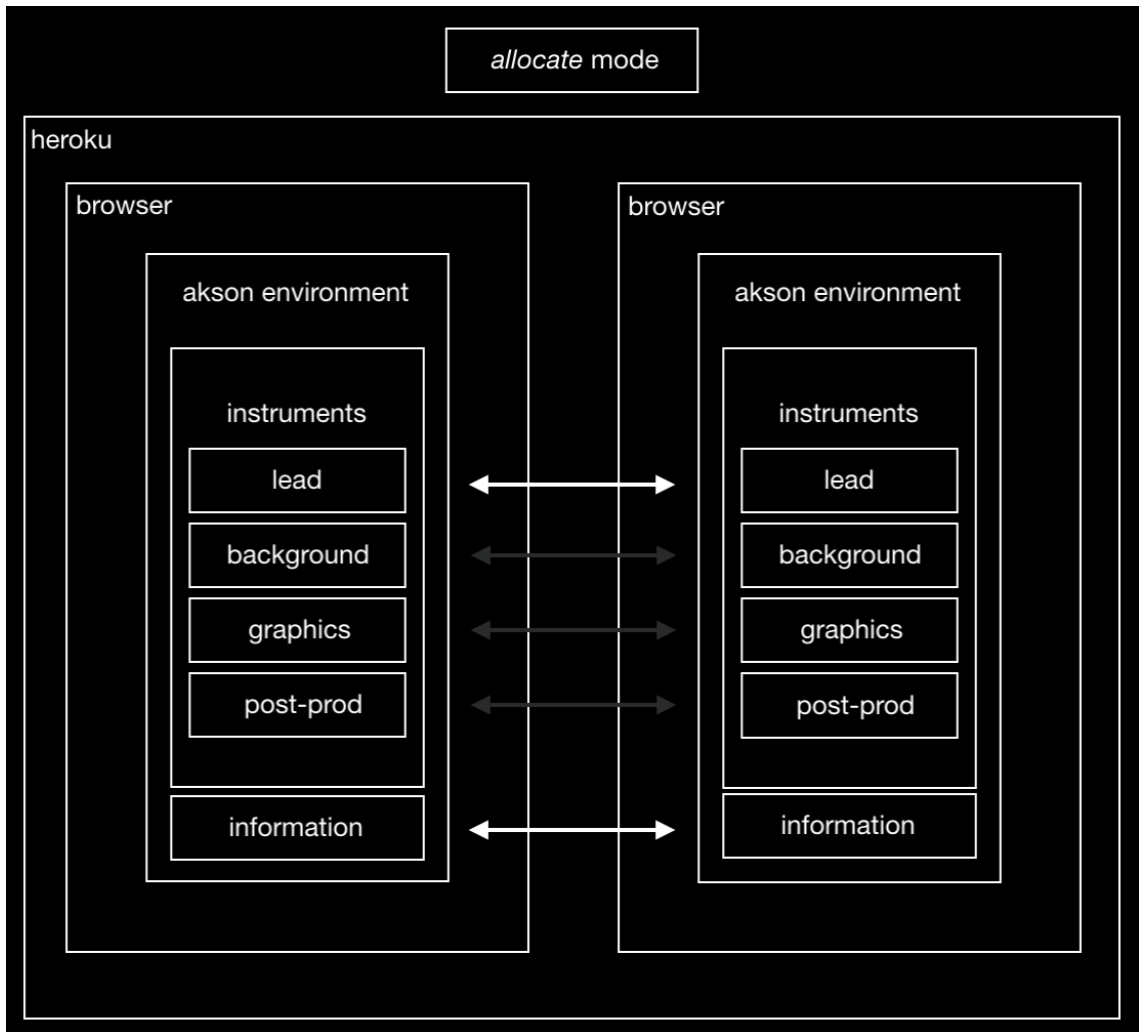Figure 3.16: Diagram of Akson's *streamed* model.

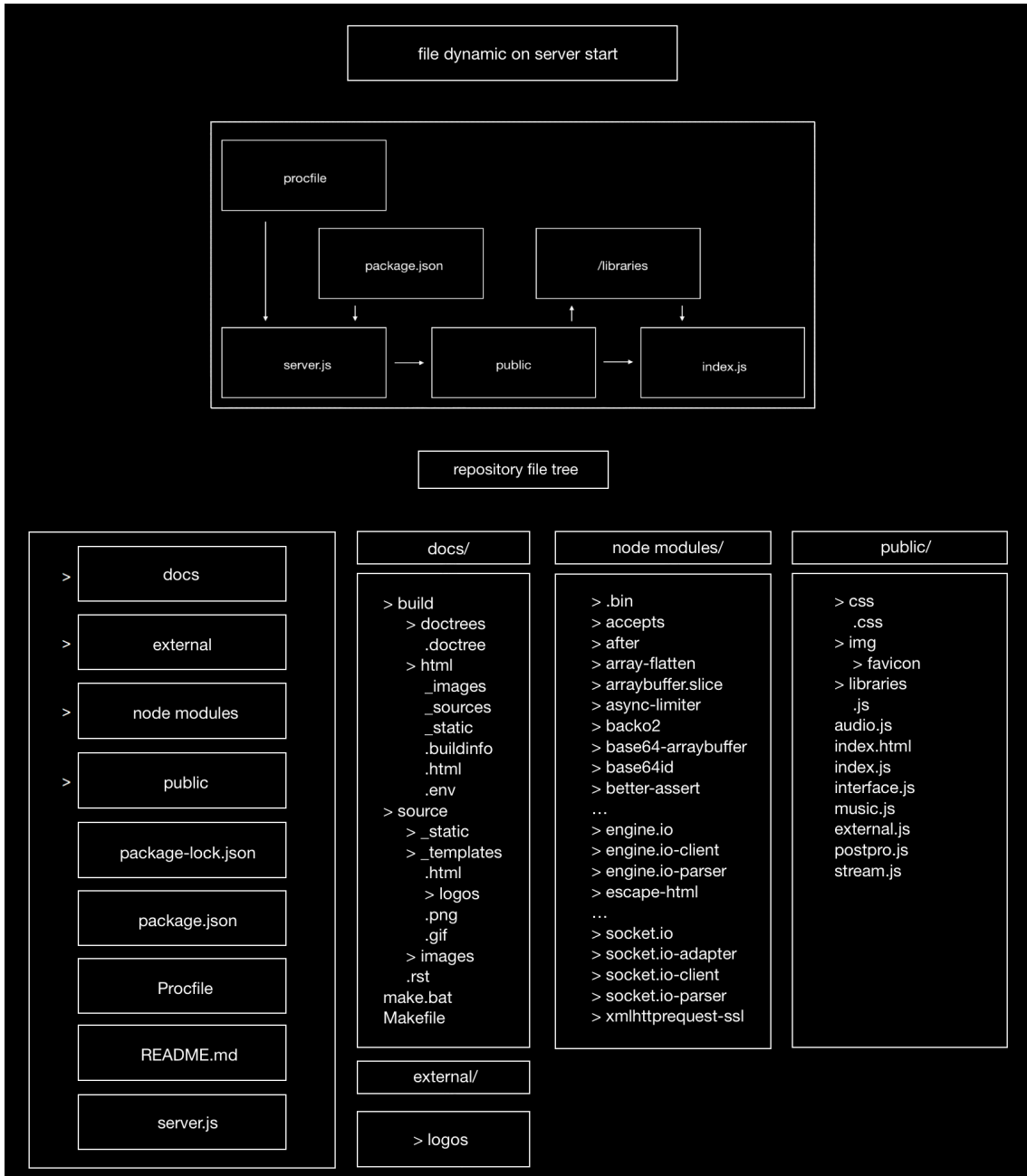Figure 3.17: Diagram of Akson's *allocate* model.

Figure 3.18: Diagram of Akson file tree and folder communication flow. Starting on the Procfile (top-left).

Chapter 4

Akson Public Experiments

This chapter is intended to document the public experiments done with Akson, detailing the process carefully. Its evolution and the choices made thanks to feedback from the use of the system in conjunction with various artists and researchers had profound implications on how the various iterations were developed. This type of validation also helps to create a healthy relationship between the development laboratory and the public domain of experimentation. The three experiments explore the three interaction models Akson provides for collaboration, a careful description is found on the last chapter.

4.1 Experiment at CARA

The first experiment was performed on February 19th in Centro de Alto Rendimento Artístico[1] (CARA) located in the Real Vinícula, home of the Matosinhos Jazz Orchestra[2] (OJM). The equipment used, was kindly provided by its Educational Service[3].

4.1.1 The Performance

The rehearsal was composed of 6 people all with advanced musical knowledge and with experience in public performance. Participants knew that it was a public test of experimentation belonging to a research in collaborative audiovisual systems and had all relationships linked to the academic environment, both by the Masters in Multimedia and by the Doctoral Program in Digital Media at the University of Porto.

The hardware and sound system was provided by OJM Educational Service, with the WI-FI network of CARA. There were 9 computers, 9 sound devices, a mixer, a sound system, 3 mobile phones, an electric guitar and the WI-FI connection was relatively quick. The computers were of model iMac 2017 - 21.5 inch running macOS High Sierra, version 10.13.6 with a processor of 2.3

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[1] Official CARA website http://www.ojm.pt/pt/projectos/musica/Cara/sobre [accessed 27/06/2019]

[2] Official OJM website http://www.ojm.pt/pt/ [accessed 27/06/2019]

[3] Official website of OJM Educational Service http://www.ojm.pt/pt/projectos/servico-educativo/ [accessed 27/06/2019]

GHZ Intel Core, RAM memory of 8GB 2133 MHZ DDR5 and an Intel Iris Plus Graphics 640 card 1536MB of 1920x1080. Each sound device was connected to each computer and going to the main mixer, and were of model Focusrite Scarlett 2i2 (2nd Gen), an audio interface of 2 entrances and 2 way outs on 96KHZ with 24-Bit conversion and 2 pre-amplifiers. The connection was done by TRS terminal to the mixer Mackie Micro Series 1402-VLZ of 14 channels and then by XLR to the Meyer Sound sound system. There were two ultra-compact wide coverage loudspeakers of model UPM-1P at each corner of the room that squeezed all these channels to a big stereo. Alongside the computers, 3 mobile phones connected to the system that were not flowing the audio to the mixer but served as resonating devices in the room. They were all Android devices, two were running EMUI 5.0.3 and the other Android 9.0 Pie operating system. One of the participants that brought his personal guitar of model Ibanez RG2570 EX Prestige was playing alongside the other participants and was processing the sound using Bias FX from Positive Grid in his own laptop.

There were more devices than participants so there was a bigger freedom in the usage of the system and regarding the internet connection there were no problems to solve in the OJM network, we just connected and we had no perceptible latency. It was done a speed test before the experiment that showed that ports 8000 and 5000 were opened, we had 43.20MS ping, 6.26MS jitter, a download rate of 60.77MBPS and a little volatile upload speed of 92MBPS. The experiment started at 15:00 and took 15 minutes until everyone stopped playing with the system.

4.1.2   The Participants

The participants after the involvement demonstrated some similar opinions regarding Akson and its use. There was a clear general desire to increase the relationship between musicians while playing, and a more visible form of contact between them.

- The participants agreed that it would enhance the performance if they had some kind of visual display of what the others were doing in the user interface, while playing.

- The participants also felt the need to have a main master control to shut down the system at the same time.

- There was a general opinion that there should be more clarity in the propagation of sound between machines, when that happens and why.

This was what originated the interaction model explored in section 4.2. The subsection 3.7.2 gives a better insight of the overall state of Akson when that model is chosen. This way, it's possible to respond to the various communication needs described.

Before the subjects started playing, they knew it was a networked collaborative system but they actually didn't knew how to interact with the interface and how to control it. To provide a good user experience on how to start playing with Akson, was presented an image moments before starting that had some instructions on the very basic things such as how to change visual scene and how to trigger the GUI (fig. 6.3).
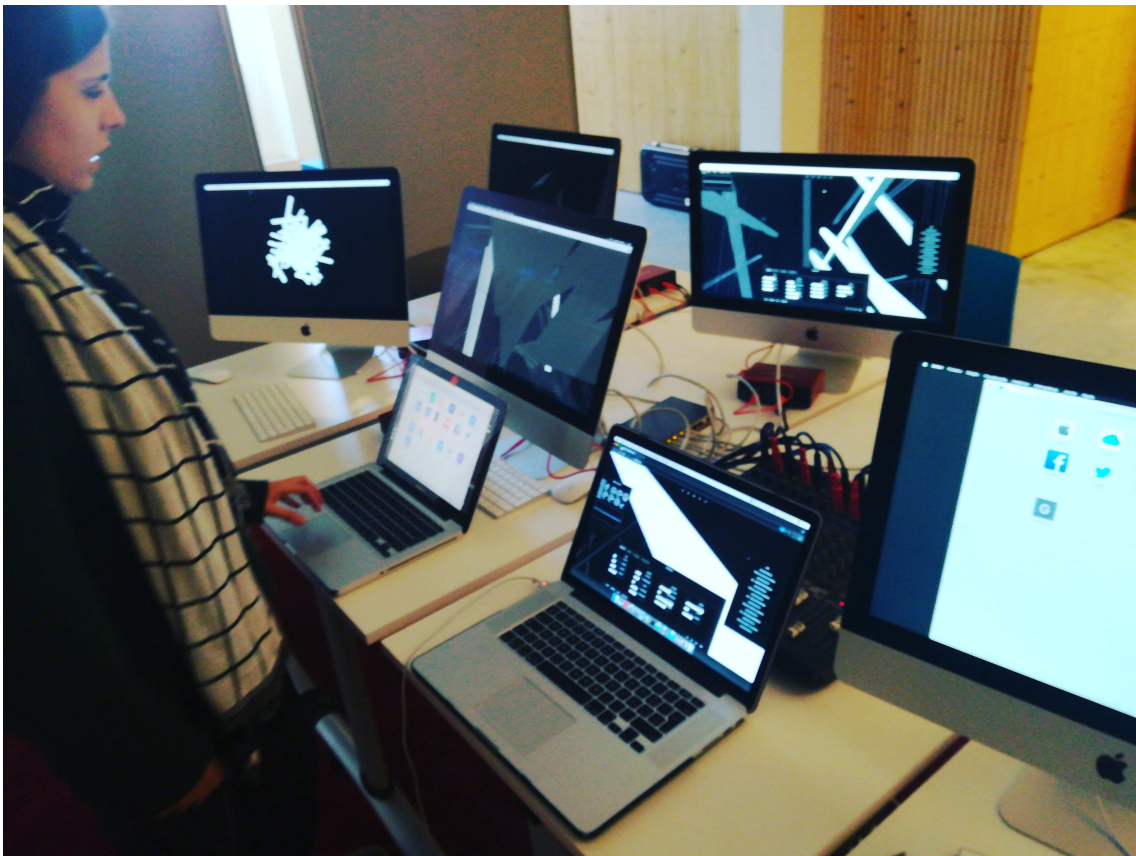
Figure 4.1: A photograph that shows part of the space where the experiment was done, seven computers with Akson running and Joana Rodrigues, a professional musician and participant of this experiment.

4.2   Experiment at gnration

The second experiment was done on April 27th in gnration[4] gallery located in Braga during it's annual *open day*[5]. It was done under the context of Braga Media Arts (BMA) with equipment provided by its Educational Service[6].

4.2.1   The Installation

The second public experiment of Akson happened in the form of an interactive station. It was presented as an installation with interactive features that was also able to explore in people's personal devices. It was presented from 11:00-13:00 and 14:00-17:00 without fostering differences between participants. This experience was much wider in terms of public feedback, also thanks to the participatory nature of the installation. All the equipment that was used in this experiment

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[4]Official website of gnration http://www.gnration.pt/ [accessed 27/06/2019]

[5]Official website of gnration open day http://www.gnration.pt/event/gnration-open-day/ [accessed 27/06/2019]

[6]Official website of BMA Educational Service http://www.bragamediaarts.com/pt/agenda/c/servico-educativo/ [accessed 27/06/2019]

was kindly provided by BMA Educational Service and the gnration Educational Service[7] was also involved in the setup.

The station was composed of 5 computers a sound system and video projection. We had the central processing machine which was of model Mac Pro (late 2013) with a processor 3.7 GHZ Quad-Core Intel Xenon E5, RAM memory of 12GB 1866 MHZ DDR3 ECC, Graphics card AMD FirePro D3000 2048MB running OSX El Capitan 10.11.6. This machine was connected to the main projection and sound system. The main HDMI connected to an OPTOMA GT1080E, a 1080p (1920x1080) resolution projector with 3000 ANSI Lumens. The sound system chain started with an USB 3.0 connection to a Behringer U-Phoria UM2, an audio interface of 2 entrances and 2 way outs with 48KHZ on 16-Bit. It connected by TRS terminal to an Alto Professional 350 Watt MIXPACK Express PA. This sound system came with two 10 inch speakers, a built-in mixer with seven-band graphic EQ and integrated Alesis DSP with 24-bit effects that weren't used.

Alongside the main processing machine there were 3 13-inch MacBook Airs running OSX Mojave version 10.14 with a processor 1.8GHZ Intel Core i5, RAM memory of 8GB 1600MHZ DDR3, a Graphics card Intel HD Graphics 6000 1536MB. And one MacBook Pro running OSX Sierra version 10.12.6 with a processor 2.2 GHZ Intel Core i7, RAM memory of 16GB 1600 MHZ DDR3 and a graphics card Intel Iris Pro 1536MB. These served as resonating devices in space and were displayed around the table that was in the room. The video was pointing to a wall without posterior mapping but carefully calibrated, and the sound system was equalized in accordance with the room so the other installations wouldn't be disturbed.

The preliminary tests that were done in the WI-FI network used were very satisfactory given the volatile nature of possible number of inputs in the network that can happen in a public gallery. The speed test showed a latency of 11MS, a jitter of 3MS, a ping of 10MS, a download speed of 58.51MBPS and an upload speed of 56.95MBPS. It also showed that the port 8000 was opened and 5000 closed.

4.2.2   The Participants

The interaction model explored in this experiment is a model that was born from a solution to the previous experiment. Everyone that connected to the system this day was by default in this method. This method allows all users to be a master controller. Any changes made to the instrument are sent by all users who are connected, and in the same state. It allows everyone to jointly build an experience in a single distributed interface. It allows everyone to leave at the same time and in this way there is a clear notion of what other people are doing.

There was no clear general opinion that all participants shared. However, some behaviors were consistent throughout the day.

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[7]Official website of gnration Educational Service http://www.gnration.pt/programacao/servico-educativo/

- Most people used the equipment provided by the station and not their own mobile devices to interact with the system throughout the experience.

- Apart from musicians and artists that asked questions about the system, who spent more time interacting were children and young people up to 30 years old.

- Overall, while interacting with Akson, people were more focused on the graphics until they discovered the capabilities of the GUI.

Even if the system had a dedicated screen to show attendees an image with key controls to interact with the keyboard (see fig. 6.4), help was always given to anyone entering the installation space. Most people also interacted verbally when they came across the setup and some participants also used their devices, the most successful ones were Chromium-based browsers (currently default on Android is Chrome). That helped to see the performance on all kinds of devices (Safari wasn't always successful and a "No MIDI Support" alert was common).

Figure 4.2: Courtesy of gnration's communication manager. Photograph took on the site of the installation during the morning of *open day*.

4.3   Experiment at Openfield

The third experiment was done on May 6th in Openfield[8] Creativelab, located in the center of Porto, home of a Media Art Collective. It was performed with equipment kindly provided by the Atelier.

4.3.1   The Performance

The third public experiment of Akson as a research context happened as a performance. It was done with the help of the musician Francisca Gonçalves (also member of the Openfield collective) and took place in the laboratory. The nature of this experiment was based on a more conventional laptop performance (see section 2.1.5). The two performers played without any previous rehearsal.

The equipment was kindly provided by the Atelier, apart from the performers personal material (laptops and audio devices).

The system was composed of one computer to each performer, a sound system and a projector. This experiment took 10 minutes and started at 10:15 in the morning with 6 researchers as public. One computer was a MacBook Pro (late 2013) with a processor of 2.7GHZ Intel Core i5, 13.3-inch (2560x1600), RAM memory of 8GB 1867MHZ DDR3 and a Graphics card Intel Iris Graphics 6100/1536MB running OSX Mojave 10.14. The second computer was of model MacBook Pro (late 2015) with a processor of 2.2GHZ Intel Core i7, RAM memory of 16GB 1600MHZ DDR3 and a Graphics Card Intel Iris Pro 1536MB running OSX Sierra 10.12.6. The first computer was connected to a Scarlett 2i4 (2nd Gen), an audio interface of 4 way outs up to 192KHZ with 24-Bit. The second computer was connected to a Roland Quad-Capture, an audio interface with 2x2 analog outs up to 192KHZ at 24-Bit. These two interfaces connected to the main mixer of model Alto L-12, a twelve channel legacy mixer with integrated DSP of 24-bit that connected to 2 Tannoy Reveal 502. The second computer connected by HDMI to a projector EPSON EB-S05 of 1080p (1920x1080) resolution with 3100 ANSI Lumens.

Both the equipment configuration and the performance interaction mode were resolved before it happened. It was defined that the two performers would have two distinct functions during their duration, one focusing mainly on the synthesizer (Lead) and another on the filter-noise (Background). In this way they could explore various resolutions of the work with predefined rules.

This is the third and last mode of interaction to be integrated into Akson. As explained in chapter 3.7.3, it divides the central control (dashboard and bidirectional connections) into four parts so that it can be divided between performers. The tests were done in the WI-FI network one hour before the performance and were satisfactory enough so we didn't have to setup our own network for speed improvement. We ran speed tests that demonstrated a latency of <13MS and

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[8]Official website Openfield http://openfield-creativelab.com

<4MS of jitter. The download speed was of <45.00MBPS and upload speed of <53.00MBPS. We also had the port 5000 opened to serve Akson.

4.3.2   The Participants

Participants involved in this performance as a public had all experience with performing arts and were involved with the academy as researchers. They did not know what method of interaction the two performers took, nor was it explained how the performance would take place, they were only told that if they wished they could connect to our system via the Akson official link, projecting a figure on the wall with the address (fig. 6.5).

When the participants shared their views regarding the experiment there was a clear agreement on the various topics mentioned.

- Participants liked to know more about Akson and how it works as a system, not just staying for the content it created.

- They wanted to know exactly what the performers were doing, separately.

- They agreed that, given the aesthetics of the sound and the graphic load, the performance should take more than 10 minutes.

Compared with the other experiments, the audio-visual relations were more accurate. There was clear graphical feedback when some kind of sound was generated. However, this kind of performance always brings a great abstraction of embodied personal interaction.

When the performance was over, impressions were exchanged on how Akson worked, also to match the participants first overall impression. There were no external connections to the two performers

Figure 4.3: A photograph of the performance at Openfield. Courtesy of Marcelo Sousa, researcher and public.

4.4   Performance in xCoAx 2019

As the next public validation, at the beginning of July, an already accepted networked performance will take place on xCoAx[9] 2019. An international conference on Art and Computation in Milan, Italy.

Here, alongside musician Gilberto Bernardes, will present two different interaction models based on the architectures of Akson. We will explore *The Conductor Model*, the paradigm of the *Symphony Orchestra* where the conductors are the master controllers shaping the dynamics and directing time flows. And the *Free Improvisation* method, based on the free jazz movement of the sixties that produced performances that were highly interactive, spontaneous, expressive and unpredictable (Winkler, 1998). Dynamic control will be done in the two modes of interaction that are established with the audience of the venue or with anyone who can join Akson globally.

It is presented in the section 5.2 a future development of a midi learning system using Web-MIDI so the artists can connect different devices to Akson and map the controls to the GUI. This

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[9]Official xCoAx website http://xcoax.org [accessed 27/06/2019]

can be achieved using public open-source API's. Akson already accepts MIDI, but is specific to the authors peripherals and there is no way of introducing different ones without *hard coding*.

4.5 Conclusions

In this chapter the public experiments of Akson were presented. As a collaborative digital interface the three modes of interaction (see section 3.7) were explored with it's process documented.

These experiments, above all, served to develop the final version of Akson presented in this document. Much of the feedback obtained was analyzed as reflection material. The great decisions made throughout Akson's development have always been based on this process as a creative loop (something that can also be seen on the official repository). An example of that are the interaction modes chosen. Not only based on references, they were the result of common opinions regarding interpersonal collaboration after the experiments.

The proposed interaction methods were all publicly tested within the time proposed as research (one school year), and are technically finished allowing them to be tested and demonstrated to the world.

Chapter 5

Conclusion

In this chapter we present the general conclusions of the research. A list of achieved objectives is made and a set of future work is proposed. The chapters presented between the introduction and the present one are the description of the path this research has taken and the underlying technologies used. A work done in the light of the BMA group in AV collaborative web interfaces.

We approach the proposed problem and research question in a practical way presenting a finished, open-ended, free and cross-platform solution to the world. The Akson environment. Here, also target of several future work proposals.

This research had a great deal of software development which suffered some adversities. Akson is a system with several features in different fields and we tried to match the same level of complexity, aesthetics and functionality in all of them. All these issues were resolved by keeping a record in time and with the help from artistic experiments.

The objectives for which we have proposed the research were carried out, and we maintained a very careful relationship with the possible contributions so that the results could be achieved in the proposed time scale.

5.1   Contributions

There are several contributions in this research that can generate conclusions.

- A web-based collaborative AV environment that can serve as structural fabric in collaborative artistic performance and/or interactive installations.

- A public course in software development that can serve as map for future research. Both front-end and back-end.

- A collaborative digital space that offers three different modes of interaction between performers/artists/audiences, publicly tested and free to use.

- Duly detailed public experiments that can serve as artistic or scientific inspiration/exploration in future projects.

- The performances and the installation done increased interest and attachment to the local artistic community.

- Artistic experiments that materialize a custom aesthetic pattern, chosen by the authors.

- An AV environment that can extend the artistic gesture through the cloud with potentially large distances across the globe.

- An AV generation stream that can be used as content disseminator by large numbers of devices as resonant and visual machines in space.

- An online space of free access that can be used by anyone in the world who has access to the internet.

The various contributions listed can always have ramifications between them. They can point to various types of future work and in various areas. In the next section we will list several possibilities as future research.

5.2 Future Work

After the work introduced, documented and completed come up some options that can be taken as future investigative work.

We, as artists and researchers, have come to various conclusions regarding the path that this project can take. Based on reflections taken in relation to the work done, we propose ramifications in various areas. Some more linked to scientific development and others more related to artistic experimentation. We believe that Akson has the potential to be integrated into more domains apart from what this dissertation explores and that can be extended to other areas. Here we will list the various areas that we consider relevant work.

- A good exploratory continuation of this research would be the study of more modes of interaction and their integration into Akson. Winkler's proposed methods (1998) can be one great reference.

- A branch of work more focused on the AV relationship and with a more detailed theoretical development in historical events. For example in color organs and synergies between sound and image also found in the work of Rodrigo Carvalho (2013).

- A development of work not only exploring the internet and its infrastructure as medium but also as art in itself. The fundamental structure that defines Net Art. A great reference on that can be the book *The Art Happens Here: Net Art Anthology* (Connor, 2019).

- The development of Akson as an automatic content generation system for exploration of large-scale sound sculptures taking advantage of the internet as a medium.

- Synthesizer note generation through stochastic modelling such as variable markov models (VMM's), allowing the ability to create musical phrases between people without deterministic induction (section 3.6.3.2).

- The development of a peripheral control learning system using WebMIDI (Wyse & Subramanian, 2013).

- The possibility of streaming sound and graphics through WebRTC technology (Johnston & Burnett, 2012).

- Explorations in a performative context in which the Akson is used as an instrument in conjunction with other classical instruments (e.g. violin, cello).

- The study of distributed electroacoustic reproduction systems with complex arrays of machines (e.g. computer and/or mobile phones).

- We underline that one of the great future possibilities of Akson may involve its integration into artistic practice outside the academic and scientific context.

- The use of Akson as a system of analysis and composition is also something we consider important.

All of these future work possibilities cited here were specifically designed for the Akson environment. These are projects that, based on our reflection after the development of this research, we consider potentially interesting for future work. These may give rise to varied contributions, in different ways, in different areas.

Chapter 6

Appendix

6.1 Akson gnration Synopsis
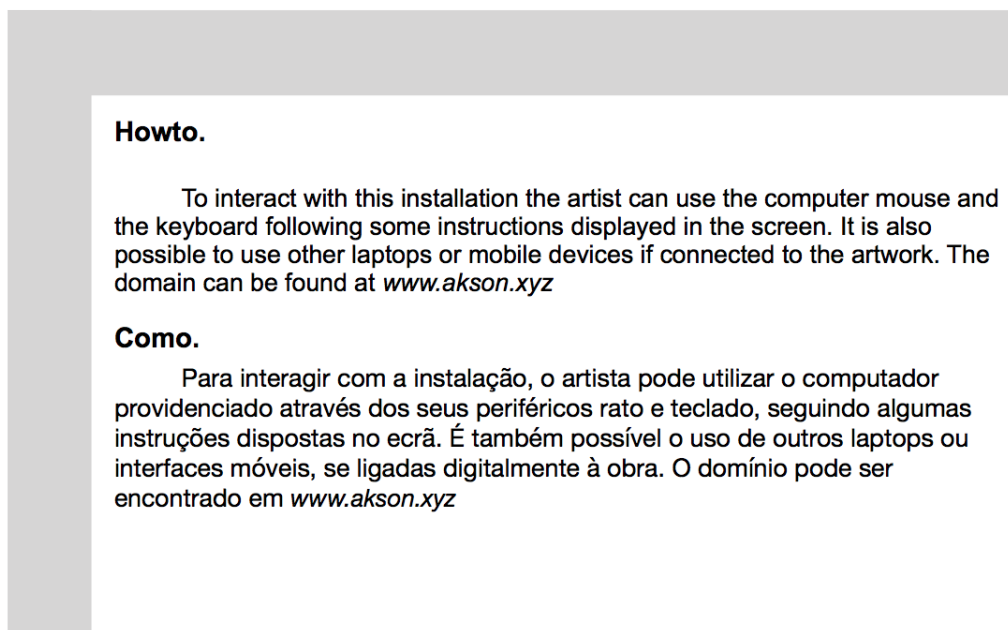
Figure 6.1: Synopsis made for the BMA Educational Service to be used as a sign in the space of the Akson installation on the open day. A paragraph is provided in English and in Portuguese to explain how you can interact with the work.

6.2 Akson gnration Rider

Akson Open-Day Rider Técnico.
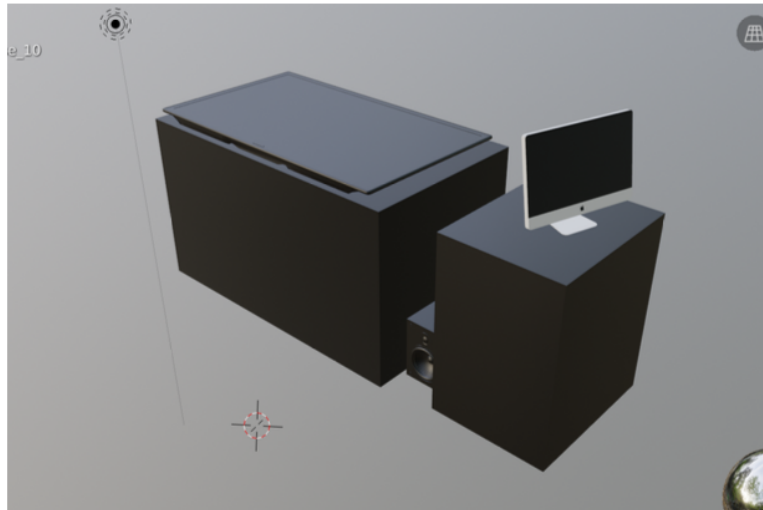
Importante

- Um computador com acesso a serviços de administrador e seus respectivos cabos de ligação à corrente.
- Um teclado e um rato compatíveis com o computador
- Uma televisão mínimo 1920x1080 e respectivos cabos para ligação ao computador/corrente (touch screen preferível para melhor interação com o público).
- Dois speakers para reprodução audio e seus respectivos cabos de alimentação e de conexão, TRS ou XLR
- Uma placa de audio que tenha compatibilidade com o computador e que receba as ligações dos speakers.
- Pelo menos 4 ligações para a corrente
- Um suporte para a televisão conseguir estar na horizontal com o seu tamanho em largura
- Um suporte para o computador que permita interação com o teclado e com o rato
- Acesso a uma boa conexão de internet

Figure 6.2: Technical Rider developed for an interactive installation with Akson. This formalization as installation was thought for a more limited equipment load exploring in the same the visualization of the instrument.

6.3   Instructions of CARA Experiment
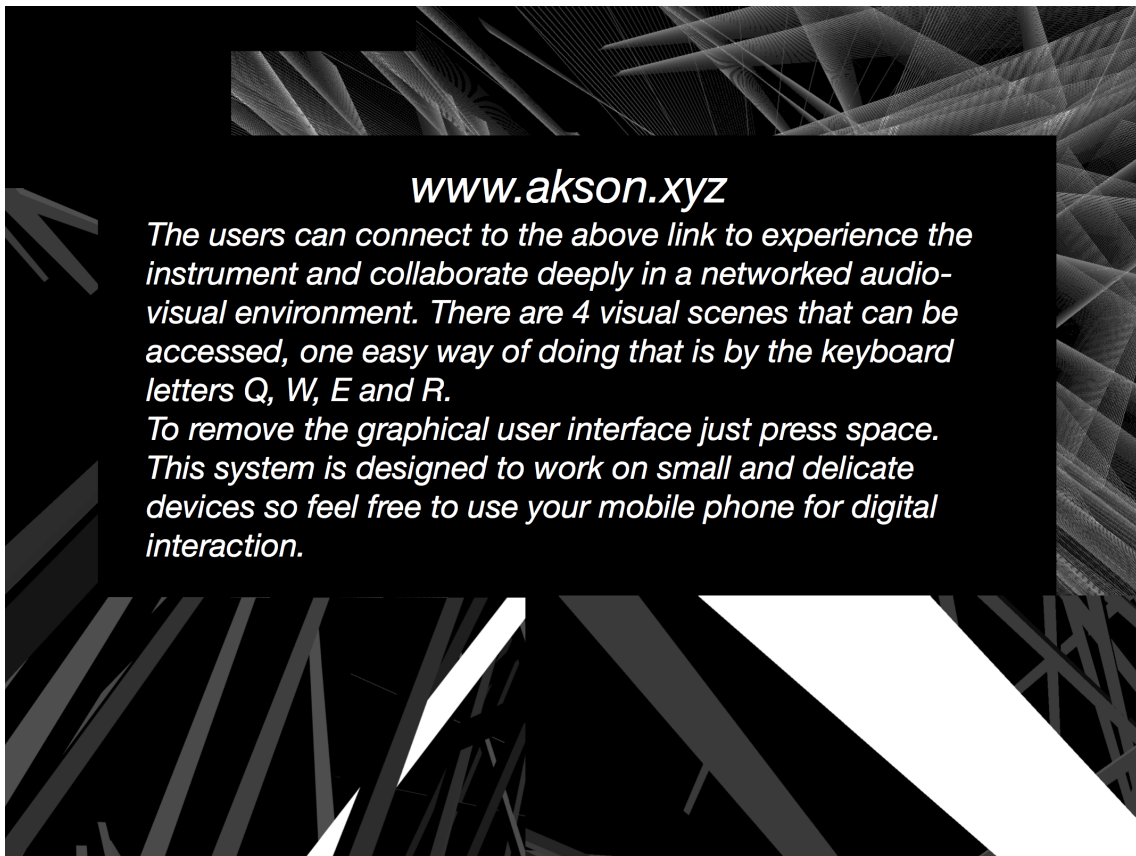
Figure 6.3: Image shown to the participants before CARA's experiment took place. Using this annotation it was possible for the participants to know how to interact minimally with the system. This image was available for viewing throughout the performance

6.4 Instructions of gnration Experiment
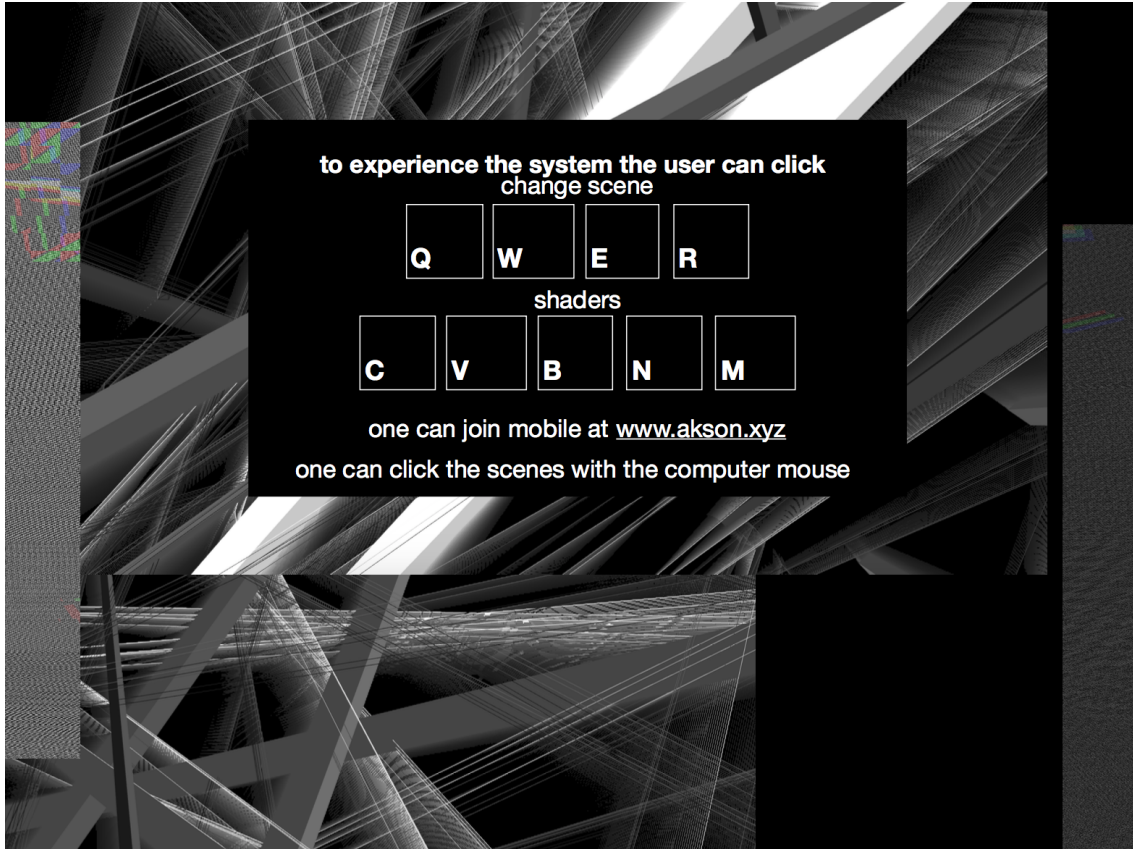
Figure 6.4: Image shown to the participants on gnration's interactive installation. This image was constantly present during the whole course of the installation.

6.5 Instructions of Openfield Experiment

Figure 6.5: Image shown to the participants on Openfield's performance. The image was demonstrated to the participants just before the start and was not shown a second time.

6.6   Akson's Camera Screen shots
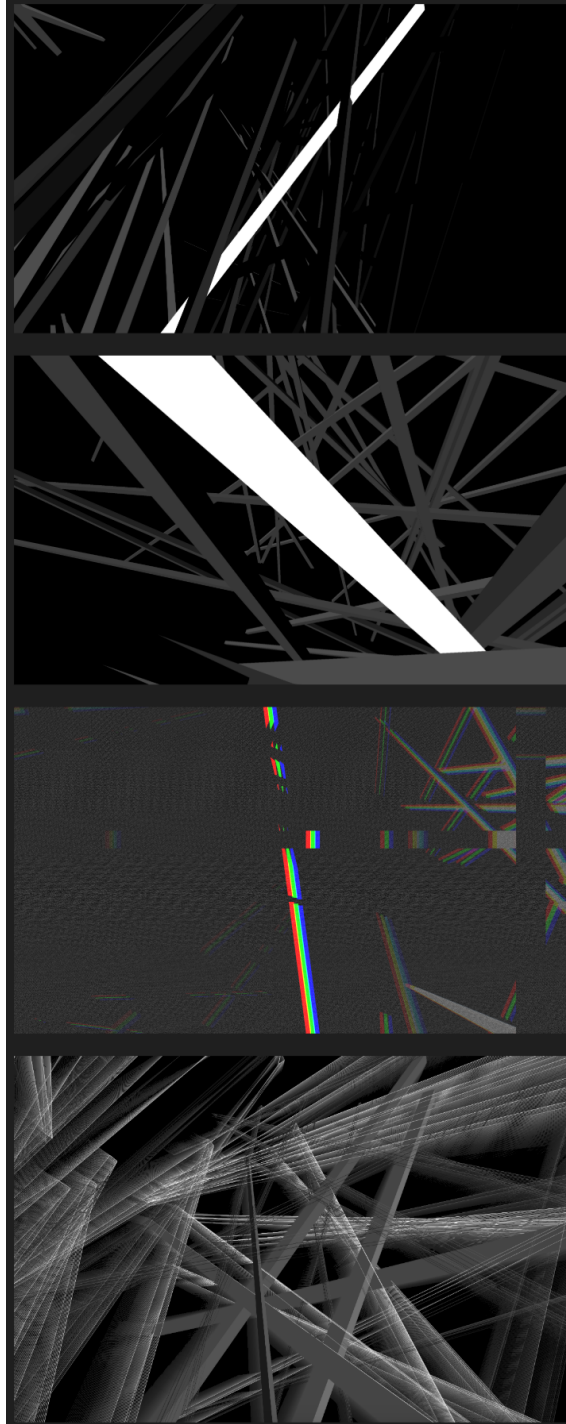
Figure 6.6: Screen shots of Akson's graphical system, taken from the virtual camera. These can be found in *http://www.luisarandas.org/akson.html*.
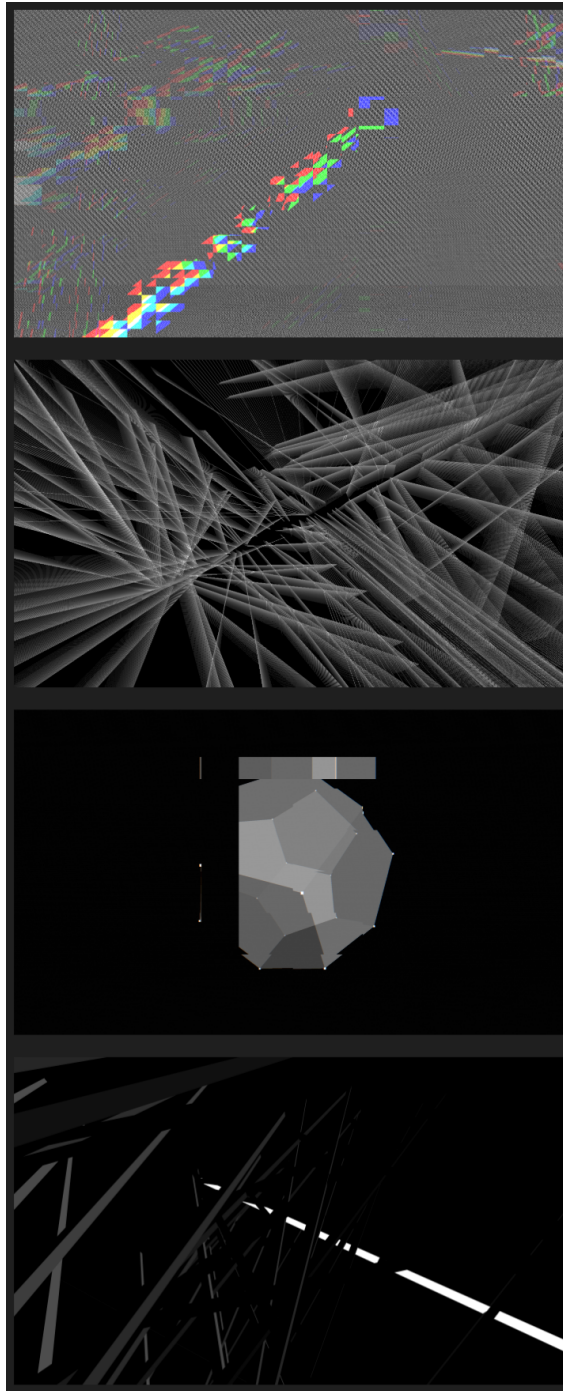
Figure 6.7: Screen shots of Akson's graphical system, taken from the virtual camera. These can be found in *http://www.luisarandas.org/akson.html*.

Chapter 7

Attachment

7.1 Akson signage in gnration

Figure 7.1: Photograph of signage arranged at the entrance of the Akson installation in the *open day*.

7.2 Articles about Akson by gnration

Figure 7.2: Article about Akson found on gnration flyer.

A completar o programa, o gnration propõe um conjunto de **atividades de serviço educativo**, umas das fortes componentes do programa cultural do gnration que está sob direção artística do programador Luís Fernandes. Para o aniversário, o gnration propõe duas atividades que aliam tecnologia e aprendizagem. **Mini Mapa Sonoro**, projeto do Serviço Educativo Braga Media Arts, promovido pelo Município de Braga, desafia os mais pequenos a fazer uma viagem pelo património material e imaterial de Braga, explorando locais de referência para os participantes, culminando na ilustração do seu próprio mapa e na gravação dos sons que o rodeiam e caracterizam. No final da atividade, o mapa visual e sonoro ficará disponível em formato interativo.
Com âmbito alargado de faixa etária, a **Estação de Experimentação: Akson convida todos a descobrir um sistema audiovisual em rede** que permite interação, colaboração e reprodução entre artistas (profissionais, amadores ou curiosos) em grande escala. Concebido como ferramenta de criação e performance colaborativa, o utilizador poderá interagir com a instalação através de um dispositivo móvel ou de um computador.

Figure 7.3: Article about Akson found on gnration website.

7.3 Vertical flyer of *open day*

Figure 7.4: Courtesy of Ilídio Marques, gnration Communication manager. A high-resolution vertical poster image that was found across the city of Braga as publicity.

7.4 Horizontal flyer of *open day*

Figure 7.5: Courtesy of Ilídio Marques, gnration Communication manager. A high-resolution horizontal poster image of the event. Was also found across the city of Braga as publicity.

7.5 Picture of Akson's Installation

A photograph kindly provided by the gnration organization. It was taken on April 27 and shows part of the exploratory station. Courtesy of Ilídio Marques, gnration communication manager.

Figure 7.6: Courtesy of Ilídio Marques, gnration Communication manager. A photograph of users interacting with Akson during the *open day*.

7.6 Picture of Openfield performance

Figure 7.7: Courtesy of Marcelo Sousa, researcher and public at Openfield experiment. A photograph of the explanation given after the performance, maintaining an interaction with Akson using a mobile phone.

7.7   Article about Akson on *Rimas e Batidas*

Vem aí o *open day* do gnration e a entrada é gratuita: a 27 de Abril, o *hub* criativo bracarense celebra seis anos de existência com várias actividades, instalações audiovisuais e música de Ammar 808, Algobabez, Graham Dunning, Sensible Soccers ou DJ K-Sets.

Recentemente nomeada cidade criativa da UNESCO para as Media Arts, Braga firmou-se, em 2012, enquanto Capital Europeia da Juventude, tendo o projecto gnration resultado desse esforço em dinamizar os campos da arte digital e da música contemporânea na cidade.

Num evento que se estende das 10h até às 4h da manhã do dia seguinte, o gnration apresenta aos seus visitantes algumas actividades de cariz educativo e instalações artísticas audiovisuais. O **Mini Mapa Sonoro** desafia o público mais jovem a embarcar numa viagem pelo património material e imaterial de Braga, com a exploração de alguns locais de referência — no final da actividade, os participantes têm acesso a um mapa visual, sonoro e interactivo da cidade. A **Estação Exploratória** aponta a uma faixa etária mais alargada e baseia-se num sistema audiovisual que permite a interacção, colaboração e reprodução entre artistas — profissionais, amadores ou curiosos — por intermédio de um dispositivo pessoal — telemóvel ou computador.

Figure 7.8: Article about Akson found on *https://www.rimasebatidas.pt/gnration-celebra-sexto-aniversario-com-open-day-recheado-de-musica-e-actividades/*. A post by ReB Team in February 22th.

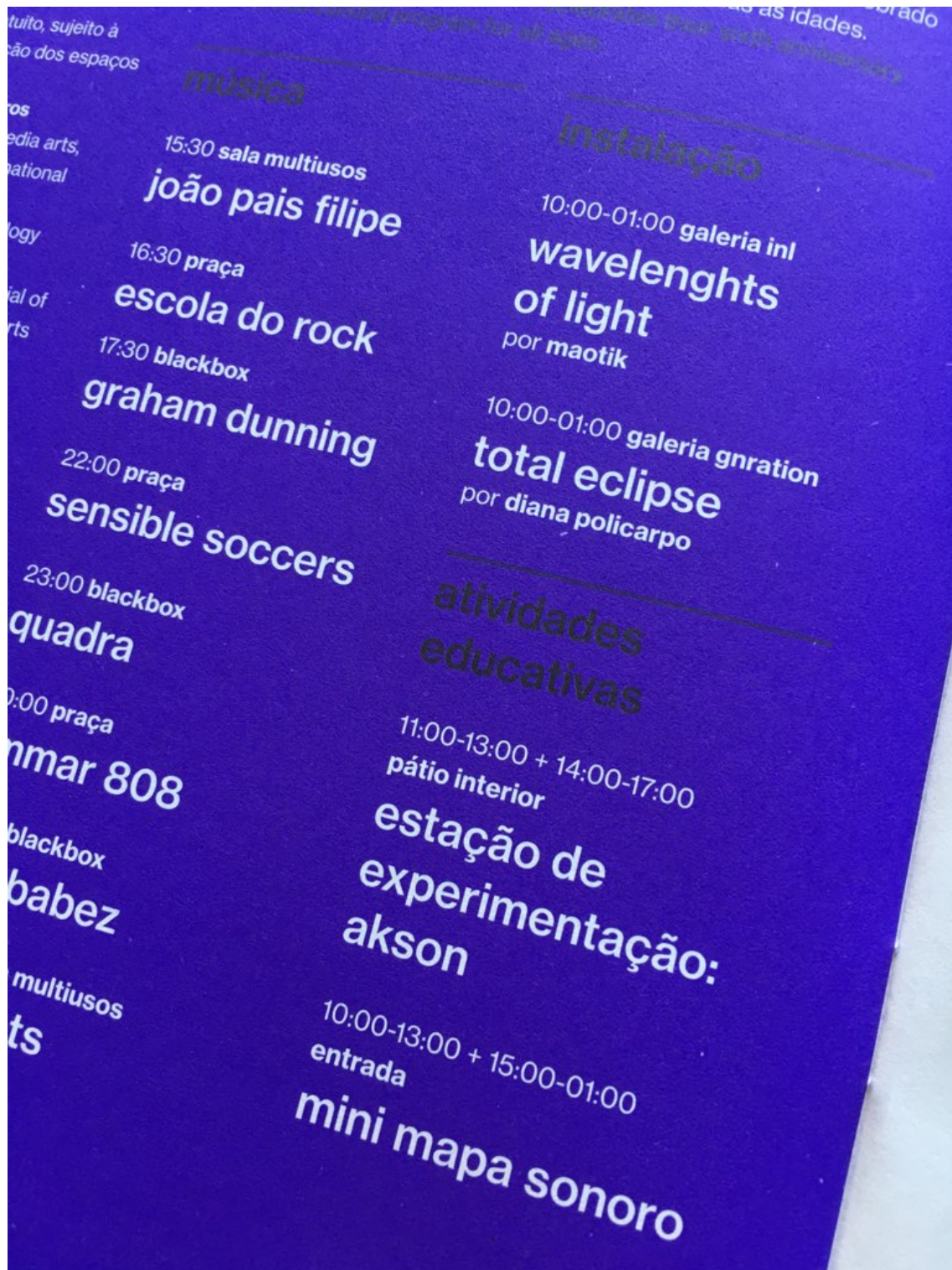## 7.8 Photograph of gnration's lineup

Figure 7.9: A photograph of a gnration flyer containing the activities of *open day*.

Chapter 8

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