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The Interface-Score

Electronic Musical Interface Design as Embodiment of Performance and Composition

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DOCTORAL THESIS

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Abstract

This thesis investigates the artistic and philosophical consequences of understanding musical instruments as artifacts embodying a score. In other words, it explores the extent to which musical instruments can be perceived as musical scores. This research examines the cultural and technological nature of digital musical instruments and it contributes to a material account of musical notation. It introduces a novel paradigm for tangible interface design called the *tangible score*. It also describes a practice-based research journey performing tangible musical interfaces.

This is a thesis in art. Opposed to a thesis on art, such as art history, my research did not have any prescribed methodology. In fact, my artistic production during this PhD may be considered both object and method. As an artist working with technology it was mandatory contextualizing my personal artistic methods. In consequence, this thesis gives answers to the question of how artists can engage artistic research with the field of human-computer interaction (HCI). I defend that the way artists can help HCI is adopting a critical attitude with our research medium -namely tangible and musical interaction design in this PhD- avoiding the instrumentalization of our artistic processes and adopting the format of artistic research. For drawing up this theory, this thesis analyzes various examples of critical interfaces. In order to capture the interest of other researchers within HCI, I present practical methods to formalize the structure of an artistic research project.

The notion of the *inherent-score* drives the beginning of my research on musical notation. I define it as the material and virtual elements of the instrument shaping and inspiring a player's performance. This notion gives us language to describe how the instrument mediates embodiment at the exact moment of performance. This is coherent with many improvisers' intuition affirming that the instrument is the score of what they play. I propose that it is possible to design new interfaces for musical expression emphasizing their inherent score. For exemplifying this option, I have built and performed a series of digital musical instruments called *Tangible Scores*. They are the center of my artistic practice during this doctorate.

This thesis contributes to a vision of digital musical instruments as *symbolic machines*. In my opinion, the principal characteristic of digital music instruments is their symbolic apparatus. The apparatus always features a program defining all possible musical realizations. For dealing with the complexities of the apparatus, designers have to deal with representations. They are helpful to inform performers about the status of the machine while they also serve for constraining the possible interactions with the program. For this reason, the *representational dimension* of musical interfaces has been addressed in this thesis. I present a vision about musical interfaces as a collection of related texts and symbols with a given arbitrary meaning. As I show in this thesis, they radically mediate our embodiment with the instrument. For this reason, I contribute towards a non-linguistic and non-representational approach to performing with musical interfaces.

Materiality is another important field of study in this thesis. I contribute to a *materialistic account* of musical interfaces defending that matter must not be only understood as the mere support for an interface's functionality. My thesis asserts that matter is an active agent able to inspire, provoke and shape performances. Therefore, my research aims at developing a new materialist sensibility at tangible and musical interaction design.

Finally, this thesis addresses the cultural and political dimensions of musical interface design. I defend that the cultural always reconfigures and redefines the technical in musical interface design. Politically, musical interfaces are never transparent technologies. A full range of cultural and political values are scripted into our musical interfaces. They are good examples of cultural interfaces.

In conclusion, this is a thesis dedicated to the study of the issues of musical interface design from an artistic standpoint. The field of study is highly interdisciplinary and cultural studies, technology and design -among many other disciplines- merged at my practice. For this reason, the background of this thesis is art, music, engineering and philosophy.

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Introduction

1.1. Prelude

In 2004 I finished my studies in telecommunications engineering and in music composition. Progressively in my practice, both disciplines merged and led to the creation of my catalog of digital artworks. Out of academia, my early involvement at collective artistic projects related to technologies (e.g. Medialab Madrid -now Medialab-Prado- or initiatives in Linz like Stadtwerkstatt, Kapu or servus.at) showed me that digital music is profoundly about social engagement with others. My interest in leading workshops led me to experiment, share and produce with others using open technologies. This creative environment also afforded innumerable possibilities for performing, exhibiting and holding discussions at international events, being them academic or non-academic. Through my specialization on free improvisation with electronics, live computer music and interactive installation I gained practical knowledge on developing systems (e.g. software and hardware) towards creating expressive digital music on stage. Along the last five years of being a PhD candidate, and now in 2018, I can perceive how the research I am presenting in this text has naturally and positively interwoven into my daily artistic professional practice.

A critical position about musical interfaces was present at the beginning of this thesis. Before starting this research, my personal perception about the state of the art in musical interfaces was frankly negative. In particular, I was determined to work against many assumed models guiding design and practice with musical interfaces, many imported from human computer interaction. At some point during the 2000s most people at hacker-spaces were more interested in developing software and hardware than in playing music. We invested endless hours putting technologies together which often never produced any concert. The underground community of those artists developing and performing with musical interfaces was small, and we often met and the same festivals in Europe (e.g. Piksel in Bergen). And it is still a small community. Before starting this thesis, I used to ask myself why so many of those musical controllers were able to produce such uninteresting music and concerts. Undoubtedly, those critical bearings were crucial to state my personal view about musical interfaces.

In order to substantiate my theoretical investigation, first I needed a profound study about the nature of musical interfaces. I realized that quite a big part of the actual literature was focused mostly on technical and phenomenological aspects. At the same time I was faced with the lack of publications on the cultural, philosophical and aesthetic dimensions of musical interfaces. In my opinion, in order to propose new models for expressive musical interfaces one also has to be aware of the many cultural and aesthetic aspects affecting them: politics of instrument design, cultural values given by users through processes of self-identification, subcultural trends, etc.

The central core informing my research is the notion of "instrument-score". This is the conceptual scaffold supporting my research. It centers my study and differences it from other possible branches of study. An understanding of musical instruments as scores is not equivalent to saying that we no longer need composition or traditional notation. Both musical instruments and musical scores remain important and efficient parts of the ecology of music. As I defend through this thesis, the 'score versus instrument' duality does not exist. In other words, instruments incorporate many aspects of notation and vice-versa. Especially in the case of digital musical instruments it is not easy to define precise borders between instruments and scores. The reason is that instruments -understood as complex and distributed computational systems- need to be pre-configured for specific performative uses. At the moment of designing digital instruments, we often need to constrain many aspects of the system in order to adjust its technologies to a specific composition or improvisation we want to play. Performing with digital musical instruments is then a typical example of a contemporary cultural practice which is highly mediated by technology. For that reason musical interfaces are difficult to define, classify, analyze and categorize. But it is my impression, as an artist, that it is much useful if we analyze study from the opposite direction. As technologies reconfigured by cultural aspects.

In this thesis, scores are studied in the context of what notation means today. Especially almost fifty years after the publication of John Cage's treatise *Notations* in 1969. It was also necessary to design, build, perform and evaluate a number artistic artifacts (the *Tangible Scores*). This practice was never instrumental to my theories. In other works, my practice has not served as a proof of concept for many of my ideas. My practice was in fact the path to gain new knowledge about musical interfaces. This practice-based research method afforded new interpretations and philosophical insights which I never imagined at the beginning of working on this thesis. Even more, I saw how some parts of published papers at the beginning of my thesis needed to be updated. All through these years, touching, performing, designing and defending artistically *Tangible Scores* have not shifted the initial questions of this thesis. However, practice has become an experiential grid helping me to identify the really important issues of performing with digital musical instruments. In my opinion, musical interfaces are technologies suffering from an acute hyper-abundance of representations. Its effects -as I will defend- are a linguistic understanding of performing sound with interfaces. We try to control sound as if it were another non-phonetic entity. Not surprisingly, sound rebels itself through the curse of non-interesting music.

This thesis therefore aims at identifying many states of affairs in musical interfaces for bringing forward alternative models. First, I try to understand their politics, cultural mediations and technological mindsets. Second, I extend the notion of notation towards materiality in order to explain why and how musical instruments also afford many aspects of the work to play. This materiality is more than a mere support for instrumental functionality. It is able to afford musical inspiration and performative practice.

In summary, this practice-based research aims at reconfiguring the relationships among three elements of musical interfaces -instrument, representation and embodiment- towards a new materialist sensibility in design and performance. A sensibility providing instruments the agency to suggest musical works.

1.2. Research Field

In musical tradition players benefit from years of training and experience performing with their instruments. Musical instruments have evolved their qualities, for instance due to players musical demands. As Puckette (1993) explains, musical instruments usually show a 'reason' to exist, as well as taking particular physical form, for developing specific playing techniques and musical roles.

Acoustic instruments (i.e. at philharmonic orchestras) have been with us for centuries. However, it was only during the last century that electronic music instruments appeared. Nowadays, almost every week we discover revolutionary new music interfaces existing at on-line crowd-sourcing sites like *Kickstarter*. The Computer Music Journal is a good repository of early musical interface design (Cadoz, 1997; Gillespie, 1992) while newer specialized academic conferences like NIME (New Interfaces for Musical Expression), TEI (Tangible, Embodied and Embedded Interaction) and SMC (Sound and Music Computing) seem to bloom with new musical interface applications every year. The key for understanding this apparent continuous revolution in musical interface design is efficiency. With musical interfaces, computers are offered as musical instruments where musicians can design interfaces without regard to the way sound will be produced. Interface design becomes released from sound phenomena. For example, it is possible to produce bass sounds with tiny instruments. And efficiently, digital instruments can today be studied separately from the subjectivities of music and its interpreters. The dream of every objectivitist.

The caveats of Joseph A. Paradiso (1999) are explicit:

> *Throughout most of the history of electronic music, the interaction end of instrument design could be classed loosely as a branch of ergonomics. Over the last 15 years, electronic instruments became digital, and within the next decade or so, their functions will probably be totally absorbed*

into what general purpose computers will become. Thus, for all practical purposes, musical interface research has merged with the broader field of human-computer interface.

The constant 'state of revolution' in musical interface design is mostly driven by novel methods of capturing gestures through the use of new sensors and due to innovative ways of sound generation. It is also true that a certain 'humanistic turn' has been produced within human computer interaction, giving a louder voice to philosophers and ethnographers. But the state of affairs is that musical interface design is mostly perceived as an engineering activity informed by other disciplines. For instance, according to the developers of the *reacTable*, one of the most successful instruments developed in academia in the last decade, the instrument is (Jordá, 2005):

"a state-of-the-art music instrument, which seeks to be collaborative (local and remote), intuitive (zero manual, zero instructions), sonically challenging and interesting, learnable and masterable, and suitable for complete novices (in installations) and for advanced electronic musicians (in concerts). The reacTable uses no mouse, no keyboard, no cables, no wearables. The technology it involves is, in other words, transparent to the user."*

It would be interesting questioning the notion of transparency in a reacTable. As its developers declare, "the technology it involves is transparent to the user". Necessarily it is a technical notion of transparency inherited from the field of human-computer interaction. It reminds mostly to the 'interface transparency' defended by Donald Norman in *Why Interfaces don't Work* (1990):

The real problem with the interface is that it is an interface. Interfaces get in the way. I don't want to focus my energies on an interface. I want to focus on the job. . . . An interface is an obstacle: it stands between a person and the system being used. . . . If I were to have my way, we would not see computer interfaces. In fact, we would not see computers: both the interface and the computer would be invisible, subservient to the task the person was attempting to accomplish. (209, 219)

This type of understanding of the notion of transparency was already criticized by the digital humanist Søren Pold (2005) exactly in 2005, when the reacTable was presented to the international community. Under this ideal of transparency we face in fact a deliberate effort towards black-boxing technology. Interfaces become transparent at the risk of limiting many other alternative functional possibilities. Additionally, this transparency would mean that a reacTable does not interfere our musical impetus. But we can all acknowledge how much interfaces, and especially the reacTable, mediate musical production. For Pold (2005):

If the computer and the interface really had become truly invisible and transparent, computers would mingle almost seamlessly with the world as we know it–perhaps making it a bit "smarter." If this were true, digital technologies would probably not have any paradigmatic effect on culture and aesthetics since they would not make a marked difference, but of course reality has proven otherwise, and we can now begin to acknowledge the massive cultural and aesthetic impact of digital technologies.

When technology is black-boxed, a performer's design role resides in a re-configuration of the system. Performing stands the risk of becoming an act of control and not a free act of interpretation. This situation locates performers on a very particular relationship with our instrument. Our commitment with digital instruments can sometimes be sustained only at very superficial levels.

The origins of this vision of musicians performing in front of operating control panels has a history. Michel Waisvisz (2004) describes post-war music and how much we have forgotten about it:

Electronic music was at that time (in to some degree still is) shaped by mathematical functions implemented in various kinds of control generators. Composers acted like managers of formulas and processes. The clean sine wave sweeps of tonal structures and sound dynamics was totally in tune with the modern non-romantic formalized world view of 50's high-tech futurism. Interestingly enough a special breed of today's laptop music culture has reverted to a similar exploration of the performer's role as an 'operator' or 'sound process manager'; someone who controls, tweaks, navigates the electronic sound creation process in a very distant, minimal effort strategy and mistakenly suggesting the making of music is a purely cerebral affair. A self-image very much related to

> *the scientific aura of the early electronic music composers, sort of being shy freaks, imagining themselves as operating as art-scientific supervisors in control of a 'music machinery' with the scope a nuclear research plant fueling culture into cosmic dimensions.*

An important topic which this thesis further explains is how can we approach a compositional practice with musical interfaces. During the design process of a musical interface, some kind of musical practice -if not a composition or an improvisation entirely- needs to be imagined. And it is understandable that once we have decided to use a particular instrument we will have to assume how it mediates -non-transparently- our music. As J.G. Ballard (1994) asserts: *Typewriter: it types us, encoding its own linear bias across the free space of the imagination.* Ballard hints at a fundamental and unique aspect that can be applied to every technology, digital or not. Musical works are shaped by the process of instrument design. But, can this shaping process be explored actively as a process of composition? Can design be considered a compositional practice?

These questions are in fact not new. Within the electronic music avant-garde in the 1960s, composers were often instrument makers too. It was the case with David Tudor and Gordon Mumma. They, among others, noted how circuitry was perceived as scores. Within their practice, these composers-builders have shown us that the circuitry of an electronic musical instrument was able to afford specific ways of a performer's interaction with the instrument. For example, Scot Gresham-Lancaster (1998) contextualizes his compositional practice for *The Hub* using the following arguments:

> *Independent circuits developed by individual artists represented a further development in this genre. [...] The unique aspect of this type of work lay in the circuit's de facto equivalence to a score.*

During a personal conversation with Nicolas Collins[1], the American performer clarified how in fact this perception has a long history among performers:

> *As it happens, it's been an area of low-key speculation for me over the past year or so. It was very common in the 1970s (when I was a student) to spout the "circuit as score" mantra, but it was only recently that I asked myself, "Well, if its a true score then there should be a way to analyze it as such, rather than simply use it as a recipe to build an instrument."*

In addition, Alvin Lucier (1998) describes how within many of the works produced by the Sonic Arts Union:

> *there were no scores to follow; the scores were inherent in the circuitry.*

The idea that a musical instrument can be considered a musical score too, or that the instrument is the score has come to the academic discussion partly in the field of interfaces for musical expression (Tomás & Kaltenbrunner, 2014), music notation (Maestri & Antoniadis, 2015) and performance of electronic music (Mooney, 2012). Certainly, when a performer approaches a musical instrument a number of limitations or constraints will be revealed. These characteristics of the instrument are often considered a score by virtue of its property of shaping the musical work.

From these examples, I affirm that the *instrument-score* notion exists as it is perceived by music performers. This affirmation is very important, as it becomes the core of my research.

1.3. Establishing the research questions

My research questions, modulated by the trans-disciplinary nature of our field, are the following:

- Many musicians agree that the instrument-score exists: it is the inherent and performative score available at (within) every musical instrument. It suggests and mediates our play. Is it possible to define and study the instrument-score?
- If the instrument-score exists (hypothesis), can we create new interfaces for musical expression emphasizing their inherent score, designing their form, spatial distribution or uniqueness as an object? What would be the mechanisms to achieve this?

[1] Email communication with the author in May 2016

1.4. Research Methods: Art and Design Methods

A PhD in Arts integrates both theoretical reflection and artistic practice, intrinsically related and complementary to each other. With research in art -as opposed to research on art, such as art history, for instance- there is no set goal or expected result and even no prescribed methodology. As an artist dealing with research in art, I had to develop my own working methods. My artistic work is therefore both object and method.

Julian Klein (2010), in the Journal for Artistic Research (JAR) asserts that according to the UNESCO definition, research is “any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge about humanity, culture and society, and the use of this knowledge to devise new applications” (OECD Glossary of Statistical Terms, 2008). Art can exist without research. Science can also exist without being research. The discourse of artistic research emerged in the 1990s in Anglo-phone countries and Scandinavia. It mostly occupied researchers of Visual Arts departments. Today it has also reached the fields of design, theater, film, music and dance. Art, science, music, philosophy, mathematics, etc are not separate domains. They are different dimensions of the common cultural space. Art can be to some degree scientific. Dance can be partially philosophical. In the same manner, science can be more or less artistic.

In my PhD, certain artistic processes (or artistic experiences) are also considered ’research’ when their development created knowledge.

But, what is artistic knowledge? When does it happen? Some scholars (Jones 1980) defend that artistic knowledge must be declarative knowledge. In other words, it must be able to be verbalized. Others say it is embodied in the products of art (McAllister 2004, Dombois 2006, Lesage 2009). Artistic knowledge is often characterized as tacit, sensual and physical. It is often defined "embodied knowledge". For Klein (2010) artistic knowledge "has to be acquired through sensory and emotional perception, through the very artistic experience from which it cannot be separated".

Artistic research practice leaves room for a diversity of research methods with openness and complexity. Researchers in art usually combine various methods. There is not anything like the "artistic method". Henk Borgdorff argues for methodological pluralism defending that “artistic research does not have any one distinct, exclusive methodology” (2012). Given the multiple artistic possibilities, ramifications, transformations, mutations of the methodological forms which could be applied to my topic, it was clear that I had to narrow my focus. At an artistic research process, researchers apply aesthetic means and artistic methods. In this thesis I have used methods imported from practice-based artistic research, which is described in the following subsection.

My work has been also informed by design, a field bringing its own culture and research methods. For this reason this PhD had to combine methods from artistic research and from design research.

In figure 1.1 we observe a landscape representing the state of design research (Sanders and Stappers, 2008). This map uses two intersecting dimensions. One is defined by approach and the other is defined by mind-set. The research-led approach has been developed traditionally by applied psychologists, anthropologists, sociologists and engineers. The design-led approach is much more recent recent. Examples are "Design Thinking" and "Critical Design". The left side of the landscape represents an expert mind-set where researchers design for people considering themselves the experts. People are described as “subjects,” “users,” “consumers,” etc. Designers working on the right side of the landscape design with people how are seen as true experts of their own experience.

During my PhD, I found my research following a few methods imported from design. I have developed critical design activities (e.g. study of non-functional interface designs), user-centered design methods (e.g. user studies and interviews) and participatory design processes (e.g. co-creation workshops). In the figure 1.2 I resume my own landscape of methods imported from design.

In the following sections I describe how I have engaged all the these methods -both from art and design- into my PhD.

1.4.1. Practice-Based Research Methods in the Arts

Practice-based research in interactive arts has been described by Edmonds and Candy (2010) as a "range of trajectories" comprised of three main elements: practice, theory and evaluation. For instance, one research trajectory would consist in acquiring theoretical knowledge for the production of new works. The artifacts created would be evaluated in terms of the theory. However, a practice-driven trajectory may begin with practice. For Edmonds and Candy, "*research questions and design criteria are derived through the creation of works and this leads to the development of a theoretical framework which is used in the evaluation of the*

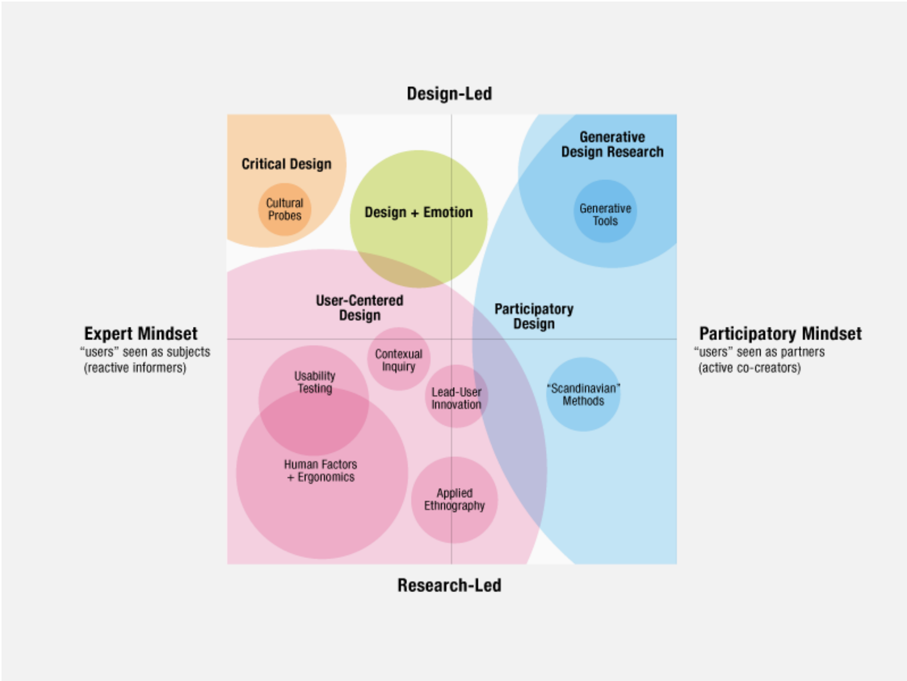


Figure 1.1: Landscape of design practice and design research (Sanders and Stappers, 2008)

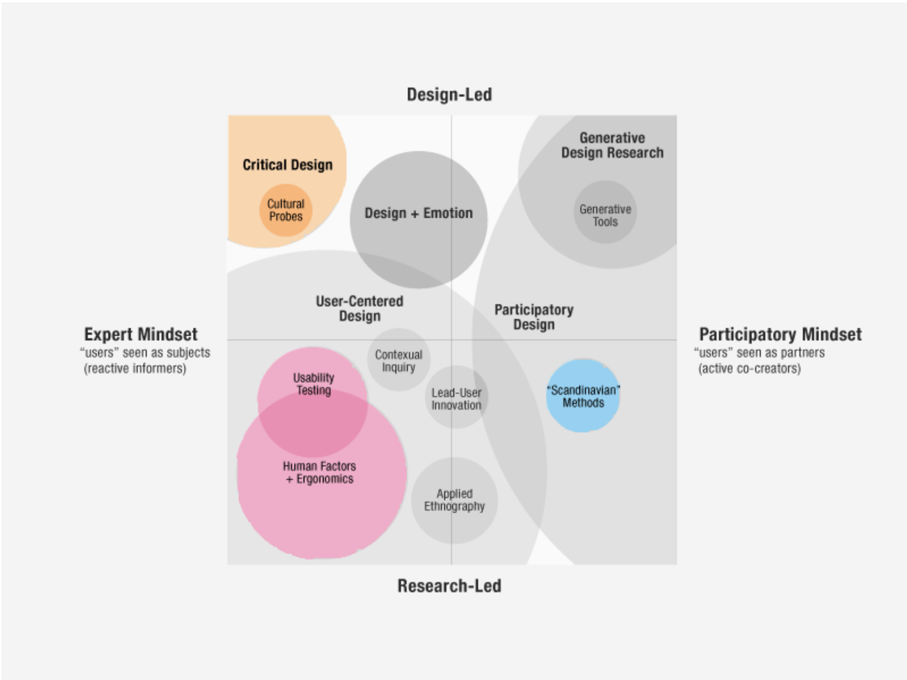


Figure 1.2: Methods imported from design I have used in this thesis (colored)

results of practice" (Edmonds & Candy, 2010, p. 130).

Consequently I hereby define the field of new interfaces for musical expression (NIME) as my body of knowledge for practice-based research. NIMEs are embodied by theories explaining various aspects of musical interaction and sonic expression. The crucial questions are how I can, as a practitioner/researcher, make these embodied-in-the-interface theories visible to others and how can I present them in an open way for collective reflection and evaluation.

The trajectories of my practice-based research are threefold:

- Prior to a new design: professional artistic practice with musical interfaces (built by me and others). Reflection about my personal embodiment and expression with the digital instruments. What are the issues constraining it? Design of theory frameworks from this reflection.

- During the design of a new artifact: an iterative process of theoretically-informed action and reflection on design research (Lewin, 1946, Simon, 1981; Hevner et al., 2004). Artistic and scientific literature provides an initial criteria informing new instrument design.

- After a new design: professional artistic practice, presentations, showcase at exhibitions. Personal evaluation of the experiential part of playing in front of others. Reflection and evaluation after feedback received from others. Iterative design and refinement of the theories supporting my musical interface. Iterate this trajectory again.

A long time struggle in the field of NIME has been finding a meaningful approach to evaluation (Wanderley and Orio, 2002). Not only measurable parameters should be incorporated into evaluation. Even more, measurable criteria have a radical dependence on particular artistic contexts. Design towards specific aesthetic targets reduces the risk of lacking cultural context. Perry Cook advises designers to "*make a piece, not an instrument or controller*" (Cook, 2001, p.1). In other words, designing instruments for all types of musical expression is usually highly inefficient. From my experience, different performers can interpret quite differently the physical and symbolic affordances of a digital instrument. Musical interfaces, from a post-structuralist approach, are codes dependent on a performer's own personal concept of music.

How can musical practice generate new theoretical models? Schön (1983) describes reflection-in-action as 'action present'. It means reflecting on the incident whilst it can still benefit that situation rather than reflecting on how you would do things differently in the future. At performative arts we often need to react to an event at the time it occurs rather than having the luxury of being able to think about what happened and make changes at a later time. When someone reflects-in-action becomes a researcher in the practice context. Researcher is not dependent on the categories or established theory and technique but he or she constructs a new theory of the unique case. Playing a musical instrument is a goof example of a process of reflection-in-action. We find ways of playing a difficult passages of notes trying physically alternative models to the theoretical approach. This not only represents an ad-hoc solution for a particular case. It often becomes a model a performer extrapolates to other performative situations.

In the chapter six of this thesis, a relevant part of my evaluation is built on a process of 'reflection-on-action' (Schön, 1983). It helped me to reinforce my theoretical models towards particular ideas. Alternatively, it allowed me identifying sources of problems and false assumptions about interface design. For example, reflection-on-action guided my work towards non-representational computing to become more concrete and less personal.

Evaluation, when it has been well develop informs about:

- How the musical interface embodies the criteria

- The relationships between a theoretical criteria manifested by the digital instruments and the real experiences lived by performers who use it.

Practice-based research is characterized for featuring various methods as well. Usually researchers/practitioners do not apply a single method but they combine them for studying different aspects of the same topic. Alternative methods can be complex to compare sometimes. However, non quantitative information may be extracted from a set of methods. This information must be put in context of the method employed. The results of these methods have articulated the following activities in my thesis:

- The acquisition of knowledge and expertise in imagining, designing and building new electronic musical instruments, following a critical perspective with the research medium.
- Performing, composing, and improvising my own works with interfaces.
- Analyzing and reflecting about my own practice-based research, with the aim of better understanding the objective and subjective mediations and inter-relations of elements in my field. For example, the embodied and cognitive dimension of performing sound with digital instruments, its emotional or artistic associations and the mediated relationship between performer, instrument and musical work.

In particular, these initial ideas have been explored through the following parallel methodological paths:

- Creating musical interfaces and instruments in which the score to be performed is inherent to its circuitry, digital realm or in its form in the space it inhabits.
- Identifying patterns of
  1. musical contents
  2. hardware and software configurations
  3. elements informing how to play those configurations
- Creating interfaces through a permanent process of iterative design, based on a cyclic process of prototyping, testing, analyzing and reflection for refining the instrument throughout continuous evaluation from musical practice.

In conclusion, the contributions of the practice-based to my research are theory frameworks relating the experiences of musicians to instrument characteristics and refined design criteria informed by practice and research.

1.4.2. User-centered Design Methods

Musical interfaces exist because they usually exhibit a functionality. With them we perform digital sound and music. In a complementary relationship with other critical aspects I have embodied in this thesis, performativity requires examination of at least functionality, usability, ergonomics and expressibility among other techniques. In order to better understand the implications of those parameters I imported methods from user-centered design.

User-centered design is an iterative design approach which departs only after having gained a prior deep understanding of users' need. Its methods are a mixture of investigative activities (e.g. surveys and interviews) and generative (e.g., brainstorming). In this thesis I have developed workshops with surveys and user studies to understand how user engage physically and perform with my interfaces.

The activities developed through these methods were:

- Recording videos of users playing my interfaces at concert and installation situations.
- Organization of workshops with users for gathering feedback about aspects of usability, functionality and expression.
- Sharing my artifacts with other performers trained in different musical instruments and aesthetics. Observing and analyzing the results of their performance in terms of personal engagement with the instrument and proposed works. Finally, the analysis of the subjective impression of the audience regarding the performance.
- Analysis of my own performances.
- Asking affiliated composers to create compositions for these instruments, studying and analyzing possible difficulties of projecting their artistic imagination over a particular interface or object.

These activities are fully described at chapter six of this thesis.

1.4.3. Collaborative Design Methods

Collaborative design describes an approach to design that attempts to actively involve all stakeholders in the design process to ensure the result meets their needs and is ultimately usable. Collaborative design is characterized by the involvement of people's agency in shaping products and decisions. It marks a clear shift from formalized models of work dominated by traditional and hierarchical decision-making which usually transform work into disembodied procedures and make invisible the social nature of everyday work routine. The beginnings of collaborative and participatory design are rooted on the 1960s and 70s, when social agents in many Western societies demanded to participate in collective action around shared interests and values For example, in Scandinavia and during the 70s, the so called "workplace democracy movement" was aimed at providing workers with better tools for doing their jobs. Giving these workers a voice in decision-making about designing tools, environments and social institutions, in the co-design of the artifacts that shaped their lives was found as a positive trend to integrate different interests.

Roughly speaking, at a co-design project, participants undertake two main roles: users or designers. Users need to have a voice in design without the need of speaking the language of professional engineering. For that, and as we will see later in chapter six, different methodologies will be needed: prototypes, mock-ups and other representations of systems and practices.

At the end phase of this PhD, two performers playing my interfaces decided to develop a collaborative design workshop for evaluating my interfaces. At this workshop, participants could revise "Tangible Scores" from their perspective, pointing to the aspects that they did not like (both from my interfaces and from a concert they attended) for re-designing them together through a collaborative process. This workshop is also fully described at chapter six of this book.

1.4.4. Critical Design Methods

I dedicate the second chapter of this thesis to explain my critical approach to human-computer interaction from an artistic viewpoint. In particular, how the arts can help us to question many of the assumed models in HCI and NIME.

For Anthony Dunne and Fiona Raby, critical design "*provides a critique of the prevailing situation through designs that embody alternative values*". The term Critical Design was first used in Anthony Dunne's book "Hertzian Tales" (2006) although the concept was already outlined together with Fiona Raby at "Design Noir: The Secret Life of Electronic Objects" (2001). Its opposite is affirmative design: design that reinforces the status quo of a discipline. For Dunne and Raby (2009):

> *The critical sensibility, at its most basic, is simply about not taking things for granted, to question and look beneath the surface. This is not new and is common in other fields; what is new is trying to use design as a tool for doing this.*

Jeffrey and Shaowen Bardzell (2013) have found a clear relationship between critical design and the older critical philosophy of the School of Frankfurt (Adorno, Marcuse, Horkherimer among others). Critical Design would be a research strategy dedicated to "transgressing and undermining social conformity, passivity, and similar values of capitalist ideology, in hopes of bringing about social emancipation" (*ibid*). Critical design is a form of social research. It is primary intended at producing knowledge and not at designing products.

Unfortunately, Dunne and Raby have not offered many details about how critical design can be developed. They characterize critical design as more of an "attitude" than a "method". They often use terms like transgression, provocation, satire and the staging of dilemmas as actions.

In their list of Frequently Asked Questions I found at their website, Dunne and Raby were asked why critical design was not art. They answered "*if it is regarded as art it is easier to deal with, but if it remains as design it is more disturbing, it suggests that the everyday as we know it could be different, that things could change*". In other words, Dunne and Raby understand that art is isolated from the everyday. This would be like bracketing aside aesthetic artifacts by the public as "just art" (Bardzell, 2013). However, it is difficult to create an ontological separation between critical design and art. Although certain artists work with the concept of "shock and extreme" there exists as well a large landscape of art living our everyday. If not directly as another part of our living rooms and kitchens, at least very close to us.

Critical research means, in the scope of this thesis, being critical with our research medium. Questioning, destabilizing the pillars of HCI in the quest for unexpected relationships. As it is explained in chapter two, I have taken into account and analyzed the critical works of various media artists, together with Søren Pold's "Aesthetic Interfaces" philosophy (2005) to propose three methods within critical design. These methods are "problematization", "methodological conceptualization" and "artistic inquiry". More into detail, during the first semesters of my thesis I established the following:

- Problematization: is there a possibility to create musical interfaces incorporating the idea of 'musical score' at this configuration? Which could be the philosophical and practical consequences of understanding musical interfaces as musical scores? Which elements of Human-Computer Interaction do become destabilized by this idea? Which problems will I face to implement it? Is computer science ready to host many of my artistic ideas? How can I design an artifact for this purpose? Do I have enough time to implement it within five years?

- Methodological Conceptualization: it was clear to me, as an active performer for many years, that I had to follow a practice-based research. In this case, my practice (concerts, composition, etc) with the interface would be the basis of the contribution to knowledge. Whilst the significance and context of the claims of research could be described in words, a full understanding can only be obtained with direct reference to the practice outcomes. Especially because I expect many aspects of its contributions to research to come after the direct observation of the artifact created, once it exists. Thus, following this methodology, the artifact will inform important concepts which were in fact not formulated at the moment of design and performance: they can only be perceived at the moment of experiencing it, at the moment of practice. In addition to practice-based, the need for adopting a critical methodology, as it has been explained before, would orient and focus my practical work.

- Artistic Inquiry: until the third semester of my thesis, the first artistic processes did not point me in a particular direction. Among many different possibilities and interests for using specific materials and aesthetics, my practice took the course of exploring graphic scores, an artistic field which I had used intensively during my compositional practice. The idea of augmenting 'the graphic' towards materiality, brought me to a personal and subjective selection of graphic figures that inspired new and imaginative ways of interpretation.

1.5. Research Contributions of this PhD

From this practice-led process of designing, performing and reflecting a number of contributions were produced at various levels: at the theoretical, at the methodological and at the practice-based.

These contributions are here only outlined for the clear and rapid introduction to this thesis. Chapter seven dedicates ample space to describe and discuss these contributions:

1. The definition and study of the concept of an instrument's inherent score.
2. The definition of a novel paradigm for musical interface design: the tangible score.
3. A methodological framework for the adequate engagement of artists in human computer interaction research projects.
4. A description of musical interfaces as symbolic machines.
5. A comprehensive framework for modeling my performative practice with musical interfaces,based on three interdependent layers: instrumental, performative and technical.
6. An account of the performative moments of the interface.
7. An analysis of the representational dimension of musical interfaces.
8. A study on the cultural and political nature of musical interfaces.
9. A study on the notational nature of the instrument's inherent score.
10. A materialistic account of musical notation.
11. The steps to program and control a polyphonic concatenative synthesizer driven by real-time audio signals.
12. A systematical description of my practice-based activity with Tangible Scores.

13. An analysis of the possibilities to enhance a non-linguistic communication with computers during musical performance.

14. A vision of interface design as a compositional activity.

1.6. Outcomes

In this section I am presenting a list of tangible outcomes produced during five years of research. It is important to note that only academic and artistic activities fully related with this thesis are presented.

- **PUBLICATIONS AT BLIND PEER-REVIEWED ACADEMIC CONFERENCES**

  Various sections of this thesis have been peer reviewed and published in conference proceedings and journal publications.

  Parts of chapter 2 are included in:

  - **Tomás, Enrique. (2017). "How can the Arts help tangible interaction design: A critical re-orientation" in Informatics, 2017, 4(3), 31; doi:10.3390/informatics4030031**

  Parts of chapter 3 are included in:

  - **Tomás, Enrique (2016). "Politics of Musical Interfaces: Ideologies and Digital Disenchantment", in Proceedings of the First International Conference on Interface Politics, Barcelona, 2016.** (**not Blind-Peer Reviewed**)

  Parts of chapter 4 are included in:

  - **Tomás, Enrique (2016). "Musical Instruments as Scores: A Hybrid Approach", in Proceedings of TENOR 2016, International Conference on Technologies for Music Notation and Representation, Cambridge, 2016.**

  Parts of chapter 5 are included in:

  - **Tomás, E.; Kaltenbrunner, M. (2014) "Tangible Scores: Shaping the Inherent Instrument Score". In Proceedings of the NIME 2014, New Interfaces for Musical Expression Conference, London, UK, 30 June–3 July 2014; pp. 609–614.**

  - **Tomás, Enrique (2016). "Tangible Scores" in Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded and Embodied Interaction, Eindhoven, 2016.**

  Parts of chapter 6 are included in:

  - **Belsunces, A.; Benitez, L.; Brandstätter, U.; Escudero Andaluz, E.; Lamoncha, F.; Pin, P; Tomás, E.; Diffractive Interfaces: Diffraction as an Artistic Research Methodology. In Art-Nodes journal 2017, 2 (1)**

  - **Goudarzi, V., Tomás E. and Gioti A. (2018). "Collaborative Design Methods towards Evaluation of a Tangible Interface" in Proceedings of ICLI 2018: International Conference on Live Interfaces, Porto, June, 208.**

- **PERFORMANCE AT BLIND PEER-REVIEWED ACADEMIC CONFERENCES**:

  I have performed or presented as an artistic installation Tangible Scores at the following academic conferences through a blind peer reviewed selection process:

  - **LAC**, Linux Audio Conference, May 2013.

  - **NIME**, New Interfaces for Musical Expression Conference in London, July 2014.

- **ICMC+SMC**, International Computer Music Conference and Sound Music Computing Conference (combined that year) in Athens, September 2014.

- **TEI**, Tangible, Embedded and Embodied Conference in Eindhoven, September 2016.

- **SELECTED PERFORMANCES AND EXHIBITIONS WITH TANGIBLE SCORES**:

  - University of Art and Design Linz, May 2014. Installation.
  - Sónar Festival 2014, Barcelona. Installation.
  - Ars Electronica Festival 2014, Linz. Installation and concert
  - Muziekgebow Amsterdam, January 2015, dance representations.
  - Ars Electronica Festival 2015, Linz, Concert.
  - Festival MEM, Bilbao, March 2016, Concert.
  - IRCAM Paris, June 2016, Concert.
  - November Music Festival 2017, Den Bosch. Dance representation.
  - CTM Festival 2017, Berlin, February 2017, Installation.
  - IEM Cube Graz, May 2017, Concert.
  - Blauesrauschen, Herne and Dortmund, October 2017, Concert.
  - MEQ Festival, Montpelier, October 2017, Concert.
  - Alte Schmiede, Vienna, November, 2017, Concert.
  - LEV Festival, Gijón, April 2018, Concert.
  - University of Fine Arts Pontevedra, April 2018, Concert.
  - Euphonic Festival, Tarragona, August 2018, Concert.

- **LECTURES AND CONFERENCES GIVEN**:

  - University of Fine Arts of Bilbao, Spain. March 2016.
  - IRCAM Paris, New Notations Symposium (invited lecturer), September 2016.
  - Digital Humanities Lab, University of Sussex, Brighton, October 2016.
  - Kunstuniversität PhD Kolloquium, four times between 2013 and 2017.
  - CTM Festival, MusicMakers Hacklab, February 2017.
  - Transient Topographies Conference, National University of Ireland in Galway, Moore Institute for Research in the Humanities and Social Studies, NUI Campus. April 2018.
  - Fine Arts University of Pontevedra (Spain), May 2018.

- **REFERENCES TO MY PUBLICATIONS**

  My publications have been cited by the following papers and sections of books[2] by other authors:

  - Maestri Eric, Antoniadis Pavlos. "Notation as Instrument: From Representation to Enaction" Proceedings International Conference (TENOR). OInternational Conference on Technologies for Music Notation and Representation, 2015.
  - Diemo Schwarz, Gregoire Lorieux, Emmanuelle Lizere, Ariadna Tarres, Frederic Bevilacqua. "A Topo-Phonic Table for Tangible Sonic Interaction". International Computer Music Conference (ICMC), Oct 2017, Shanghai, China. International Computer Music Conference (ICMC), 2017.

[2] Please check https://scholar.google.com/citations?user=60KC5zQAAAAJ&hl=en for an updated list

- Palle Dahlstedt. "Physical Interactions with Digital Strings-A hybrid approach to a digital keyboard instrument" in Proceedings of the New Interfaces for Musical Expression Conference (NIME) 2017, Aalborg, 2017.

- Augoustinos Tsiros, Gregory Leplatre, "Evaluation of a sketching interface to control a concatenative synthesizer" in Proceedings of the Sound and Music Computing Conference (SMC) 2016, Hamburg, 2016.

- Simon Alexander-Adams, "A Flexible Platform for Tangible Graphic Scores", Master Thesis Bachelor of Fine Arts, University of Michigan School of Music Theatre and Dance, 2014.

- Pierre Couprie. Algorithmique et technologies numeriques dans la notation musicale. Sylvaine Leblond Martin. Musiques Orales, leur Notation et Encodage Numerique (MEI), Oct 2015, Paris, France.

- Luís Alberto Teixeira Aly. "DIGIT - DIGItal sTeps". Master Dissertation at the University of Porto, 2016.

- **PRESS AND RADIO REVIEWS. ONLINE PRESENCE.**

  - Creative Digital Music, 2 February 2017.

  - Adafruit, 27 February 2017.

  - IX ACM Inteactions, Review TEO 16 exhibition, 2016. Demo hour. interactions 23, 3 (April 2016), 8-11. DOI: https://doi.org/10.1145/2904383

  - The Overloaded Score, Sul Ponticello Magazine, February 2017.

  - Blaues Rauschen Festival Review, WAZ Newspaper, 10 October 2017.

  - WDR Broadcast, WDR3 Open Sounds, 3 March 2018.

1.7. Structure of this Thesis

This thesis is structured along eight chapters. Chapter one sketches my personal intentions in defending a thesis on musical interfaces. It presents my relationship with the field, my research questions and it resumes a few background considerations about the state of the art in musical interfaces. With the objective of offering a fast track to the academic community, chapter one includes a resume of my research contributions and a list of tangible outcomes.

Chapter two presents the particular methodological framework supporting this thesis. Deeply embedded into artistic research, the methods employed propose a critical appraisal of Human Computer Interaction (HCI) from an artistic standpoint. In this regard, the motto "How can the arts help HCI" serves to describe the value of the artistic methods in the process of cultural and technological inter-mediations. In particular, I show how through the production of critical interfaces -critical with their own research medium- it is possible to evaluate and update many of our assumed notions in HCI.

The third chapter examines the compound nature of musical interfaces. First, musical interfaces are defined from their technological dimension. The effects of their decoupled (from sound) nature are discussed and I propose that digital musical instruments can be easily modeled as apparatuses programmed for the production of symbols (digital music). The second part of this chapter examines musical interfaces from their cultural dimension. In particular, how certain politics of interface design have revealed an acute disenchantment with 'the digital' and how, at the same time, musical controllers can help to enhance our social engagement through musical activities.

Chapter four examines the issue of notating live musical performance with digital instruments and it presents the important notion of 'inherent-score', the score inherent to every musical instrument. I answer to the question of what can be notated and I examine the case of dance, a stage-based discipline without a generalized notational system. After presenting the historical origins of the instrument-score perception, they are examined as notational systems under a Goodman's notational test as they are described in *Languages of Art* (1968). Finally, the philosophical consequences of extending notation towards musical instruments are examined. Which elements within a musical instrument's body can change our perception in such a way that we start feeling it as a score? A generalized notion of score is proposed and the concept of inherent-score is described as a multi-dimensional space of physical, virtual and musical affordances and constraints.

Chapter five is centered around *Tangible Scores*, the series of artifacts produced during this thesis. In this chapter I define the *tangible score* concept, their material aspects and various examples of them. Tangible

Scores were produced in part for evaluating my theoretical hypothesis. They turned into a very complete research tool and platform supporting my artistic investigation. Through my practice with Tangible Score I have been able to gain artistic knowledge on interface design as well as on many other related topics. Finally in this chapter, many aspects of their fabrication and software implementation are fully described.

Chapter six details five years of intense practical activity with Tangible Scores. I relate a long process of events causing me to implement new elements of Tangible Scores. At the same time, this chapter describes many aspects linked to the evaluation of this thesis. Evaluation is here understood as a process of self-reflection after action.

After an intense period of artistic practice in 2016 and 2017 chapter seven was written. The contents discussed here were informed by reflection after practice. This chapter then expands, and partially updates part of my prior philosophical discourse. For instance, I discovered how a certain neo-materialist sensibility was ingrained in my thesis without having been aware of it. Also, how the notion of enaction was easily applicable to the experience created by a tangible score. An alternative schema for modeling musical interfaces which could include the notions of notation and performance is proposed and defended. In addition, I discuss how different, in terms of the type of mediation employed, are the various moments of working with musical interfaces -design, build, configure, learn and perform-. Similar discussions are maintained in this chapter in regard to three fundamental aspects: language, touch and musical intention.

Finally, chapter eight chapter eight contains the conclusions of this research. It includes a comprehensive list of research contributions. The potential importance of this contributions is discussed and future work in this field is advanced.

2

Methodologies: How Can the Arts Help Human Computer Interaction?

I don't want to use my creative energy on

somebody else's user interface.

Jeff Bezos

There is a long history of creative encounters between interface design and the Arts. However, in comparison with media art, tangible interaction seems to be quite anchored to many of the traditional methodologies imported from human computer interaction (HCI). As an artist, how can I contribute to this field? This particular question has driven the creation of my methods within my artistic practice-based methodology. These methods formalize along this chapter a way to engage artistic research with HCI. They can be applied by HCI researchers interested in understanding artistic research and for preparing the integration of a group of artists in their labs.

This chapter builds on Søren Pold's *Interface Aesthetics*, a re-orientation of the role of the artist towards a critical examination of our research medium—tangible and sonic interaction—is proposed. The benefits of incorporating artistic research and its methodologies into our field are described. With these methodologies it is possible to better assess experiential aspects of interaction—a relevant attribute which traditional HCI approaches cannot afford. In order to inform our community, two examples of critical artworks are comparatively studied and discussed.

2.1. Introduction: Tangible Interaction and the Arts

In 2016, the media art festival Ars Electronica (Stocker et al, 2016) gave special relevance to the field of tangible interaction design presenting the project Radical Atoms (Ishii, 2012) together with other works by the MIT Tangible Media Group. A number of tangible interfaces were presented as the artistic highlights of the year. Indeed, the reacTable project (Jordá, 2010) had won the "Golden Nica in Digital Musics" at the same festival in 2008. Certainly, there exists a history of intersections between the media arts and the field of tangible interaction design. In 2007, the first International Conference on Tangible, Embedded and Embodied Interactions (TEI) was established "to be aimed at bringing together researchers, students, designers, practitioners, and artists" (Ullmer et al, 2007). Just a few years later, this initial impulse for integrating artistic proposals in the conference resulted in a separate Arts Track for TEI. A much earlier example of this history of creative encounters is the development of the "Marble Answering Machine" by Durrell Bishop at the London Royal College of Art in 1992.

As Hornecker and Buur (2006) have described, *"tangible interaction tends to emphasize materiality, physical embodiment of data, bodily interaction and embeddedness in real spaces and contexts"*. However, these are also concepts serving well to describe the intentions behind the work of many media artists (Iles, 2016; Shanken, 2009). Hence, novel developments in tangible and embodied interaction have gone hand in hand with new ground in the Arts and vice-versa. Interestingly, this crossroads of cultures was emphasized after the so-called *practice turn* in interaction design during the first decade of the 2000s (Fernaeus, 2008). This change of mentality motivated tangible interface designers to focus more on designing interactions than on the interface itself. Since then, explains Hornecker (Hornecker, 2015), human action, creativity, and social action are topics which have been increasingly adopted into our research agenda, thus unlocking definitively the door to artistic production within academia and interaction design labs.

As an active artist and researcher in the field of tangible interaction, the spark for writing this chapter came from a process of inquiry about the actual role (we) artists have often assumed at this confluence. If tangible interfaces—especially those created by engineers at academic labs—also seem to feature enough artistic contents to be presented at gallery spaces as aesthetic artifacts, why is the artistic collective not so much present at tangible interaction labs? Which role should artists assume at human–computer interaction (HCI) labs? Which is the real value that the Arts can now offer to tangible interaction design?

This chapter suggests a re-orientation of the artist's role towards the creation of "critical interfaces": interfaces which are critical with our own research medium (e.g., tangible interaction design). This re-orientation encourages the shift from a traditional vision of artists as mere producers of aesthetic content to a more updated and useful vision of the Arts fully engaged in research. This contribution is built on Søren Pold's "Interface Aesthetics" (Pold, 2005) which recommends the incorporation of digital arts into HCI as a method to evaluate its long-assumed paradigms.

As I will explain further, "critical aesthetic artifacts" would be interfaces especially designed to criticize our own research medium and trigger reflection about assumed paradigms of our field. In fact, cultural interfaces have often been described as "critical" (Nam, 2014), as they can also convey a social or political role. However, the specific type of critical interface which is proposed here orients its existing critical dimension towards our research paradigms and accepted assumptions about HCI and its applications. For instance, a critical interface of this type would be an interface designed to visualize and compare the degree of "invisibility" (Norman, 1999) which certain interface technologies promise to their users[1].

To illustrate the benefits of this re-orientation of the artists' role in HCI, this section first studies why interfaces specifically afford artistic exploration. Then, it presents Pold's treatise on "Interface Aesthetics". After that, the field of artistic research is introduced in the context of our topic, as well as some of its methodologies and methods. Two examples of recent critical interfaces are analyzed, compared, and discussed in order to exhibit some of their design patterns.

2.2. Interfaces: Definitions

Before centering our discourse on aspects of interaction with interfaces, it is necessary to define 'interface'. In the scope of this thesis 'interface' is a point of interaction between humans and computers. For Pold (2005a):

> *The purpose of the interface is to represent the data, the data flow and data structures of the computer to the human senses, while simultaneously setting up a frame for human input and interaction, and translating this back into the machine.*

Interfaces can appear under various manifestations, even in an invisible form. It is often said that 'the interface' is a dynamic form, a dynamic representation of the changing statuses of processes and data, to inform users during interaction. Consequently, the interface is often not a static, material object.

Musical interfaces are interfaces used during musical interaction. The interdisciplinary origin of computer music has historically attracted diverse types of contributions. From computer science to cognitive science. From arts and music to ethnography. Interestingly, disciplines with diverse research methodologies have contributed equally to to the rapid growth in the number of studies about musical interfaces. In continuation of its engineering tradition, research in Human-Computer Interaction (HCI) and research in musical instruments crystallized under the name of New Interfaces for Musical Expression field (NIME), the academic umbrella covering the development of this thesis.

[1] Invisibility is a central topic studied by Donald Norman's in his book "The Invisible Computer" where the author asserts that "technology should be invisible, hidden from sight"

For the scope of this thesis, it is also crucial to define the field of tangible interface design. The first reason for that is that my research inherits many concepts from tangible interaction design in order to explain the particular embodied and haptic relationships established with my artistic artifacts (called *Tangible Scores*, see chapter five). The field of tangible and embodied interaction provides many tools and frameworks to envelope, compare, evaluate and disseminate my research. It also features a large community around the academic conference TEI (Tangible and Embodied Interaction). Therefore, a tangible (user) interface is an interface in which a person interacts with digital information through the physical environment by giving physical forms to digital information, thus taking advantage of human abilities to grasp and manipulate physical objects and materials. It is not necessary to further explain the field of tangible interaction design at this moment. The interested reader can find information about the field in chapter three, section 3.2.1.

2.3. Critical Interfaces: Interface Aesthetics

2.3.1. Interfaces as Aesthetic Artifacts

The central point of this section is revealing a vision of interfaces as non-neutral technologies for communication. As it will be shown, this non-neutral character is the key factor which makes tangible interfaces suitable for becoming aesthetic artifacts.

The study of interfaces as an aesthetic category has occupied a large part of the Cultural Studies research agenda. During the 1990s, Don Norman answered the question of *Why Interfaces don't work?*, Steve Johnson published his book *Interface Culture*, and Manovich released *The Language of New Media* and *Interface as a New Aesthetic Category*. Since then, a significant number of authors have continued studying the consequences of the massive use of interfaces from the perspective of Digital Humanities and Digital Arts.

Akrich and Latour (1992) have noted the ways interfaces are scripted with predefined roles of use and with specific politics. For Galloway (2012), an interface is not a thing, it is mostly an effect: often we can only perceive the interface through its effects. For Don Ihde (1992), interface technologies are never stable entities, as they are conformed from a multiplicity of black-boxed processes and assemblies we cannot fully achieve. Reinforcing this argument against neutrality, Manovich (2002) asserts that *"the computer interface acts as a code which carries cultural messages in a variety of media [...], and in cultural communication a code is rarely simply a neutral transport mechanism"*.

Interestingly for us, this perception of interfaces as non-neutral technologies has definitely sparked an interest in artistic exploration. For Pold (2005a) and Galloway (2012), interfaces can be considered "autonomous zones of aesthetic activity". Certainly, if we are confronted with a medium of entangled non-neutral mediations between agents, this can surely be the perfect midst for enacting unexpected but meaningful relations. Through artistic exploration, critical aspects of this medium can easily provoke imagination. Thus, interfaces will not only adopt a particular functionality, but they can also extend themselves towards aesthetic experiences (Pold, 2005a). In short, interfaces extend themselves towards the Arts. Their permanent exhibition at media art festivals or their presence at art academies (Sommerer et al, 2008) illustrates that this phenomenon is already happening, while it still offers huge expectations for the future.

Especially for our community, the practical consequences of this extension towards the Arts are double:

1. An extension of tangible interface design towards aesthetics shifts the perception of interfaces as strict functional objects to a vision of interfaces as artifacts with an expressive intention, as long as their components, representations, and interactions can afford aesthetic relationships. As a consequence, interfaces can appear highly disembodied from their original functionalities at the level of the computer system. For instance, a computer keyboard attached to a tennis racket which allows typing on facebook while its user is playing[2] can afford aesthetic relationships. However, if some of its keys happen to get broken after impact with a tennis ball, the aesthetic experience will not be affected decisively. The work is mostly about the act of random typing. We can say that some broken keys would not radically change its expressiveness.

   However, it is important to clarify that 'the aesthetic' does not define itself as the opposite of 'the functional'. Aesthetic extensions re-organize many elements of artifacts towards an expressive or artistic intention. This is a typical mechanism of the Arts. A classic example is Man Ray's work *Cadeau* (figure 2.3), where a flat iron of the sort that had to be heated on a stove is transformed into a dysfunctional, disturbing object by the addition of a single row of fourteen nails. The transformation of an item of

[2] This is an idea inspired by the artwork Writing_racket by the artist César Escudero Andaluz

ordinary domestic life into a strange, unnameable object with sadistic connotations exemplifies the power of the artistic methods.

Indeed, the aesthetic dimension of an interface does not act against its functional part. In fact, aesthetics and functionalities always engage together at the point of expressiveness: they are both active agents at the dialectic nature of interfaces. That makes it possible, for instance, that a non-functional interface could be expressive too. In fact, a lack of function always alludes to the already known original functionality of the interface. Thus, the aesthetic reconfigures but never acts against functionality.

2. If these aesthetic interfaces are also critical with their research medium, they can become a language and a valid medium for research. They can engage us in aesthetic experiences, but they can also serve us well to evaluate the validity of accepted assumptions regarding design and user experience in our research medium. In conclusion, they can be used as a methodology for research within HCI. This possibility is studied in the following section.

2.3.2. Critical Interfaces

In this section, the benefits of designing critical interfaces are explained. Therefore, this section defends the role of artists as suitable experts to create critical artifacts within our research medium.

The main objectives of creating critical interfaces are twofold:

- Evaluating our accepted assumptions about HCI design
- Proposing alternative models inside HCI which could better assess aspects of user experience and interaction

The theory about *critical interfaces* was elaborated by Søren Pold and presented in his articles *The Critical Interface* (2005b) and *Interface Aesthetics* (2005a). For Pold, designing *critical interfaces* means unfolding the paradoxes of assumed interaction paradigms, their standardized limitations and preconceived ways to deal with tasks such as data manipulation or user experience. Hence, critical interface design would be suitable to evaluate the validity of our research methods and the experiential aspects of interaction.

A critical re-orientation of tangible interface design, or as Pold claims, an *aesthetic* approach to tangible interface design, allows us to explore tangible interfaces as a form, as a language, and as a medium for research. For Pold, the improvements of being critical to the assumptions regarding interfaces can be quite relevant. Through *interface aesthetics*, HCI becomes re-oriented as a critical field—a feature that traditional HCI methodologies do not tend to incorporate.

Critical interface design suggests the use of alternative methodologies open to the inclusion of cultural and idiosyncratic aspects of interaction, at least with the same weight that the search for efficiency at the computer level has traditionally sustained. As Søren Pold defends, art-based methodologies allow us to observe in a closer and more complete way the assessment of the various aspects and effects produced by interfaces. Not only their functional aspects but also their sociological, cultural, and economic features. In a world where interfaces are often becoming invisible, digital arts show us *"how the interface changes what and how we see, how we experience and interact with reality and how this reality is reconfigured through the computer"* (Pold, 2005a).

From a vision where designing tangible interfaces would be aimed at increasing user-centered design and efficiency, art-based research proposes a perspective aimed at evaluating the validity of long time acquired assumptions and research methodologies within the field of study.

In conclusion, for Pold, digital arts are the adequate research companion for HCI (Pold, 2005a):

> *"Instead of focusing only on functionality and effects, digital art explores the current materiality and cultural results of the interface's representational effects. What are the representational languages of the interface, how does it work as text, image, sound, space and so forth, and what are the cultural effects, for instance, of the way it reconfigures the visual, textual or auditory? How does the interface reconfigure aesthetics and what does it do to representation, communication and, in continuation of this, the social and the political?"*

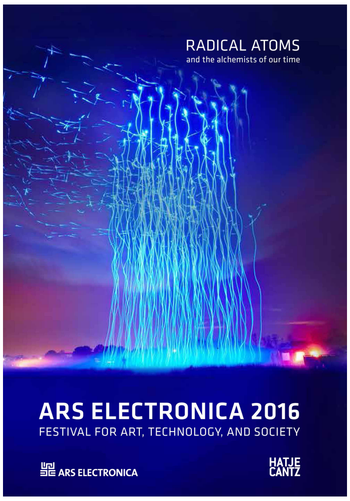


Figure 2.1: Cover Ars Electronica Festival Catalogue 2016

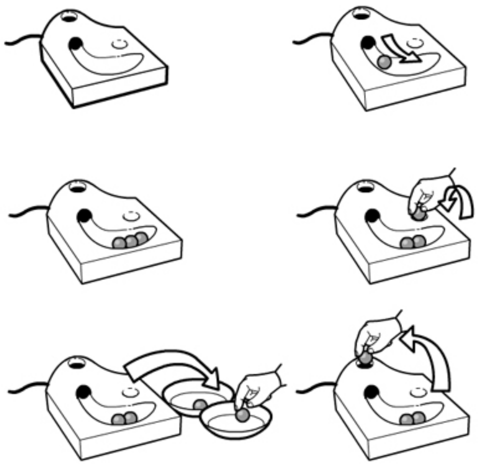


Figure 2.2: Schematic of the human computer interaction project Marble Answering Machine (1992) developed at the Royal College of Art in London

Figure 2.3: Man Ray. Cadeau (1921)

2.3.3. Traditional visions about the Arts in HCI

A certain vision of artists at the end of the production research chain still exists at many HCI labs. For instance, after the first public exhibition of the tangible interaction project *Transform* (Ishii, 2015) by the MIT Tangible Media Group, its director Hiroshi Ishii asserted to the press:

> *"This (Transform) is a white canvas, paintbrush and ink waiting for a Picasso"* (McGoogan, 2015).

Contrasting it with Pold's critical perspective, this vision diminishes the role of the Arts as a valid medium for research. As we will see in the following section, contrary to many methodologies inherited from HCI, the artistic research object is not instrumental for the engineering apparatus. This means that art-based research does not function as a proof of the theories exposed. It works towards creating unexpected relationships between the elements of the field of study. Thus, and following the concepts behind critical interfaces, the artist's role does not begin accepting the research medium as valid for the creation of aesthetic contents. Our role is more related to the visualization of the paradoxes present in the research medium. For instance, applying this concept to *Transform*, a possibility would be questioning the design decision to focus all interaction only on the surface of the artifact.

Another traditional idea within HCI is formalizing the Arts as a source of inspiration. Certainly, artistic research can have an epistemic value, and artworks can inspire reflection. For Nam (2014), art installations carry embodied knowledge; they can convey useful critical messages about their social and political situations and propose novel representational forms. However, for these authors the artistic artifact—the artwork—is always something external to HCI. It is an object of study, a case of analysis done by others. It is art, but it is not research, as the artwork does not follow any methodology towards improving some aspect within HCI. Therefore, the role of the artist is disconnected from the flow of HCI research.

2.4. Artistic Research and Human Computer Interaction

Although there exists an evident mutual interest between art practitioners and the rest of our community, the application of artistic research methods in Human Computer Interaction labs is still not generalized. For Edmonds (2014) while practice-based research in media arts is pushing the boundaries of our knowledge about experience design, arts-based research methods are little-known, if not unknown.

Artistic research has attracted academic interest for the last two decades (Candy, 2014) but interestingly Pold's *Interface Aesthetics* does not mention its contribution. As I explained in chapter one, an artistic practice is considered research if the aim of its production is creating some type of knowledge. For Julian Klein (2010), the type of knowledge created by artistic research projects is sensual and physical; it is purely an embodied knowledge. This knowledge must be acquired through sensory and emotional perception—precisely, through artistic experience. Tere Vadén (Knowles & Cole, 2008) explains the notion of artistic research as any artistic process which argues for a point of view —an act inside of the artistic practice carrying some contextual, interpretive, conceptual, or narrative work.

A decisive factor in artistic research is the acknowledgement that it is not possible to define 'the artistic method'. Instead, there exists a multiplicity of methods which can be applied and combined in artistic research projects. Interestingly, the foundations of science have been dominated by the idea that science is different because it follows the scientific methods (Popper, 1934)—a characteristic which separates 'the scientific' from other fields of research and experience. In contrast, within artistic research it is assumed that a methodological abundance is the most productive approach.

As listing and fully describing relevant artistic methodologies is out of the scope of this essay, as it would certainly need an independent article, a long and well-documented list of research methodologies for the creative arts and humanities can be found at ECU's on-line Research Methodologies for the Creative Arts and Humanities guide [3]. However, we can mention Action Research, Constructivism, Ground Theory, Critical Discourse Analysis, Ethnographic Research, Longitudinal Analysis, Positivism, Practice-Based Research, Qualitative Research, Social Constructivism, Survey Research, etc.

Interestingly for us, the concept of experience plays a central role in artistic research. Gary Knowles and Andrea Cole (2008) have defined artistic research as the systematic use of the artistic process as a primary way of understanding and examining "experience". This is coherent with Dewey's notion of 'art as experience' (1934). We can agree that the scientific methods implement experience in a way that can always be controlled,

[3] Available online: http://ecu.au.libguides.com/research-methodologies-creative-arts-humanities (accessed on 14 September 2017).

repeated, quantified, and manipulated. However, in cultural phenomena, experience is at odds with repeatability and control. Let us simply think of a live concert or a theater piece where non-systematic repeatability is awarded. For this reason, an artistic experience —or as it is also defined, an aesthetic experience— usually requires alternative means for being studied and evaluated. For this reason, artistic research is still a discipline slowly merging with other fields of study which were established a long time ago (e.g., scientific research).

Finally, aesthetic experiences deal with unreflective and non-conceptual contents which can be materially anchored to physical artifacts transcending their medium. For instance, when a research idea becomes embodied in an art installation. Thus, it is possible to say that aesthetic experiences can be good examples of embodied experiences. This fact is especially relevant for the field of tangible interfaces.

In summary, the goal of artistic research is to open up new visions and interpretations into some proposed questions and artistic experiences. In the special case of critical interfaces, as we will see a few sections below, the goal is the critical study of their own research medium.

2.4.1. The Limits of Artistic Research

In *The Question Concerning Technology* (1977) Martin Heidegger expresses his difficulties to find a definition for 'technology'. For us here, it is crucial to discuss Heidegger's notion of 'enframing'. Both technology and artistic research, as much as it is a technologization of artistic thinking, can frame our vision of *Being-in the world*[4]. In other words, technology drives us to a place where we begin thinking the world under the technological reign, thus technology 'enframes' our thinking. Heidegger upholds an alternative against the danger of technology, a mechanism for adopting an orientation of *Being-in* which could investigate all other aspects of the world: the Arts.

As John David Zuern writes in the on-line resource *Critical Link*[5] (pag. 338-341), in *The Question Concerning Technology* Heidegger proposes that we look back at the origins of technology in the ancient Greek world, where Heidegger explains, the concept of *techne* included both instrumentality and fine arts. In the words of Zuern:

> *Heidegger idealizes a classical Greece in which Art does not have a separate function within society. Art would be an unifying force bringing together religious life, political life, and social life.[...] In our own time, Heidegger suggests, 'enframing' can be resolved by adopting the artistic or the poetic orientation of being in the world.*

For Heidegger a poet looks at the world and writes about it in order to understand it, certainly, but this inquiry "*does not seek to make the world into a 'standing-reserve'. The poet takes the world as it is, as it reveals itself*" (*ibid*). The artistic relationship with the world is different from the relationship created by technology. If *"technology is about measuring, classifying, and exploiting the resources of the world"* (Bolt, 2010), then Art is about taking part of a process of 'being-in', which for Heidegger is the process of making sense of things and revealing the characteristics of the world where we (as persons) have been thrown. In a similar manner, Heidegger suggests that science as research 'enframes' us too through its ability to reduce everything to an object. It sets a limit on what and how we think about the world. Don Ihde notes that for Heidegger, Art is not as reductive in the same way as Science as research (or technology), since "*Art is essentially anti-reductive in its imaginative fecundity*" (Ihde 1977:129).

It is crucial for this thesis to question the limits of artistic research. If not, a certain 'enframing' of our world could also be produced by our artistic inquiry. In other words, the danger of artistic research would be understanding the world as an instrument towards proving artistic inquiry. For Barbara Bolt (2010), "*in a time when artistic practice has increasingly taken on the quality of inquiry or research, the critique of the technologization of thought raises urgent questions*". And this situation crucially applies to artistic research. If we simply assert that 'art is research' then it could be defended that artists, like scientists or the technocrats, could look at the world as another 'standing reserve'. Through artistic research, we artists and researchers could be tempted to model the world, securing the world for our own use. This discussion occupies quite a big part of the agenda of the artistic research community nowadays. For instance, recently the International

[4] Being-in-the-world is Heidegger's replacement for terms such as subject, object, consciousness, and world. For him, the split of things into subject/object, as we find in the Western tradition and even in our language, must be overcome, as is indicated by the root structure of Husserl and Brentano's concept of intentionality, i.e., that all consciousness is consciousness of something, that there is no consciousness, as such, cut off from an object (be it the matter of a thought or of a perception).

[5] last accessed 13/11/2017 http://www.english.hawaii.edu/criticalink/heidegger/guide9.html

Conference on Artistic Research 2018 has defined that their annual topic will be "*Artistic Research Will Eat Itself*" which should be understood as:

> *[...] a warning against the dangers of methodological introspection, or as a playful invitation to explore the possibilities of a field in a constant state of becoming.[...] If artistic research eats itself, digests itself and then releases its own waste, does it stink and linger, fertilize new growth or invade new destinations on the bottom of someone's shoe?*

For Barbara Bolt (2010) "*the dilemma for artists is how to resist the temptation of conceiving the world only as a resource for her/his ends, whilst remaining open to the world so as to experience what-is as being*".

It was crucial for me, as an artist with the challenge of doing research, quickly becoming aware of this danger. Certainly, it has been mandatory to conceptualize and problematize my artistic activity during various phases of this research. But at the same time I have always sustained a deep concern: if what I was doing as a researcher was still within the Arts. Interestingly, those artifacts I could have created to prove some questions, they have been exactly that: proof of concepts. They have served me well to model and encapsulate a part of the world towards proving a particular thesis. For example, modeling acoustic responses of a material for controlling some sound synthesis techniques. But as a painter who dominates technique and creates realistic portraits, one does not push the boundaries of representational language just improving technique. We are immersed in a continuous flow of stimuli. From physical phenomena to political, social, etc. How this 'reference frame' changes our objectives as artists is something we probably won't be able to understand. Sometimes, as Althusser (2006) explained, historical events had to evolve towards some direction but an 'aleatory encounter' changed the original plan. When artistic thinking encounters (and not 'meets') the world some sensible aspect of the world is always revealed. It can be important academically or not, but it can be considered research when it pushes the boundaries of how we understand or perform within Arts. Finally, in my opinion, artistic inquiry must result in artworks too. Its outcomes are not a new type of hybrid or artifact at an intermediate phase between Science and Art. Sometimes these artifacts can easily communicate why they are artworks. But sometimes another expressive encounter with them is necessary. A performance with the artifact.

I understand the outcomes of my artistic research, mostly artworks and academic theories, as a kind of philosophical toolkit. They have revealed and visualized characteristics of electronic instrument design that I was not aware before their production. They also serve to communicate various aspects of my research which cannot be verbalized. For instance, how much dependent the actions of the hand and the eyes are (see section 7.3 of this thesis). In that sense, I have the impression that both artifacts and practice have revealed to my audiences a message I was never fully able to explain in a lecture. Yet, it has been very tedious making my audiences understand my theories but not my practice. As an example, the music curator Eckart Waage explained to me that he was not able to understand various aspects of my theories but that anyway my artworks and performances directly caught his attention and communicated my intentions.

Thus, I can advance now one of the important lessons I learned from artistic research: without experiencing my artifacts, my research is understood as an artistic manifesto. After experiencing it, people necessarily take part and manifest their opinions. Therefore, my research escapes from its 'standing-reserve' fortunately.

2.5. Examples of Critical Interfaces

In order to understand the different forms a critical interface design can adopt, I decided to make the exercise of analyzing two critical artworks by two different authors. For the selection of these examples, as the whole argument of this chapter is built on Pold's *Interface Aesthetics* (2005), the three types of interface realism cited by Pold (which will be explained next) were used to select the artworks. It is important to remark here that the data used to describe these examples was obtained through various academic papers published by the artists, two from TEI's Arts Track conference (2014 and 2016), as well as from direct communication with the artists.

For Pold, critical interface artworks should go beyond the safe borders of the autonomous artwork. In other words, to serve as research, artworks should not only be made of autonomous aesthetic contents. In that case, he recognizes three types of works dealing with alternative realisms of the interface which can be combined in the same artwork:

1. Artworks dealing with Functional realism: those visualizing the functional elements of the instrumental medium as components with aesthetic possibilities. Those artworks making use of operational ele-

ments of the interface which can be constituted of some aesthetic value. For example, artworks hacking hardware or software components or reconfiguring some functionality to create unexpected situations.

2. Artworks dealing with Media realism: artworks going beyond the visual surface of the interface towards the imperceptible and unreadable code. Artworks of these type can, for instance, show the codes behind the screen and reveal the normally hidden flow of codes that the user interaction causes.

3. Artworks dealing with Illusionistic realism: artworks beyond pure representation, interfaces maximizing reality towards immersive simulation. These artworks make the user forget about the interface and become immersed in the illusionistic world it presents.

Therefore, three artworks have been selected herein following Pold's types of realism, and they will be presented in the next sections. A comparative analysis as examples of artistic research is described after its presentation.

2.5.1. Interfight: Functional and Media Realism

Interfight (Escudero Andaluz, 2016) by the artist César Escudero Andaluz is a set of *data polluters* living on top of devices incorporating touch screens (figure 2.4). A number of small robots equipped with conductive plastic sheets attached to motors are designed to freely stroll on top of our tablets and smart-phones. These bug-shaped robots pollute our tangible interfaces by clicking, selecting, zooming, or scrolling indiscriminatingly. For instance, they can type random comments on your social networks or search non-existing concepts on Google.

Interfight was created with a critical intention with HCI in mind. It shows us the following critical characteristics present at our touch interfaces:

1. **Interface Design Homogenization**: Nowadays many commercial websites track human input activity with hidden services to automatically improve their GUI (Graphical User Interface) design using machine learning strategies. *Interfight* make us aware of this issue and pollute those tracking services with random data produced by physical bots. They are a mechanism against interface design homogenization.

2. **Against stable interfaces**: These artificial bugs entangle and reconfigure the graphical interface in strange ways, re-arranging desktop appearances and graphical customizations. They work as a mechanism against the principle of 'perceived stability' (Gentner & Nielsen, 1996) which which propounds that the elements in the computer interface should not be changed without the user's involvement.

3. **Bodily interaction**: Touch interfaces limit our bodily interaction to an extreme degree—we are radically reduced to the surface of our finger tips. That is what makes simulating physical human input so easy.Interfight questions why we have accepted that other parts of our body are not suitable for interaction. Or maybe, that we should extend our fingers with other non-human artifacts?

To conclude, Interfight proposes a dysfunctional extension of a tangible interface for studying the actual interaction paradigms implemented in tablets and smartphones. A critical re-orientation of the standard way we access information using touch-screens. Malfunctioning is here the key to re-orient our focus and to better address experiential aspects of interaction on these types of interfaces. Interfight deals with both functional and media realism. Functional because it rearranges the original elements of touchscreens into aesthetic components (e.g., desktop). The utilization of media realism is clear, as the artwork shows us the hidden mechanisms which commercial websites use for tracking our human activity.

2.5.2. Hatching Scarf: Illusionistic Realism

The Hatching Scarf (Youngsuk, 2014) is a wearable by the artist Youngsuk Lee (figure 2.5). It is composed of a feathered scarf and pouch. The scarf is equipped with servomotors and sensors. It opens and closes itself with similar movements to those which baby birds usually do for requesting food. The artist also has included some pieces of jewelery in the form of larvae which vibrate and make sound when the nest moves[6]. A flex sensor is used to detect when the user puts her arm close to the mouth as if to eat. The pouch contains chocolate.

[6]A video can be found at the artist website http://www.youngsuklee.com/Hatching%20scarf.html

Apart from its aesthetic dimension, Hatching Scarf holds a critical position with its research medium. For the artist:

> *"In HCI there are many applications and tangible objects that focus on how we can measure quantified data about ourselves, which encourage us to pursue desired behavior and to support our achievement of goals. Yet to what extent do many of these persuasive technologies inadvertently contribute to unhealthy anxieties?".*

For the artist, Hatching Scarf is designed to help us interrogate:

1. **Self-identification at Interaction**. Hatching Scarf attempts to study how we identify and represent ourselves by experiencing the aesthetics of interaction. Evoking critical thinking via socially engaged objects, the work explores the concept of 'extended self': how one's 'colors' may by revealed depending on their personal history, philosophical differences, perception gaps, experience, interests, culture, education, and so on.

2. **The language of design**: Interface rules and intentions are communicated using different levels of rhetorics to grab user's attention: informative (rational and without emotional impact), entertaining (with a soft emotional impact) and affective (with high impact to persuade audiences). Hatching Scarf makes us aware that these strategies for communication are also designed, and let us think if the language of the interfaces we use daily are always the adequate for our emotional situations.

3. **Personal Affection of design**: Designs in HCI can carry or generate unexpected personal conflicts and anxieties to its users. Are devices solving our needs or generating new personal issues? Hatching Scarf, an artificial device, puts us at an estranging situation simply by eating some pieces of chocolate. Thus, the work encourages us as interface users, to reflect on our persons as both objects and subjects of knowledge which are affected by the characteristics of certain design decisions.

Hatching Scarf bring us to an embodied relationship with the interface where technology is designed for affecting us to the maximum. The artwork plays in the Illusionistic realm.

2.6. Discussion: How to Formalize Artistic Research Projects at HCI Labs

The objective of this section is proposing methods to the HCI community for a better understanding of how artistic research can be approached and systematized. In this section the critical aspects described in the previous examples are analyzed in a comparative way. Then, this section can inform the HCI community about possible design patterns for integrating artistic research projects in HCI labs. I propose a model of analysis based on three concepts:

1. <u>Problematization</u>. The systematization of artistic research projects within HCI as *problem-solving* processes, as suggested by Oulasvirta and Hornbaek (2016) can help to transform an artistic process into a process of research, even more than the fact of enveloping it together with some theoretical discourse. For illustrating this model, let's imagine the case of a photographer who problematizes how she can better approach certain critical discourse about a community of people within her practice. For her, she will solve her research problem if she finds an adequate solution to communicate specific concepts within her work through some expressive means.

2. <u>Methodological Conceptualization</u>. After having problematized the artistic research case, artists will need to choose among different methodologies for carrying out their research, or even to utilize a combination of them. Following the example of the photographer, let's imagine she decides to make use of some ethnographic research method, studying the culture and social organization of the community she is focusing her work. The data obtained from this ethnographic process serves to create a theoretical analysis of her practice which will be used to transfer her conclusions again into practice.

3. <u>Artistic Inquiry</u>. The conceptual element, the theory behind the practice or the phenomena being researched, now will need material inquiry, material perception inspired by some aesthetic subjective decision. Again, in the example of the photographer, she will now work in the field taking photographs,

Figure 2.4: Interfight by César Escudero Andaluz

Figure 2.5: Youngsuk Lee. Hatching Scarf (2014)

but having a more substantiated and developed strategy for remarking on aspects she finds interesting about her work. Undoubtedly, the new design process will create new theoretical questions. Thus a permanent cycle between the conceptual and the material elements is produced forcing the researcher to learn, sometimes producing new approaches and new works of art.

Certainly, this three-steps model of artistic research will usually be iterated a number of times. The process, not always sequential or linear, can alternate between conceptual elements (e.g. communicating some theory about practice) and material elements (e.g. an art installation) as a continuous process of problem-solving. In fact this is not an specific issue of artistic-research but for any type of research. A notable reference of this iterative research process is Bruno Latour's Actor-Network Theory (Latour, 1996) applied by the author to research in natural science. For Latour, research is characterized by 'friction, surprise and the obstinate nature of objects in the environment', suggesting a continuous cycle of research.

2.6.1. Problematization of the examples

- The idea for producing *Interfight* came from an invitation from the research program MEMBRANA, a residency for 'Artistic Interface Criticism' offered by Hangar (Barcelona) aimed at providing support to a visual artist interested in developing an artwork based on the concept of interface, and participating in the investigation of a Critical Interface Manifesto. Thus, Escudero Andaluz problematized his project as follows: Is it possible to create an interface-artifact to criticize the actual efffects of computer interfaces? Which are the aspects of interfaces that are not visible and interesting to analyze nowadays?

- *Hatching Scarf* comes from the problematization of a personal intuition. The fundamental theme in YoungSuk Lee's work concerns how "*ecosystems, societies, and life itself form an interconnected web where the disturbance of any part affects everything. As human beings an inescapable part of life is our interaction with other creatures*" (Youngsuk, 2014). For the artist, environmental influences evoke inevitable engagements with social norms. This forces one to adopt socially desired ideals in response to certain pleasures, attitudes, etc. Thus, the research in Hatching Scarf attempts to solve the problem of creating socially engaged artistic artifacts which can help to show how one becomes fragile in a nervous a situation under the societal influence.

A conclusion obtained from this analysis is that the questions formulated at the initial moment of problematization are precise, but still far from the critical knowledge created by each artwork (and described in section 3). These initial questions carry the research force of every artistic project, but the final artifacts will be the most relevant source of knowledge as the embodied and aesthetic experience will afford much more relevant aspects about each of the topics investigated.

2.6.2. Methodologies of the examples

All the examples presented above share Art-Practice as a research methodology as long as the artistic artifact created is the basis of the contribution to knowledge. Without experiencing the artistic artifact, all knowledge it contributes (be it of any type) could not be fully achieved. For example, without experiencing the possibility of wearing and touching the Hatching Scarf, it is impossible to understand the real value and type of the knowledge proposed. For instance the sensations and emotions created while wearing it as well as the critical message is conveyed. Additionally, the authors of these artworks manifested the influence from the following methodologies as the most relevant:

- *Interfight* makes use of the Media Analysis methodology too. This methodology suggests the examination, interpretation and critique of both the material content of the channels of media of communication and the structure, composition and operations of corporations that either own or control those media in the Internet. For developing it, Escudero Andaluz investigated different strategies of control that companies are using through the Internet without informing their users. Among different possibilities, the artist found it suitable to work with those hidden tracking services for GUI optimization. For instance, many websites track the path users take with their pointers on screen while navigating their pages, where do they usually stop it, etc. Thus, through this methodology the artist obtained enough data to understand fully the issue of manipulation for being able to respond with an artistic artifact.

- *Hatching Scarf* shows a typical example of use of Critical Discourse as methodology. It asserts that human interaction and social practices are tied to specific historical contexts and are the means by which existing social relations are reproduced or contested and different interests are served. It deals with the questions pertaining to interests that relate discourse to relations of power. The methodology accompanying Hatching Scarf criticizes the social aspects of HCI's language of design, thus giving enough examples of devices and clinic cases of study which inspired the final artwork.

We see how methodologies have been instrumental in the creative process to unify attention, to focus the perspective of every of these projects towards one research direction, towards the creation of a particular type of artifact. Methodologies have informed the authors about the complex reality of their research in an objective way, opening up different possibilities for developing the material part of the interface. But also they serve for limiting those cases which do not seem interesting enough for the artist.

2.6.3. Artistic Inquiry of the examples

The artistic inquiry process gets informed by the conclusions or data extracted from the previous two steps. This is the moment for materializing the artistic process which characterizes the artistic research project. An important facet of this process is that many of the decisions taken will have a clear subjective and idiosyncratic character. As every artist understands her artistic practice differently, only her artistic culture will help to decide which particular aesthetic direction will be taken. This decision depends on the various influences of cultures and artistic trends which have driven the artist..

- *Interfight* follows the aesthetics of dysfunction, understood as an artistic practice emerging from the alteration of functional change of some of the physical elements of an electronic artifact, affecting part of the interaction between a device and its users. The dysfunctional strategy reconfigures the original 'reason to exist' of devices. At the same time, dysfunctions can create new unexpected, even ironic, relationships with the objects, shifting the original intention of an artifact from the functional to the artistic or poetic. Transforming a tablet device into a dysfunctional artifact made it possible to communicate the author's critical intention. Escudero Andaluz extended the interface with elements (the robots) that can interact with the normal capacitive screen. Those small robots, equipped with conductive plastics, create valid human input interaction for confusing on-line tracking algorithms. While convincing a person to act randomly for hours in front of a table might be difficult, those small and simple robots show themselves to be quite efficient at that task.

- *Hatching Scarf*: in this case, the artwork follows the aesthetics of estrangement as an expressive strategy. The wearable transforms its user into a kind of artificial bird, while the aspect and movement of the scarf creates a deep sentiment of estrangement. The inclusion of the colors red and black, and even jewelry reminiscent of larvae contributes to this perception. The strategy of estrangement is typical from the Arts (Danto, 1981). But it has also been used as a successful method for improving or suggesting novel design developments in tangible interaction (Bell, 2005; Wilde et al, 2017). Being confronted with a certain estrangement requires re-learning the environment, bringing the mind and body to unfamiliar situations, therefore producing certain enactment of reflection and new embodied relationships. For Wilde, Vallgårda and Tomico (2017) estrangement creates a confusion which prolongs the moment of arriving to an understanding, hence provoking a deeper and more intimate relationship with the concepts and materialities the situation carries. These authors proposed a framework for analyzing estrangement in HCI following an iterative process of answering 'what is done to disrupt', 'what is destabilized', 'what emerges' and 'what the whole embodies'. Thus for Hatching Scarf:

    1. The physical aspect of the socially engaged wearable is made to disrupt, to make the user feel estranged.

    2. The self-representation of oneself during interaction and the communication with others get destabilized.

    3. It emerges a reflection about how certain types of HCI design can create personal anxieties to their users in socially constrained environments.

4. The whole process embodies knowledge about the risks of choosing inadequate languages of design (e.g. in the case of technology dedicated to children). Additionally it embodies a full identification with other people suffering certain personal affections when using technology at certain personal, social or political situations. Why the simple action of interacting is making me feel estranged? Is it because it visualizes my concerns about snacking and my weight?

2.7. Conclusion: How the Arts can help Human Computer Interaction

Through this chapter I have described that the role of artists in HCI has to be more with being critical with our research medium than with creating mere artistic experiences to inspire novel forms of design. With the analysis of two examples I have informed about various different directions for developing artistic research projects in relation to three notions: problematization, methodological conceptualization and artistic inquiry. Far from suggesting any dogmatic solution within a field where there are not universal solutions, the following conclusions act a theoretical solution of our own problematization inquiry in this section:

How can the Arts help Human Computer Interaction?

1. **Adopting a critical attitude with our own research medium: in our case tangible and musical interaction**. Artworks act to breakdown the standard discourses of tangible interaction design. They should allow us to discover new interpretations and notions, often unfolding the tension among established conceptions of our fields of study and their real value in our societies.

2. **Adopting the format of artistic research**. The Arts are a valid medium for research. The Arts create a type of knowledge which is not afforded by traditional HCI methodologies, especially in the case of embodied technologies. But research in the Arts should have a clear formalized structure and focus. Finally, it may rely on the problematization of its aims and the proposal of alternative methodologies.

3. **Avoiding the instrumentalization of its artistic process**: The artist's role deals more with a permanent questioning of the inner pillars of the research field. It must be more to do with destabilizing than with supporting what has already been fixed. Artists should not start their research process at the end of the HCI research chain.

2.8. Contributions of this chapter

In this chapter I have established the following viewpoints:

- Before centering my research on musical interface design, I build on Pold's *Interface Aesthetics* for suggesting that a critical revision and re-orientation of our research objectives in regard to interface design is needed. A shift from a vision of artists as contents creators towards one of artists as researchers is proposed. As researchers, artists can question the many long-time assumptions and relationships between Arts and HCI.

- I contribute a vision of interface design as an aesthetic practice. In my opinion, the aesthetic dimension of interfaces can be seen as an extension of functionality. It reorganizes interfaces towards a particular expressive intention.

- In my opinion, if this aesthetic practice is also critical with the research medium (interface design), it can become a language and a valid medium for research. Apart for engaging us in expressive experiences, it can also serve to evaluate the validity of accepted assumptions regarding interface design and user experience. In conclusion, critical interface design can be used as a methodology for research within HCI.

- A new methodology -critical design- has been incorporated into my research flow. It has served to re-orient my investigation towards a most effective way to solve my artistic intentions too.

- Examples of critical artworks produced by other artists are described and discussed under a three-steps theoretical framework which I have proposed: problematization, methodological conceptualization and artistic inquiry.

- My personal viewpoint about the dangers of artistic research is presented. I defend the idea that the results of artistic research must be artworks and not hybrids between Science and Art.

3

Musical Interfaces

We're standing on stage with our microphones,
but we don't play guitars
Got the Sherman up here with us, no we don't play guitars

Chicks on Speed, We don't Play Guitars, Album 99 cents, 2003.

The field of musical interface design seems to stay in a continual state of revolution. The result of the last *New Interfaces for Musical Expression* conference (NIME 2017) is a 524 pages book of blind peer-reviewed contents. Outside of academia, on-line crowd funding platforms like *Kickstarter* or *Indiegogo* overwhelm us with designs promising the last 'most expressive MIDI interface'. How can one deal with this huge amount of information? What type of revolution is happening and what transformations are occurring? The objective of this chapter is contributing to a multi-faceted understanding of the nature of musical interfaces. Musical interfaces are very specialized technologies but -as I defend in this chapter- they are also cultural artifacts highly mediated by the politics of music production and consumption.

3.1. The Compound Nature of Digital Musical Instruments

In my opinion, digital musical instruments (DMIs) are a compound of two main types of realms: the technological and the cultural. The technological nature of DMIs, the one which has been more studied, defines the functionalities of an interface in relation to the technical elements it incorporates. A technology itself affords specific types of interaction (Gaver, 1991) which can also be designed. The other one, the cultural nature, less studied, reconfigures the technical and promotes the appearance of cultural intentions and expectations. The cultural nature of interfaces is informed by the ideologies and politics of 'doing' -designing, performing, composing, etc.- in its specific reference frame. For instance, the social behaviors and norms of human societies.

I accept the existence of many other types of natures which undoubtedly are also present in musical interfaces. For example political, economical, material, social, biological, etc. However, in my opinion culture and technology dominate the other aspects of musical interfaces. Cultures and technologies have been formalizing their rules for millennia. As Lev Manovich argued in his *Language of New Media* (2001) the nature of interfaces is "*an odd mix between long time achieved cultural forms and the novel affordances and constraints imported from Human Computer Interaction*". Certainly, these two natures are not independent from each other. We already know how for Heidegger (1977) technology 'enframes' design and thinking. This is an effect that can also be applied to music. It is easy to see how various technologies, even before computer music, have 'framed' musical thinking too. For Thor Magnusson (2002):

> *With the invention of the phonography we get a new organisational network for the economy of music. The consumption of music became individualised and the main goal of the producers would be to create increasing demand for music so they could produce and stockpile musical products in an increasingly capitalistic market system. Music became 'framed' to use the generic term of Heidegger. Instead of being primarily a live performance phenomenon, music became something that was recorded, mass-produced, distributed and sold in innumerable copies.*

Today this argument could be easily applied to the hyper-abundance of musical contents offered at digital platforms like *Spotify*. Or, for example, to the amount of new musical instruments offered at *Kickstarter*. For all these reasons, this chapter subdivides the nature of our problem in two sections. Our attention will be given first to technological aspects. Then the cultural will be analyzed.

3.2. Musical Interfaces as Technology

3.2.1. Definitions

As has been explained in the previous chapter, an interface, from a technological perspective and in the scope of this thesis, is a point of interaction between humans and a computer. This interaction can include all types of possible modalities (e.g. tactile, graphics, sound, olfactory, etc) and their multi-modal combinations. For Søren Pold (2005), the purpose of the interface is

> *to represent the data, the data-flow and data structures of the computer to the human senses, while simultaneously setting up a frame for human input and interaction, and translating this back into the machine.*

The main concept widely accepted about interfaces is recognizing their ability to configure the way we interact with computers. Interfaces inform about the internal status of various processes running in computers, while they also open a window for interaction with these processes. For instance, a graphical user interface shows that the process of copying a large file is taking place. It allows canceling if users press a button on a physical interface, namely the computer mouse. It has been the interface designer who has decided which elements are accessible at every moment. In other words, which information users need to know and which interactions are available. In fact, while copying a large file, one could certainly be offered more possibilities for interaction. For instance, pausing the process or defining the memory block size. Although these are mid-level functions completely accessible from the operating system, certain politics have decided that they cannot be shown. Who defines these politics and how are they defined? Why do we as users always accept these politics? Are there alternatives? These questions are studied in section 3.3 of this chapter, referred to as musical interface politics. The second observation we can devise from the 'large-file copying' example is that we cannot speak about 'the computer interface' as a singular entity. Human computer interaction needs a multiplicity of interfaces to be running in parallel. Human Computer Interaction is fraught with an atomized structure of software and hardware interfaces interleaving various parallel tasks. For moving a pointer on screen, our interface makes use of a cascade of interfaces: capturing our computer mouse movement from an infrared sensor, transferring this movement data to the computer over serial protocol, updating pixel information to the peripheral display using a particular bus communication, etc. For simplicity here, we will continue speaking about 'interface' in singular although as it has been observed, its intrinsic nature is plural.

A musical interface is an interface used in a musical situation. In industry, musical interfaces are often named 'music controllers' probably due to the influence of the well established field of 'game controllers'. A digital music instrument is a musical instrument -and not only an interface- if it also incorporates a 'sound synthesizer' coupled to the interface. A sound synthesizer is a sound generator which can be of any nature (e.g. software, mechanical, robotic, etc). Therefore, the idea behind a digital instrument is that sound generators are controlled by human input acquired at the interface.

In parallel, performers are usually informed about the internal status of the machine using some display (e.g. visual, tactile, auditive or using any other modality). This is the "representational dimension" of the instrument. Ideally, the field of musical interfaces only deals with aspects of interaction and representation between performers and computers. Thus, control and sound synthesis are seen as two decoupled tasks of the instrument. Interfaces can be designed with independence of the sound production technique employed and vice-versa. Musical interfaces can be connected to various sound engines or synthesizers which define the sonic personality of a digital instrument.

Musical interfaces can adopt any aspect and form. They can be physical or virtual if the interface 'lives' on the computer monitor. To illustrate some possible aspects I propose comparing two musical interfaces. One is based on graphic user interfaces (GUI) and the other on tangible user interfaces (TUI).

On figure 3.1 we observe the GUI of *Lazerbass*, a virtual instrument. It is a digital music instrument created by Michael O'Hagan for the programming environment *Reaktor* by Native Instruments. Technically, it consists of an additive frequency synthesizer, a chain of filters, and a time sequencer. We talk about additive synthesis when multiples signals (partials) synthesized by independent oscillators are mixed. In *Lazerbass*, every parameter available is represented graphically on screen. *Lazerbass* incorporates sub-menus where more parameters become accessible. For representing those parameters *Lazerbass* uses textual information. We can observe how the designer has fixed many aspects of the instrument. For example, the synthesis' range values, the possible combinations of effects, the aesthetic aspect, etc. Certainly, those biases configure our impression of what the instrument can accomplish while it also guides and inspires musical contents and styles.

On figure 3.2 the *reacTable* (2005) by Sergi Jordà, Marcos Alonso, Günter Geiger and Martin Kaltenbrunner can be observed. A *reacTable* is a digital musical instrument based on both tangible and graphic interfaces. A number of cubes incorporate graphic marks called 'fiducials', a kind of graphic ID which can be detected via computer vision algorithms. These fiducials embody digital information about the instrument. In particular, each of these cubes corresponds to a module of the instrument: a particular synthesizer, an effect or a controller of parameters. When the cubes are put on the surface, a camera can observe its fiducials. This image is analyzed with computer vision algorithms and the position of each of the cubes as well as their rotation angle is obtained. At the same time, a video projector installed under the table projects a representation of the actual status of the program. This graphic display conveys direct feedback of the parameters used during performance. In the case of a *reacTable*, its tangible interface is the key factor to control the different parameters of a musical situation. And the graphical interface constitutes its representational strategy. Importantly, without these tangible artifacts the instrument cannot be played.

Other examples of physical controllers can be observed from figures 3.3a to 3.3h while examples of virtual digital instruments can be observed from figure 3.4a to 3.4h.

Musical interfaces have retrieved relevance in modern musicology (Tresch & Dolan, 2013) for having discontinued the traditional embodied sonic relationship among interpreters, instruments and sound. This occurs, as has been explained, as much as in digital instruments gestural control and sound synthesis are completely decoupled. A performer's physical gesture with a digital interface do not necessarily produce any sound (e.g. controlling music with a Kinect). For performing with a digital instrument our corporeal articulation is captured in real time with sensor technologies, then converted into digitally encoded information and finally mapped into sound using some type of software or hardware. This decoupled nature has severely redefined the long-term and deeply rooted practices of composing or performing music with instruments. Interestingly, the origins of this decoupled nature can be found a few centuries before when harpsichord builders introduced a new user interface to traditional harps. The harpsichord used a system of linkages and hammers to interface mechanically keyboard and strings. The same happened to church organs when their builders were able to set apart keyboard and organ pipes, even up to dozens of meters.

Years later, computer music technology only observed what had been done before and adopted similar models. As a result we have naturally assumed that musical interfaces can be studied separately from music or sound. It can be much more efficient dividing the problem of designing digital musical instruments into two parts. However, this paradigm makes composing for musical interfaces less efficient. Yet, for most of these musical interfaces we cannot use a standardized notational system. As a consequence, composing musical works for digital instruments is a very tedious task. The effects produced in the musical system have been so profound, that even a new field of research called New Interfaces for Musical Expression (NIME) had to be born in order to study their new particularities: instrumental, compositional, technical, philosophical, etc. Innumerable authors have already studied the profound implications of this paradigm of design (Puckette, 2003; Paulo Ferreira-Lopes, Mailis Rodrigues, 2008; Magnusson, 2010).

Figure 3.1: The Lazerbass instrument by Michael O'Hagan

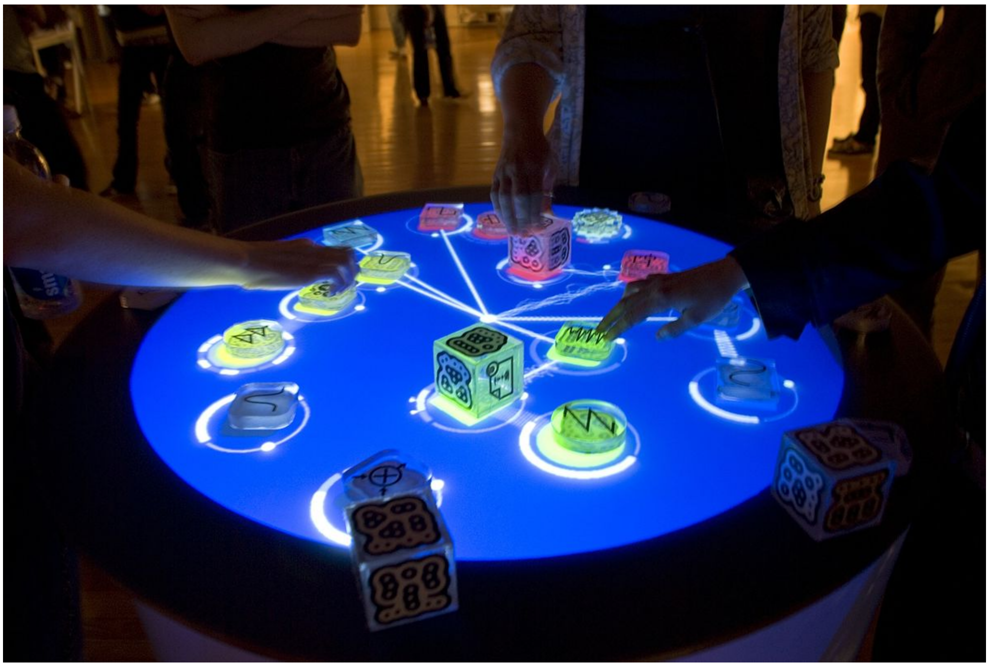


Figure 3.2: The reacTable, photo by Daniel Williams

(a) The Oval MIDI Handpan

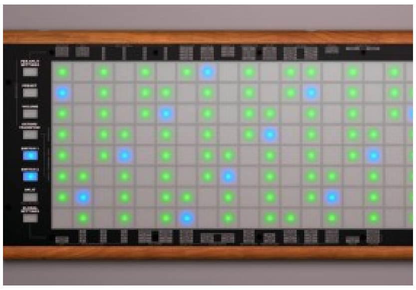
(b) AKAI MIDI Controller

(c) The Continuum by Haken

(d) The Roli Seaboard

(e) Wind MIDI Controllers

(f) The Push Pull Instrument by Dominik Hildebrand Marques Lopes, Amelie Hinrichsen and Till Bovermann



(g) The Linnstrument by Roger Linn

(h) The Mine modular MIDI controller

Figure 3.3: Examples of Musical Controllers

(a) Native Instruments Rhodes instrument

(b) Strings Cakewalk Instrument

(c) The Vacuum virtual synthesizer

(d) The Vocalizer virtual instrument

(e) The Boom synthesizer by AIR Music Technology

(f) The Broomstick bass virtual instrument

(g) Native Instruments Horns instruments

(h) Native Instruments Flute

Figure 3.4: Examples of Virtual Instruments

When Adolph Sax developed the saxophone in 1840, it is possible to say that he had various intentions in mind: a technical intention, a musical, an economic and probably social and personal intentions. The musical intention was none other than trying to play with the projection of a brass instrument and the agility of a woodwind. However, without the technological skills acquired during years of improving existing instruments, mostly the bass clarinet, could Adolph Sax have developed the new instrument. Diverse types of knowledge, from metal crafts and acoustics to instrumentality and musical composition were necessary to produce the instrument. In the same manner, novel digital instruments are developed by digital luthiers -or teams of them- in academia and private living rooms. Their goal is to produce novel and better musical expressions with computers. Also the types of knowledge needed to carry out this task are also numerous and varied: software programming, physical computing, ergonomics, fabrication skills, applied musical culture, etc. These new 'crafts' adopted from computers are those inherent to human-computer interaction which often cannot be achieved by the direct exploration of a physical phenomenon. For instance, if one person wants to design an acoustic mono-chord instrument, the task inevitably begins with observing how real strings behave in the world. Materiality informs us. We can perceive patterns, causes and effects in materiality. We can induce the notion of frequency observing and manipulating a string. On the contrary, computers do not inform us 'per se' about how digital instruments work and sound. Unfortunately, one does not learn how to program a Pure Data patch listening to a digital instrument coded with this platform. However, if we have access to the source code we can always learn -at least partially-from it. Even in the case of not having any programming skill we can modify the program and infer rules. Probably we will soon understand the programming language grammar. Finally, if we invest time enough, we will learn from other programming examples and we will understand the code. In my opinion, keeping our interfaces alive is the greatest benefit obtained from leaving our code open to others. In the future not many experts will be able to use our actual programming languages. Giving them the possibility to read the source code of our interfaces will help them to update or rebuild these systems under newer programming platforms.

3.2.2. The Apparatus of Digital Musical Instruments

The paradox within human-computer interaction is that for simulating our real world we are forced to use a vocabulary of given symbols which only exist at the symbolic realm of computers. We can say that our role as digital musical instruments (DMI) designers is dealing with symbolic apparatuses. Once we understand the apparatus we can try to accomplish the difficult mission of codifying our cultural intentions.

Why is it important to study the apparatus of digital instruments? It is often assumed that digital instruments inherit directly from their relatives, the family of acoustic musical instruments. For example, it could be possible to affirm that digital instruments are similar to acoustic instruments but produced with software and circuitry. However, the nature of digital instruments is radically different to the one of acoustic instruments. As I will defend along this section, digital musical instruments are symbolic machines incorporating a technological apparatus programmed to produce symbols. This major difference does not make acoustic and digital instruments ontologically different. Both share aspects of the other. There exists digital instruments which are until some degree acoustic and vice-versa[1].

Before entering into details and defining the 'apparatus', it is important to remark that the contents of this section (and the following) have been heavily influenced by three authors. On the one hand, Vilem Flusser's notion of 'apparatus' from *Towards a Philosophy of Photography* (1984). In this treatise, Flusser describes how cultural objects cannot be described today as they were conceptualized during industrialization. In current day 'information societies' human tasks are no longer about 'production' but mostly about dealing with the program of many technological apparatuses. On the other hand, Friedich Kittler's 'materiality of communication' as it is described in *Gramophone, Film, Typewriter* (1999) informs this section. As Kittler describes, human being '*essence escapes into apparatuses... And with this differentiation - and not with steam engines and railroads - a clear division occurs between matter and information, the real and the symbolic*'. Finally, Thor Magnusson´s PhD thesis *Epistemic Tools: The Phenomenology of Digital Musical Instruments* (2009) constitutes the last author informing this section.

Coming back to my argumentation, it is often said that technical devices are digital tools. Can we say that digital instruments are tools? For instance, Thor Magnusson defines DMIs as epistemic tools: "designed tools with such a high degree of symbolic pertinence that it becomes a system of knowledge and thinking in

[1] Many digital instruments are inspired by the properties of some acoustic instruments, like the Electronic Glass Harmonica (Paisa, 2016) or instrument with synthesis based on physical modeling (Marshall, 2018)

its own terms". Photographic cameras (digital or analog) are not known as 'instruments'. Cameras are more often known as 'devices' or 'tools'. Similarly, computers are not 'per se' instruments but 'tools' or 'devices'. Let me clarify the terminology using the Merriam-Webster English dictionary:

- An 'implement' may apply to anything necessary to perform a task;
- A 'tool' suggests an implement adapted to facilitate a definite kind of stage of work, and suggests the need of skill more strongly than implement.
- A 'device' is a piece of equipment or a mechanism designed to serve a special purpose or perform a special function. Something fanciful, elaborate, or intricate in design.
- An 'instrument' suggests a device capable of delicate or precise work.
- Machines are operated devices for performing a task.
- Technology is a manner of accomplishing a task especially using technical processes, methods, or knowledge
- Apparatus implies something that has been organized and put together, like a machine or a group of tools.
- A 'computer' is a programmable electronic device that can store, retrieve, and process data

The landscape of technological artifacts has been evolving during centuries. What it was known as a tool now could have become a sophisticated machine or device. Therefore, the etymological denomination (i.e. declaring that DMIs are tools) does not necessary define the artifact in question. I propose simplifying this problem defining (like Flusser did) cameras and digital musical instruments are 'cultural objects'. By cultural I mean constructed by a specific culture and defined from its rules and values. I do not mean 'artistic or creative' culturally. Interestingly, for Flusser there are two types of cultural objects. The first type, 'consumer goods', are in the world for their consumption. The second type, 'tools', are good for producing consumer goods. Therefore, a camera would a tool for producing consuming goods (photographs). A digital musical instrument would be a tool for producing digital music.

The idea that human beings are *Homo faber* or *Homo fabricatus* was supported by philosophers like Henri Bergson, who defined intelligence "as the "faculty to create artificial objects" (1911). For Bergson, in particular we are intelligent because we create "tools to make other tools, and to infinitely variate its makings". Karl Marx in his *Capital* (1867) cites Benjamin Franklin asserting that "humans are the animals who produce tools". Latour (1998) cites how for Hegel and Leroi-Gourhan *homo Faber* is "a movement that ends by making us sons and daughters of our works". In the 20th century, Max Scheler and Hannah Arendt (1951) remarked the human ability to control our environment through the use of tools[2]. An argument referenced by Umberto Eco's *Open work* (1979) where he refutes the negative connotations that tools have increasingly gained in philosophy (mostly due to Heidegger). Instead, Eco argues that the *Homo faber* is a manifestation of humans's innate being-in nature. However Eco's negative conception of the *homo faber* has to be more with the 'objectification' of nature. Interestingly, the notion of *homo faber* is central in Pierre Schaeffer's *Traité des objects Musicaux* (1977) as the figure responsible of the creation of music from a brute (not refined) intuition about sound. For Schaeffer the *Homo faber* always precedes the *Homo sapiens* in the process of creation.

For Flusser, what is the value of tools in the *Philosophy of Photography*?

> *Tools in the usual tense tear objects from the natural world in order to bring them to the place where the human being is. Tools imprint a new, intentional form onto them. They inform them. The object acquires an unnatural, improbable form; it becomes cultural. This production and information of natural objects is called 'work' and its result is called 'a work'. (Flusser, 1984)*

Therefore, for Flusser cultural objects can only be understood as a result of a double process of production and information. This notion of information means embodied or simulated information within the object[3]. A tool, for Flusser who seems to follow Heidegger' s philosophy, is always some type of extension of the body.

[2]Also considered the funding arguments to the idea of the "anthropocene"

[3]A parallel precedent to the theory of Tangible User Interfaces

A tool simulates some use for the body. For example, a hammer simulates the hand and it makes it more powerful and efficient.

For Flusser, with the Industrial Revolution tools are not longer limited to empirical simulations. They grasped scientific theories and became technical. As a consequence, tools became bigger, more expensive and stronger. The things tools could produce became cheaper and more numerous. Flusser builds a narrative explaining the origins of 'machines' as industrialized tools: when tools became machines, societies got separated in two classes. First those who own machines (capitalists) and second the ones working around the machine (proletariat).

However, the social paradigms have changed quite a lot after the Industrial Revolution. For example, the basic category of industrial societies was 'work'. Tools and machines were made to work and inform the world. But nowadays, how do cameras or digital instruments inform the world? For Vilém Flusser cameras or digital musical instrument do not inform the world but change the meaning of the world. These type of objects have a symbolic intention.

From these arguments we can now answer our initial question about tools. It would make no sense comparing a camera with a wood cutting machine. Their intention is completely different. While operating a camera we create, process, store and distribute symbols. Even sometimes they do it without our intervention. These have been tasks usually done by painters, composers and writers who have produced images, scores and poems. We would not say that a painter is a 'tool'. A camera or a digital musical instrument objects are not consumable goods but they are also not tools at Flusser's ontology. They serve as carriers of information. They are not ends but means.

For Flusser, this type of symbolic activity is taken over by 'apparatuses'. An apparatus, as it is defined in the dictionary, is the entirety of means whereby a specific production is made existent or task accomplished. If in the past this symbolic task was exclusively done by humans, nowadays apparatuses work alone and they are more efficient and extensive. For example, the apparatus of photography makes the task of representing a scene much more efficiently and 'liberates' us from having to use a brush for painting it. In the same manner, digital instruments are efficient because they can embody the sonority of unlimited types of musical instruments within the same object. Also because they are not limited by real world parameters like acoustics and physics.

Which is then our task when we work together with these apparatuses? When playing digital audio or taking digital photos, humans are employed at programming and controlling those apparatuses of production. For Vilem Flusser, what was seen as the tertiary sector in our economies -the economy of services- is now central. Therefore, the category 'work' must be replaced by 'information'.

In our field of study, we can say that every digital musical instrument incorporates an apparatus for the production of symbols. Flusser calls these sets of symbols 'symbolic surfaces'. Digital musical instruments are programmed to produce digital music. They have a program which specifies all the possible results that can be produced (and only that ones). Performers engage with these instruments exhausting the program in the search for new musical realizations. The richer this program is the more iterations and realizations it will be possible to produce. Thus, a performer is not a worker but a player. A digital musical instrument is not a tool but a plaything.

Digital musical instruments release musicians from 'work' in the industrial sense. This robotization of the work makes humans being able to focus on the play with the apparatus. It is not longer necessary to stick to the physical creation of sound. We are now concentrated in playing with the apparatus, engaged with the play side of the object.

This shift from the material to the symbolic is typical from post-industrial societies. For this good reason it is said that we live within 'information societies'. Since the apparatuses of digital objects have conquered a significant part of our material world, a certain resistance against it has emerged. Recent philosophical trends (i.e. neo-materialism) propose alternative models where, without forsaking digital technologies, we are aimed at combining -if not merging- the symbolic and the material parts of our world. Especially in a more sustainable way. This is partially the intention of this PhD thesis. Through the artifacts I have created, I explore the ways in which apparatus and physical materiality can mediate actively each other (see chapter five).

3.2.3. A Post-Hermeneutic Approach to Apparatuses

A recurrent idea in Magnusson's phenomenology of DMIs is the existence of a hermeneutic dimension. The hermeneutic and the embodied modalities would constitute the most important dimensions of DMIs, among the many studied by the post-phenomenology of Don Ihde (1979, 1990). A digital instrument "is not an extension of the body, but rather a tool external to the body whose information we have to interpret (thus hermeneutic)" (Magnusson, 2010). From a phenomenological standpoint, Magnusson shows us DMIs as a text, something we have to read in our use of it.

The perception of the apparatus in a digital musical instrument has mostly to be with the hermeneutic dimension. However, I do not see the hermeneutic modality necessarily ingrained in the information produced by the instrument. In my opinion, we should better affirm that the hermeneutic is only one of the possible phenomenological effects of the apparatus in our body. As I will explain later in this section, the experience with a digital instrument -what phenomenology studies- can be more or less hermeneutic or more or less embodied (see my study in section 7.5.3). This balance depends only partially on the instrument and on its apparatus. Post-phenomenology generally argues (Ihde, 1979) that the subject and the world are not given a priori, but they constitute themselves at the precise moment of the relation. For Romele (2016) *"the designer realizes in the objects her own ethos and sensitivity. The user finds in the artifacts an occasion for thinking and acting differently"*.

It is crucial to understand here that we are confronted with two different types of interpretative acts. First, the hermeneutic, the one for reading the program of the apparatus. Second, the act of interpretation in which our body gives a meaning to a particular use of the digital instrument. Clearly, corporeality is at the center of the hermeneutic dimension of DMIs. For a hermeneutic method to interpret the experience of a body during a performance, our body cannot be left in the background. Our noisy and complex body mediates the situation as much as technology and its apparatus. In conclusion, 'a priori' nothing can be said about the hermeneutic modality of a digital instrument. It is a shared property of the relationships created between the different bodies of the agents interacting

The central philosopher who have studied the hermeneutic characterization of technologies from a post-structuralist viewpoint is Friedich Kittler. For this good reason his work has been considered *post-hermeneutic criticism*. Hermeneutics, understood as a methodological discipline, it offers a toolbox for efficiently treating problems of the interpretation of human actions, texts and other meaningful material. Kittler lived in a Germany dominated by the tradition of hermeneutics. Especially after the treatise in hermeneutics developed by Gadamer in his *Truth and Method* (1960). Gadamer's work is grounded in Platonic-Aristotelian as well as Heideggerian thinking, that rejects subjectivism and relativism, abjures any simple notion of interpretive method, and grounds understanding in the linguistically mediated happening of tradition. Kittler seeks not to understand technology but rather to document their emergence so as to make visible the structures of communication that technology both introduces and makes possible. 'Meaning', for Kittler (1986, p.166), is little more than an 'anthropocentric illusion'. Kittler clearly incorporates many aspects of post-structuralism -especially the Foucaltian discourse- elaborating what Wellbery called post-hermeneutics:

> *It abandons the language game and form of life defined by the hermeneutic canons of justification and enters into domains of inquiry inaccessible to acts of appropriative understanding. Post-hermeneutic criticism, to put the matter briefly, stops making sense. (David Wellbery, Post-Hermeneutic Criticism Foreword to Friedrich Kittler, Discourse Networks, 1800/1900)*

The concept of 'corporeality' defines the point of reference for post-hermeneutic criticism. The body is the locus upon which the various technologies of our culture connect and inscribe themselves. In the post-hermeneutic discourse the body is not the foremost agent. The question about its agency recedes. The body, in order to be first, it must suffer a cultural restriction of its possibilities. We can call this process 'training'. Thomas and Geerke (1990) understand 'culture' within post-hermeneutics as "the regimen that bodies pass through; the reduction of randomness, impulse, forgetfulness; the domestication of an animal, as Nietzsche claimed, to the point where it can make, and hold to, a promise".

Corporeality is interestingly also very present in post-structuralism. One widespread reading of post-structuralism argues that it eliminates the concept of the subject. Every subject can ideally host every concept. Methodologically, it is explained through corporeality. In the subject, concept is replaced with that of the body. A transformation which "disperses (bodies are multiple), adds complexity (bodies are layered systems), and historicizes (bodies are finite and contingent products) subjectivity rather than exchanging it for a simple absence" (Wellbery, 1999).

Kittler's post-structural thesis could be summarized with the statement "media determine our situation". Our knowledge and what we believe to be true is critically dependent on the cultural techniques that we use. For many people, especially in the First World, a great deal of contemporary life is mediated by interfaces, including laptop, smartphone, and television screens. Our musical practice suffers the same effects. Epistemologically, what we think we know about musical instrument design is mediated by the technologies of design we count. Kittler developed the 'materiality of communication' to visualize the effects of media in our techno-culture. Kittler wanted to show that the hardware that so crucially defines the materiality of the computer looks like its software. Which is to say that with every act of writing that software executes, the hardware specifies how this operation must look. Our writing instruments shape our thoughts, and it applies not only to cultural and media scholars, but also in essence to the relationship between hardware and software.

The importance of Kittler' s work in this regard lays on giving us methods to:

- describe the role of a particular communications technology;
- to demonstrate that the media scene we use is determined by the specific historical, technological or scientific conditions of the time in which it was created;
- to demonstrate that, not only is our media scene the result of specific historical or scientific conditions, but these conditions are all uncannily related in one way or another;
- and to increase our awareness and understanding of the materialities of communication.

In this thesis, I do not seek to understand the apparatus of digital musical instruments. Following Kittler' s methods, I will describe how hidden aspects of a digital instrument (i.e. representation, mapping, etc.) mediate during a performative event; I will elaborate a discourse about the technological and historical moment when they were designed; finally I will visualize the flows of information during the performative moment (which elements of the instrument, probably hidden, mediate my performance?). This is the basis of chapter 7.

3.2.4. Taxonomies, Critical Organology and Musical Organics

The first experiments with computer music in the fifties marked the debut of computers as musical instruments. Since then, musical interfaces have proliferated with every new musical style and novel technology available. For instance, Max Mathews' Radio Baton (figure 3.5a) constitutes one of earliest academic digital instruments while Onyx Ashanti´s Beat-Jazz project explores popular techno music (figure 3.5b). Laetitia Sonami (figure 3.5d), Michel Waisvisz (figure 3.5e) and the Sensor Band (figure 3.5c) are and have been active performers in the experimental scene. Nowadays musical interfaces have conquered our stages as indispensable tools for controlling many types of digital content (figure 3.5g and 3.5f). Musical interfaces embodying diverse configurations, technical protocols and visual appearances. They have varied idiosyncrasies, taken from experimental and D.I.Y. designs to the most standardized forms found in commercial music. Musical interfaces can be composed of their multi-modal nature. It can even occur that the interfaces are invisible to our human senses (e.g. using hidden infrared light sensors). Within this field, mediated both by culture and technology, how can we classify musical interfaces? Is it even possible to propose a classification for digital instruments?

A few taxonomies for real-time digital instruments have been proposed in the last two decades, mostly based on surveys and user studies (Paine 2002, Mann 2007). However, there is not a broad academic consensus about the suitability of these classification methods. When classifying acoustic instruments, the models originally developed by Mahillon (1880) and later expanded by Hornbostel and Sachs (1914) are usually accepted. This taxonomy divides instruments among five types according to the nature of the sound-producing material: aerophones, chordophones, idiophones, membranophones and electrophones. Interestingly, for Hornbostel and Sachs, electrophones include instruments with electronic action, electro-mechanical amplification and radioelectric instruments with oscillators. Thus, early electronic instruments like Ondes Martenot, Trautonium or Theremin would be correctly classified as electrophones. The problem with extending this taxonomy towards digital instruments begins when the mechanisms for sound generation are compared. In fact, as the classification of Hornbostel and Sachs is based on the physical materiality of the elements producing sound, digital musical instruments would be classified from the matter producing sound, often a speaker or a musical robot. Therefore, nothing would be said about other properties of interfaces. Both a bio-interface coupled to a performer's body or a Theremin would be electrophones.

Garth Paine (2002) and Steve Mann (2007) have proposed classifications especially designed for the case of digital musical instruments. But as Paine explains, new interfaces/instruments display a multi-faceted quality not previously seen in musical instruments. They combine the roles of controlling the system and the creation of real-time content (for example in the case of sequencers). Thus, there is no clear-cut distinction among many instruments due to the many inter-relations that coexist. In other words, problems arise when attempting to generate a coherent system from multidimensional data. Paine acknowledges that his approach has weaknesses in this regard, and that as such it is bound to be incomplete.

An impetus towards updating traditional musicology and organology into a field which could include not only the impact of new technologies, but also histories of science and sound studies is known as 'Critical Organology'. It is a recent subfield that blends the concerns of traditional organology, the history and classification of instruments and the exploration of their construction, with broader questions of the impact and implications of technology. For Emily Dolan:

> *"Instruments, machines, and technology occupy an increasingly central position within musicology. It is now possible to speak of the birth of a "critical organology"*

A few symposiums on critical organology have been developed in the last five years. For instance, Joseph Auner (Tufts University) has explored how the integration of traditional instruments with sound technologies can transform our conception of the instrument, the musical material, and performance. Eliot Bates (University of Birmingham) has questioned the limits of the instrument itself beyond its nominal 'body', suggesting that in fact it is a 'body multiple'. Roger Moseley (Cornell University) has addressed the interface of the keyboard from the perspective of media theory, drawing attention to how tracing the material configurations of keyboard instruments and their affordances of algorithmic and playful procedures outlines a musical archaeology of digital techniques. Thomas Patteson (Curtis Institute of Music) has challenged the conventional model of instrumentality implicit in the history of electronic music exploring composers' attempts to exploit electronic instruments as sources of chaos, uncertainty and play.

For Thor Magnusson (2017), digital musical instruments cannot be classified following a comprehensive all-encompassing system. The field of musical interfaces can be understood as a multi-dimensional space of characteristics in which instruments are very difficult to parameterize and compare. For example, an instrument can be characteristic because it only works connected to a network. Another one can be characteristic for using face recognition and audience participation. The number of dimensions in this space of characteristics is dynamic: new dimensions can appear or disappear as technologies do at any moment. Therefore, we face a rhizome of technological and cultural combinations which cannot be classified by single tree-decisions systems. For that reason, Magnusson (2017) suggests a more organic, bottom-up and collaborative approach. First, making use of information retrieval systems and machine learning strategies which could track relevant characteristics of digital instruments from Internet and public databases. Second, keeping the classification system open to the incorporation of new categories and add-ons. And third, promoting the production of a 'folksonomy' of data based on the permanent incorporation of meta-tags by users who are committed in helping the system. Magnusson's approach can be seen as a large database of digital instruments where algorithms trained by users generate an archive of meta-data and categories. This archive is kept open to the automatic incorporation of new instrumental categories we cannot predict.

3.2.5. Mediated Relationships Among Performer, Instrument and Sound Work

During the design process of musical interfaces, some kind of musical practice, an improvisation, or even an entire composition, needs to be imagined and conceptualized. And during this process many aspects of a particular cultural or musical practice will inform the instrument design. At some level, musical works can be also shaped by the process of that instrument design. Undoubtedly, this will determine many characteristics of the musical interface e.g. its gestural vocabulary, functionalities, ergonomics, visual aspect, etc.

Many NIMEs are not limited to a particular musical practice although some types of music will be more difficult to be played than others. For example, playing Chopin's *Nocturnes* or *Mary had a litte lamb* with a Reactable (Jordá et al, 2005) can be quite tedious, independent from the inherent difficulty of those scores. Other NIMEs are designed to constrain the playable musical elements at multiple levels. Max Mathews' Radio Baton (1991) uses a complementary program called "Conductor" to automatize the selection of notes on a predefined score. Laurie Spiegel's "Music Mouse" (Gagne, 1993) allows only interaction within very idiosyncratic ranges of frequencies. In both instruments, a predefined musical score is necessary to play the instrument. Sometimes, NIME designers develop a notational system for their novel digital instrument (Mays &

(a) The Radio Baton

(b) Onyx Ashanti

(c) The Sensor Band: Edwin van der Heide, Zbigniew Karkowski and Atau Tanaka

(d) Laetitia Sonami: The Lady´s Glove

(e) Michel Waisvisz´s The Hands

(f) The Daft Punk Pyramid

(g) Justice caught "unplugged"

Figure 3.5: Various approaches to performing with musical instruments

Faber, 2014; Ganhör & Spreicer, 2014) but my perception is that this is not a common practice. Frequently we see performers who don't use scores because they prefer improvisation although this is also compatible with following some prior annotated musical plan. For Chadabe (1989) digital instruments have transformed the act of composition into an interactive process that depends deeply on the system response. In these cases, the musical result can be completely different at every instance of a performance.

In this diversity of approaches to the problem of composing for new digital instruments, the traditional relations between composer, composition and performer are mediated by the compound (technological and cultural) nature of the instrument. Composing for digital music instruments can be quite challenging. Their apparatuses influence the whole process of composition. Composing is encoding musical ideas into symbols of a notational system which musicians can read and interpret as physical movements. This mechanism allows a musical piece to be played with different instruments. However, with the conception of electronic musical instruments, a composition is not finished until the relation between sound and gesture is defined. And this can be a very complex task.

For the comprehension of this problem it is important to understand the origins of our contemporary practice with digital instruments. Nowadays composers are generally used to dealing with gesture-based music. Many compositions after the 50s and 60s were increasingly understood as describing gestural information for performers, rather than being notations of pitch organized in time (Magnusson, 2011). We can say that during this period, part of the traditional notation system lost its predominant position since it was not able to embrace and reflect the new ideas of composers. The same problem later applied to the case of the more recent graphic scores, which often provided a rather subjective musical notation system. A graphic score is often generated from the need of a notation of sonic-facts that the performer will recreate in his imagination, an approach that anticipates the process of composing for electronic musical instruments. Cook's principle (Cook, 2001) "*make a piece, not an instrument*", reinforces a vision of engaging composition into design. According to Cook, the process of instrument design should start with an specific composition in mind. An opinion shared by the American composer Nicolas Collins who asserts (2010) that he never builds instruments without having a prior musical target (e.g. a musical idea). In other words, for Cook and Collins instruments need an artistic reason to exist. Therefore, our instrumental skills should be conducted towards producing musical pieces and not towards producing new technological developments disembodied from music. In short, instrument design must become instrumental to the work and not the opposite.

After all, like with any other cultural expression, many human factors stay at the center of technological design, not informing it but modulating it in awkward ways. Many personal and idiosyncratic characteristics impregnate every step of an instrument design. As it has been explained by Wanderley and Orio (2002), when a composer decides to build or take part in the design of a certain instrument, the vocabulary of gestures will be determined mostly from subjective decisions. This fact produces profound methodological consequences in Human-Computer Interaction as these idiosyncratic elements do not afford scientific evaluation. For example, how can we scientifically compare two concerts of Michel Waisvisz playing *The Hands*? As I will explain in the following section, a profound study and understanding of the instrument cultural 'reference frame' is needed.

3.2.6. Physical Embodiment

A typical Cartesian definition would say that, for something to be embodied, it must be perceptible to the body, or related to something that the mind has understood through bodily experience. If we accept that mind and body are the same being we cannot say that knowledge is only sensed through the body and stored as experience. Our cognition is embodied, or in other words, our body shapes cognition.

Sometimes, we think that bodily action is not necessary in order to grab knowledge about the world. However, Neuroscience has shown us that our brain simulates input stimuli and re-enacts them as multimodal information and motor activity (Leman, 2007). There are more or less embodied ways of knowing the world but every cognitive activity is necessarily embodied. This assertion is obviously valid for music cognition. For instance, composing music cannot be described as a purely mental activity. Composers do not trans-code notes coming from the mind. A musical intention is always embodied and composing that intention can be as much embodied as playing it.

At the same time, we are also embedded in a sociocultural environment giving a meaning to cognition. Therefore, we get to know the world not only through direct embodiment with it. We also have a culture defining tools, ways of doing and social constructs which contribute to the knowledge we obtain from the world. We have created since centuries archives for studying comparatively the past. Particularly true in our days, our mind extends itself using external memories and other cognitive artifacts (Clark, 2008). Cultures necessarily shape knowledge and our ways of embodiment with the world.

Then, the actual debate is not centered around analyzing if our cognitive processes are embodied or not. The most important aspect is trying to understand better how human body mediates meaning formation (Leman and Maes, 2014).

Luc Nijs, in his recent article *The merging of musician and musical instrument: incorporation, presence and the levels of embodiment* (Nijs, 2017) offers an explanation on the perception that many performers describe of having merged with their musical instrument. For Nijs, expressiveness emerges from a push-and-pull process between the musician's internal and external worlds. The internal world is the space of motor trajectories and musical intentions. It is a container of models created from the experience with the instrument. The external world is the space of sensory trajectories which emerges during interaction in an environment (Leman, 2007). The expression of this push-pull process depends highly on the relationships created between musician and instrument. If the instrument becomes a natural part of the performer's body then all the cognitive efforts can be witnessed at expression. Nijs identifies three levels of embodiment with the instrument: first-order embodiment (body morphology; physical), second-order embodiment (body schema; functional), and third-order embodiment (body image; phenomenological) (Metzinger, 2014).

At the physical and morphological level, the instrument enables and constrains physical action. At the first level "*the interaction with the environment happens without explicit computation, drawing upon reflex-like action possibilities (low-level procedures) that are hard-wired as morphological characteristics of the body and occur as automatic (i.e., reactive) responses to properties of the environment*" (Nijs, 2017). In order to make the first level of interaction (morphological) more effective, the second level (functional) adapts and regulates physical action towards some level of quality. For example, this level plans in advance motor action and predicts perceptual outcome. The third level is connected to one's emotional apprehension of his or her body. As Nijs explains, the anonymous body of the first and second levels becomes an identity and memories. In this level, specific movements (techniques) have to be learned. For instance, different methods of using the bow or tonguing in a woodwind instrument. For Nijs through his understanding of embodiment:

> *The focus on mastering the instrument in function of a pre-defined model of the music is replaced by a focus on pursuing an intimate relationship between musician and musical instrument on the basis of exploring the instrument, experimenting with its possibilities and improvising*

These three levels of embodiment will help us throughout this chapter. When musical models are not so well defined (e.g. experimental music) the only possibility for mastering the instrument, for making it another part of our body, is training us correctly on each of these three levels of embodiment.

3.3. Musical Interfaces as Cultural Interfaces

Musical interfaces are cultural interfaces too. We design, create and refine them because we are committed to develop some artistic practice: music, sound-art, audiovisual art, etc. This cultural dimension not only defines a large percentage of the instrument but also reconfigures many other aspects, the technical but mostly, the type of interaction we establish with them. A strictly functional interface can become a cultural interface if humans, the ones interacting, just give it a cultural value.

The notion of 'cultural interfaces' was developed by Lev Manovich in *The Language of New Media* (2001). As we have explained earlier in this text, human computer interfaces structure interaction between humans and computers. Specifically for Manovich, cultural interfaces 'give structure' to users' interaction with culture. Again, we see how for Manovich, interaction is reconfigured. This shift from interface to interaction was typical from the 'practice turn' at the beginning of the decade of 2000s (Fernaeus, 2008) which gives less importance to interfaces and more to the interactions we make with them.

Musical interfaces, as cultural interfaces posses their own language. A language affected by the idiosyncratic values of its culture. As Manovich explains:

> *The language of cultural interfaces is a hybrid. It is a strange, often awkward mix between the conventions of traditional cultural forms and the conventions of HCI — between an immersive environment and a set of controls; between standardization and originality. (2001,pp)*

However, if one would follow literally Orio, Schnell, Wanderley´s musical interface definition at the first NIME Conference (2002) there would be apparently no interference from the cultural or political sphere:

> *Live performance of computer music can be seen as a highly specialized field of HCI, dealing with such specific topics as simultaneous multi-parametric control, timing and rhythm, and training.*

If we accept that the cultural is involved and that it is crucial to understand musical interface, we will find a path to uncover interesting political aspects.

Defining 'culture' is not easy. Communication scholars Myron Lustig and Jolene Koester (1999) define culture as "*a learned set of shared interpretations about beliefs, values, and norms, which affect the behaviors of a relatively large set of people*". Within the same culture, individuals share some perceptual frameworks. However, all these individuals do not see the world in the same way because they have lived different experiences. Cultures are mapped to many types of characteristics, from personal space and territory to food and habits, politics, myths, the Arts, etc. These characteristics visualize a culture but they are not the frame of reference. They are a consequence and effect of a particular culture.

A 'reference frame' is the cognitive context where the rules of behavior, symbols and their interpretations are bound within a particular activity within its own structure. We perceive actions in the world but our culture teaches us how to interpret them. Which is the relationship between culture and frame of reference? Our cultural background creates our frame of reference. And it is our frame of reference which forms the basis for how we interpret messages that we receive. But interpretation is not only used to make sense of the world but it is the mechanism to make evaluations and conclusions. Interpretation would be a sort of grid we put onto reality formed by 'reference points' produced by experiences, expectations and patterns of living. Not understanding that other cultures have different reference points produces ethnocentrism: the use of our cultural reference points to judge other cultures as inferior to our own.

For understanding and evaluating performative activities, like playing a musical instrument, we also need to refer them to their 'reference frames'. From classic ethnographic studies we know how 'performances' are central to human understanding (Turner, 1988) and post-modernism has drawn attention to the way performances seek to reinforce and communicate our identities in society (Moore, 2004). Recent research on socio-situated interface design (van Dijk, Lugt and Hummels, 2014) is coherent with the idea of 'performing frame' and suggests that when performing with an interface cognitive scaffolds can only exist in the context of a social setting. Undoubtedly, the ability of 'performing' carries a substantial context and the sociological ecology of acting in front of others. In short, the performance frame influences the overall design of interactions.

Performing actions, analyzed from the side of audiences, are also interpreted in relation to reference frames. When we see a person performing, the mere physical actions of a person 'touching' an instrument do not define 'per se' any cultural meaning. For instance, a parrot kicking a drum set affords different cultural values for us and for the parrot. In the same way, when we see a person performing music we first are confronted with a particular cultural apparatus and reference frame. I am not suggesting here that the Arts need to be interpreted or understood. Also not that we have to be able to understand every reference frame. In my opinion, certain richness and a multiplicity of reference frames among cultures is probably what produces new developments in our societies.

Evaluation in this context means cultural evaluation. For instance, the evaluation of tangible interfaces for performative use has been studied extensively by Sheridan and Bryan-Kinns (2007), laying emphasis on the necessity of evaluations underlined by sociological contexts or within their 'performance frame' (Benford and Snow, 2000).

As we studied in chapter two, a relevant singularity of cultural interfaces is their confrontation with the engineering purpose of creating tools as closed-systems, designed for efficient-task solving. In the world of musical interfaces, concepts like acceptability, enjoyment or engagement are usually more important that usefulness, task solving or efficiency. For instance, 'efficiency' is usually seen as an important aspect when designing cockpit interfaces. A cockpit interface does not waste energy or add any latency to pilots' actions. But efficiency can be understood as superfluous interface attribute at a punk-noise performance. And both visions are legitimate visions within each context.

For Tanaka (2011) musical interfaces are often 'open-ended systems' because many times they appear incomplete, created for a single use, and showing unclear boundaries. This is also coherent with the frequent fact of discovering successful musical interfaces full of imperfections, even some having acquired its extensive artistic personality out of their limitations more than out of its expected functionalities (e.g. a Cracklebox).

In conclusion, we are confronted with an entangled field full of idiosyncratic decisions relative to specific cultural contexts. Therefore, musical interface design needs to be studied in relation to the 'cultural interactions' produced among musical interfaces, cultural contexts and individuals.

3.3.1. Politics of Musical Interfaces

Musical interfaces show the ability to mediate musical expression not only through their ergonomics and functionalities but also through certain cultural attitudes they seem to incorporate. As Manovich (2001) explains:

> *[...]in cultural communication, interfaces are codes which rarely are transparent or simply neutral transport mechanisms*

In our context, I assert that musical interfaces are ingrained with politics. In my opinion, playing a specific type of musical interface means accepting its inherent politics and ideologies. If we think of, for example, practitioners of live coding, virtuosi of retro-game music synthesis or finger-drummers to name a few examples, all these interfaces result in separated communities which usually perform with similar if not identical sorts of interfaces. This 'interface effect' as Galloway (2012) illustrates, comes not only as a result of a technocratic decision but mostly as a socio-political declaration of identity ingrained within media. In other words, in the same way that music has had a legacy as a medium for communicating ideologies, the act of building, hacking or performing with certain interfaces would mean manifesting the artistic vision and the distinct politics of its performers.

Can musical interfaces carry political messages? And if so, which would be those messages? To answer this extent, I bring here a musical example, *Chicks on Speed*'s song *We Don't Play Guitars*:

> *We always thought that we were not a rock n roll band,*
> *but it sure feels like rock n roll over here tonight,*
> *We don't play guitars*
> *We are standing on stage with our microphones,*
> *but we don't play guitars*
> *Got the Sherman up here with us,*
> *no we don't play guitars*
> *[...]*
> *We can go shopping in the supermarket but we don't play guitars*
> *We shop more than other people, we don't play guitars*
> *Can you play guitar?*
> *Can you play guitar?*
> *Were standing in Tobi's studio but we don't play guitars*
> *Neither do Kiki or Melissa*
> *No we don't play guitars*
> *We like to use gaffa tape but we don't play guitars*
> *Give us your gaffa tape, we don't want your guitars*
> *We don't play guitars*
> *We don't play guitars*
> *No we don't play guitars*
> *You may not play guitars but I do!*
> *You know, maybe 'cause don't play guitars but*
> *P-E-A-C-H-E-S plays guitar*
> *I play guitar, that's right*
> *I play guitar*
> *Well you may not play guitar but I play guitar*
> *And I love it!*
> *[...]*

The electric guitar accompanied many of the political movements of postmodernity especially during the decades of 1960s and 1970s. With the establishment of the so called pop culture, the electric guitar becomes both a myth and a cliché. In the 80s and 90s, the electric guitar loses part of its character of rebellion. The electric guitar becomes a 'cool' instrument, encompassing a culture of party. For Waksman (1999):

> *[...] guitarists like Kurt Cobain and Steve Vai realized what was happening to the guitar and would set out to lament the materialistic society American had become and reinvigorate the desire to explore the boundaries of electric guitar's abilities.*

But, what kind of new rebellion against electric guitars is this one of *Chicks on Speed*? In order to understand the political motivations for composing *We don't play guitars*, I decided to interview Alex Murray-Leslie, one of the artists involved in the band. This is the transcription of one part of the interview:

We made the song "We don't play guitars" as a necessity because there was so many boy-bands in indie rock and it was a reaction against that kind of music. We wanted to make fun of the guitar. We wanted to throw the guitar and burn it on stage. We wanted to hack into the guitar. We don't play guitars! And of course Melissa wanted to bring a guitar on stage and play it, and I said we cannot play a guitar on stage and that forced us to make the high heels shoe guitar. But the problem with the first high heels shoe guitar is that you couldn't wear it. So it was really great to have this device to develop different choreographies with and to move on stage but it did not fulfill the total political intention of building an interface that you could wear and repeat gestural at the same time. That let us building it again at Hangar with Alex Posadas and Max Kibardin. The reason for taking the shoe, the high heel shoe, is because it is an iconic form. It is a feminist form. Gender politics all over. And if you play it, it is even better than a guitar. It sounds way cooler. And our choreographies are a kick-ass. And we do not play guitars and we hate the wooden cock substitute. It is about creativity. It is about the freedom of the feet, the liberation of the feet, and using your feet for complex creative tasks. We don't play guitars and we don't play classical instruments either. So go out and make your own instruments. Build a song and build the show.

The high heel shoe she references during the interview is a musical interface the *Chicks* decided to build after composing the song. It can be observed at figures 3.7a and 3.7b. It incorporates various sensors to detect interaction over the short electric guitar strings installed on the shoes. This information is transmitted wireless to a computer generating sound.

In my opinion, through this trashy electro-pop song, the *Chicks on Speed* manifest artistically a particular musical ideology through an instrumental decision: not playing guitars and building a musical interface. Bringing the *Sherman* ("Filterbank") up on the stage (and the electric guitar down) is their way of affirming a particular affiliation. In conclusion, the *Chicks* have shown how to manifest artistically an ideology in regard to musical instruments.

3.3.2. Politics of Musical Interface Design

As I have explained, performing with musical interfaces means assuming certain politics. From a designer perpective, where can we ingrain those politics within an interface and how is it possible to design them?

Mara Mills (2011) explains how interfaces can embody a full range of cultural and economic values, some of which are deliberately scripted into design, others of which accrete inadvertently. For instance, these scripts would privilege some styles of music and compositional languages. For Mills, technical scripts would be *"ability scripts and as such they exclude or obstruct other capabilities"*.

Yet, if we think of the available music production tools in 2018, interfaces clearly promote or benefit specific types of music production. Obviously one could defend that interfaces get specialized or are programmed for specific uses like in the case of acoustic instruments. However, interfaces run on top of musical engines which could allow disparate uses. Often interfaces only constrain the number of uses. Unfortunately, in most of the cases, these interfaces are either immovable or slightly customizable. This is understandable, the interface is the place for interaction and interaction has become a trademark.

The possibilities of stressing particular artistic intentions through interface design has been studied by Mike D'Errico at his ongoing online project *Interface Aesthetics*[4]. The author distinguishes between two different trends in interface design, maximalism and minimalism.

A maximalist design values the creative options offered by embracing as many different types of interfaces as is possible. It would be the case of *Live Ableton*, *Renoise* or *Fruity Loops Studio* among many others (figures

[4] http://www.interfaceaesthetics.com

(a) The Sherman Filterbank

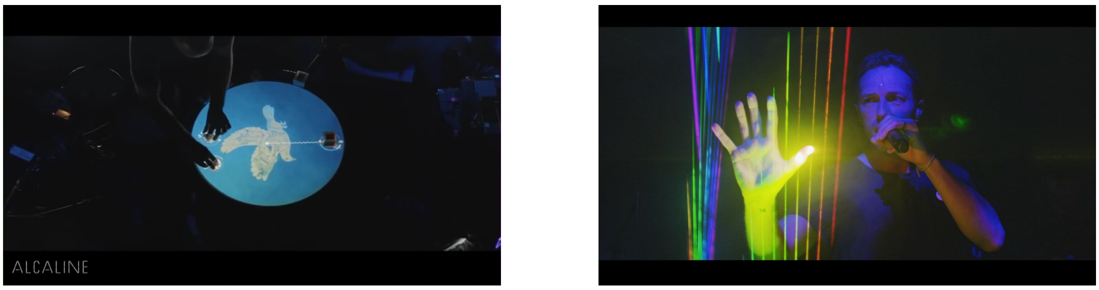
(b) Chicks on Speed, We Don't Play Guitars video still

Figure 3.6: Chicks on Speed, We Don't Play Guitars

(a) The high heel show guitar

(b) Chicks on Speed - electronics of the high heel shoe guitar

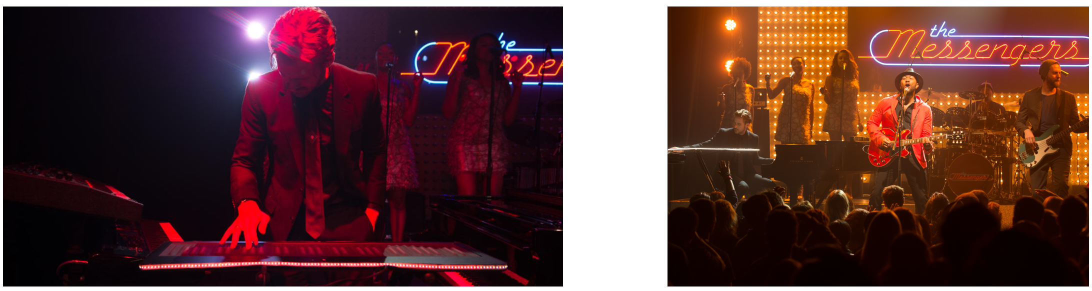
Figure 3.7: Chicks on Speed - high heel shoe guitar



(a) Coldplay's Midnight reactTable

(b) Coldplay's Midnight Light Harp

Figure 3.8: Coldplay - Midnight (2014)



(a) La La Land - Gosling Playing the Seaboard

(b) La La Land - Gosling (left) Playing the Seaboard

Figure 3.9: La La Land Film (2016)

3.10 and 3.11). Under those interfaces, a musical work can be represented and controlled from different interface perspectives. For example through the perspective of a timeline or through the perspective of the library of audio files. The elements of these interfaces present the possibility of using pre-produced presets, effects and constructions.

For the researcher Matthew Ingram (Reynolds, 2011) these systems encourage *interminable layering and inculcate a view of music as a giant sandwich of vertically arranged elements stacked upon one another.* Critic Simon Reynolds (2011) describes how this practice results into a digital maximalism in which cultural practice involves *a hell of a lot of inputs, in terms of influences and sources, and a hell of a lot of outputs, in terms of density, scale, structural convolution, and sheer majesty.*

In contrast to this maximalist approach, the minimalist design positions users in front of minimal elements, ideally a blank screen and obviously, no preset options at all. It would be the case of the audio programming environments Pure Data, Max or SuperCollider (figure 3.12). Miller Puckette, initiator of Max and Pure Data explained in a keynote at the McGill University in 2012, how those maximalist software interfaces are *useless for music composition, because in creating software environments you are ideally cutting out 90 of the possible algorithms that a computer is capable of.*

As D'Errico asserts, the maximalist interface is about a sort of fetishization of accessibility and minimalist interface design is about transparency, adaptability, and flexibility. Indeed, these two different political visions for musical interface design would relate to the two possible ideologies of consumption in the digital age: "*those who find creative potential in maximizing content within predetermined forms (maximalism), and those who wish to change the fundamental forms themselves (minimalism)—a desire couched in vaguely ethical terms*" (D'Errico).

3.3.3. Disenchantment: Post-Digitalism and Interface Objectification

"*Wow, you have to watch this*" said a research fellow in the university. It was the pop band Coldplay's latest youtube video "Midnight - Live 2014" where a song was arranged specifically for electronic musical instruments. Interestingly, it starts with an impressive close-up of a reacTable. Coldplay playing a reacTable, great!

On this reacTable, there are only three cubes (figure 3.8): an audio file player (namely " loop player") and two more global controllers, the "global output volume" and a "song settings" object. A few seconds later, a musician interacts with the instrument and we see him rotating the "output volume" controller towards higher values. Unfortunately, we cannot perceive any causal relation within the audio. The action of the hand is not followed by any change in the actual music. Certainly, and along the last thirty seconds, the overall volume has evolved but in a complete different trajectory than we expect from the action done on the reacTable.

Sixty seconds later, a first laser harp makes its entry into the video. And just before the second minute, a second laser harp is switched on. Again, both laser harps occupy a protagonist role in the video. But in the moment when the singer approaches the harp and starts playing it we perceive it does not produce any change in the song. Finally, a new "loop player" block is put on the reacTable. It has triggered some piano notes in perfect sync. Less than a minute later the camera shows us a musician's hands playing the same piano notes, with identical timbre, tempo and articulation, but on a keyboard. - *Yes, it was worth to watch it* - I thought.

An understandable sentiment of disenchantment with digital technologies can result from situations like the one I have just described. A situation which I have decided to call "*interface objectification*". Independently from the original creative intentions within a musical project, turning our musical interfaces into de-instrumentalized devices is the final confirmation of how digital instruments are also becoming "another piece of ludic capitalism" (Cramer, 2014). Whether these practices are more or less extended, their analysis serve us to visualize their political dimension. The best and most popular example of this is the appearance of the *Seaboard* interface (figure) in the Oscar awarded film *La La Land* (2016) (figure 3.9). The interface shares a prominent role with Ryan Gosling in one of the best scenes in the film, when Sebastian — the jazz pianist played by Gosling — accompanies John Legend and his band in the song "Start a Fire" :

> *Gosling played the Seaboard GRAND during a scene that signified his transition from an out-of-work pianist to a crowd-pleasing performer in a hit band.. Playing a blistering solo on its distinctive "keywaves," Gosling is now a Seaboard aficionado.* (From Roli Searboard's website[5])

[5] https://roli.com/article/seaboard-la-la-land

Figure 3.10: An example of interface maximalism, the 2020 app

Figure 3.11: The interface of Renoise

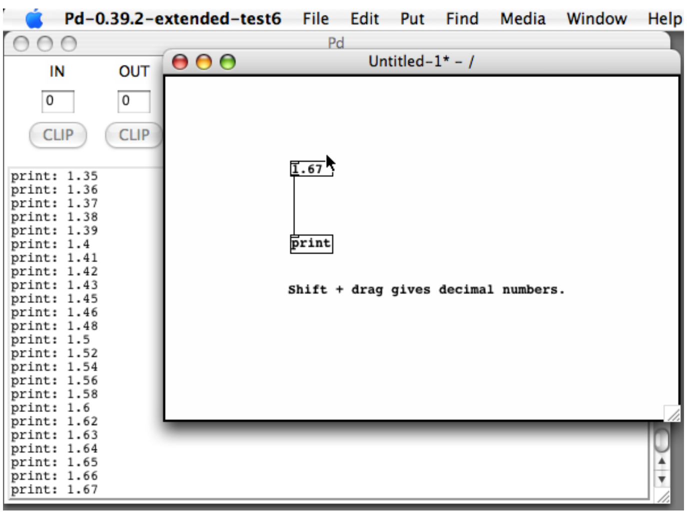


Figure 3.12: The interface of Pure Data

Nowadays, the artistic use of musical interfaces is generalized. One can easily find a forty-euro MIDI controller incorporating eight faders, eight knobs and 24 buttons (e.g. a Korg Nanokontrol), summed to the possibility of creating multiple scenes for all those parameters. That is probably more than enough for controlling a normal gig: no time to lose in hardware development. In parallel, it seems that the traditional market of GUI applications have expanded their industry towards controllers. Often, when buying a piece of music controller we are also acquiring a programming suite and vice-versa.

At the same time, popular creative technology platforms, like the 'kickstarter'[6] project, very much helped by social media channels like twitter and facebook, have been the perfect medium for promoting a massive flood of new digital instruments and musical gadgets. Certainly, the fascination for all these devices has become historical and the market follows this tendency. Like it has also happened with many digital technologies, musical controllers are another piece of 'ludic capitalism' (Cramer, 2014). Under these circumstances, Cramer explains, there exists a pertinent disenchantment with digital technologies, especially within the Arts . Also in the academy, it is a real phenomenon that art students are more attracted to engage with media archeology projects and less with courses about digital techniques. For Cramer (2010, 2014), this growing interest for the non-digital finds its roots in the inflation of the digital as a synonym of "advanced, cultural coolness and cleanness". Sensibilities going in the opposite direction have built another nostalgic cultural trend: analog records and retro-synthesizers. For Cramer "such a withdrawal seems little more than a rerun of the 19th-century Arts and Crafts movement, with its program of handmade production as a means of resistance to encroaching industrialization".

Summed to this situation, we face an over abundance of digital contents. Not the video, but Youtube and Spotify 'have killed the radio star':

> *[...]*
> *Video killed the radio star*
> *Video killed the radio star*
> *In my mind and in my car, we can't rewind we've gone too far*
> *Pictures came and broke your heart*
> *Put down the blame on VCR*
> *[...]*
>
> *The Buggles - Video Killed the Radio Star, album The Age of Plastic (1980)*

For instance, it is fascinating how we have got used to streaming music services (e.g. Spotify) which are now stepping up their efforts to provide listeners with "*the right music for every mood and moment. The perfect songs for your workout, your night in, or your journey to work*" (Harvey, 2014).

Many critical voices have formed a new sensibility around what we know today as *post-digitalism*. But interestingly, the idea of what a post-digital work could be has changed during the last decade. Originally, at its initial definition formulated during the decade of 2000s by influential artists like Kim Cascone, the term alluded to the loss of relevancy of the digital for inspiring art. For Cascone (2000), the long-time predicted Negroponte's digital revolution[7] has finally reached us. The generalization of digital music, its massive consumption and production, is real. Indeed, the digital can be considered as the new mainstream. It seems that the artistic interest in discovering the promising characteristics of the digital is over. As a consequence, post-digital artists would need to look for new understandings and inspirations of the digital.

However, only a decade after the initial movements towards a post-digital sensibility, the development of technologies merging software (virtual worlds) and physical world (e.g the Internet of Things), has redefined the post-digital. Post-digital artworks would be those tending to address the humanization of digital technologies.

For Rasmus Fleischer (2015), a world of musical superabundance:

> *might weaken the individual's ability to be affected by music in everyday life, while at the same time leading to a renewed interest in collective experience, in ways which are not limited to established notions of musical liveness*

[6] www.kickstarter.com

[7] Over a decade before writing "Being Digital" (1996), Nicholas Negroponte had predicted that by the year 2000 the three industries of computing, telecommunications, and media/publishing would have converged. In a prediction that proved to be startlingly correct, the MIT guru had reasoned that a future reliance on the same digital systems would remove many of the technological boundaries that once separated these previously quite discrete market sectors.

Fleischer sees the digital as a lost opportunity. Within this superabundance of music we have access to styles and music we were never before aware of. Unfortunately, machine learning algorithms who choose music for our taste or moods make us less attentive and sensible to our sonic environment. Instead of increasing our musical culture as listeners, they tend to homogenize us. In this context, a solution would be to attempt the cultivation of a 'postdigital sensibility', which for Fleischer means a political resistance to subvert the contemporary processes of commodification. For Fleischer

> *the quest for a post-digital sensibility may be understood as an act of resistance, based on the refusal to let music be subsumed under predefined activities or moods*

3.3.4. The Politics of the Novelty: the "World's First" Case

We plan the future using the vocabulary of the past. We need metaphors and analogies for describing novel ideas, innovative paradigms and radically new systems. Novelties are discontinuities. We understand better a novelty if it is described as a combination of elements we already know.

The degree of novelty in a new musical interface is also a design pattern. Radically new paradigms for performing digital music have been often proposed. To cite one simple example, Dave Griffiths' live coding environments *Scheme Bricks*, *Betablocker*, *Al-Jazari* and *Daisy Chain* (McLean et al., 2010). These are novel systems seriously considering the visual elements of code which are essential for the live coding experience. However performers usually do not easily adopt radical novelties independently of its benefits. For E.W.Dijkstra (1988) "radical novelties are so disturbing that they tend to be suppressed or ignored, to the extent that even the possibility of their existence in general is more often denied than admitted". For this reason novelties are usually alleviated. For instance, when we update to the latest version of our favorite digital audio workstation we do not expect a radical change in its interface. Obviously, understanding how a novel interface works takes time and effort. As the marketplace focuses its energies on efficiency and usability radical novelties are often suppressed.

Paradoxically, novelty has a remarkable marketing value. The new has something which persuades. The crowdfunding platform Kickstarter is a good example. This is what I have called the 'World's First case'. In order to improve visibility on Kickstarter, designers often sell their projects as the "World's First". Examples are the world's first squeezable metal bottle, the world's first Personal A/C watch, the world's first solar powered smartwatch, the world's first smartphone AR projector, the world's first toilet cleaning robot, the world's first binding system for diving fins or the world's first aquasonic swimming pool alarm system[8]. Musical instrument examples are the world's first innovative crossing guitar (namely the *Cross Guitar*), the world's first interactive music platform (namely the Whitestone), the world's first intelligent LED music controller (namely the Oscilloscape), the world's first intelligent turntable (namely the *LOVE*) or the world's first wireless, pocket-sized instrument designed for mobile music making (namely the *Minim*). As it can be observed, the world's first is always about adding commercial value to the product. The first intelligent, the first smart or the first interactive.

Is therefore Kickstarter a niche for innovation? Anirban Mukherjee (2017) developed a comparative study about innovation and marketing at Kickstarter. The project analyzed 50,310 projects with machine-learning tools classifying occurrences of the word "novel" and its synonyms served as proxy for novelty claims. Conversely, the sum of occurrences of the word "useful" and its synonyms became the measure for claimed usefulness. The results show that claims of novelty or usefulness, taken separately, do increase the total pledge amount. Interestingly, projects featuring both usefulness and novelty resulted in low pledge amounts. Successful projects picked novelty or usefulness but they did not combine them.

In the traditional commons industry, novel and useful products have been usually highly appreciated in the marketplace. However, it seems that the on-line crowd prefers investing in safe projects. Projects combining usefulness and innovation look suspicious. The great lesson is that, too often, creators assume that the novelty and usefulness of their product will be as salient to their audience as it is to them. But they need to make sure that their target audience sees those for itself. With persuasion but without creating false expectations. It's the crowd who decides.

[8] First results obtained from the google search "kickstarter World's First" on 13 April 2018.

3.3.5. Marketing and Musical Controllers

When musical interfaces become "another part of ludic capitalism" (Cramer, 2014), analyzing their political image is undoubtedly mandatory to understand how technology, culture and marketing interleave each other.

Let´s analyze two photos among the many possible ways of representing a reacTable instrument. They can be observed in figures 3.13a and 3.13b. Although aesthetically and politically they look quite different, their format is surprisingly similar:

1. In both cases performers are surrounded by a social reference frame which communicates the instrument value. In the first case this frame seems grandiloquent and constructed towards a marketing purpose: communicating the value of great social engagement and entertainment. In the second scenario, the social frame transmits the value of technical novelty. At the same time we see many people at the audience who actually looks totally bored with the event. Therefore, although their structure is similar each photo describes opposite energies in regard to entertainment.

2. Both photos describe the relationships created with the others. In both scenarios the performers -both men- 'control' the musical action. However, nobody in the audience really looks at the performers. The instrument attracts all the attention.

3. At both photos the 'setup' is very present. In the first case, we can imagine the necessary gear for illuminating the scene from various angles, as well as the time invested until finding a swimming pool background fitting the blue color of the reactable. Indeed, many other elements of the background are also illuminated with the same blue-ish light. In the second photo the 'setup' is very present because it reveals an intention to document the situation of an academic open event, the number of students and even including a television camera and many people filming with their phones.

This subsection unfolds a very important aspect of musical controllers. If they are given a commercial value in capitalism, marketing and communication strategy will have a louder voice in defining their properties and design decisions. Louder than HCI expertise and organology, even independently from the original designer's intention.

3.3.6. Euphoric Controllerism

A natural resistance against the proliferation of commercial interfaces would be the development of custom and critical interfaces. Alien controllers and experimental setups have been present in the experimental scene at least since the so called 'composing inside electronics' practice from the late 1960s. Also, music hardware hacking and circuit bending are not really emerging practices today but well established fields with renowned performers (Reed Ghazala, Nicolas Collins, Serge Tcherepnin, the Voice Crack duo, etc). Likewise, the D.I.Y. philosophy is not new at all. The introduction of free-hardware platforms at the mid 2000s (e.g. Arduino) served even more to lower entry costs and the technical skills needed to produce custom musical interfaces.

The result of this sequence of events was the sudden proliferation of custom musical controllers. And another possible effect, the perception that building custom musical controllers would be the 'new mainstream'. Thus, if the act of building custom and experimental setups was again converted into a conventional practice, we could only expect the next revolution to be cultural. Is there anything else out there? Yes, probably the latest and most interesting trend on new instrumental uses of musical controllers looks fresh and artistically unconcerned. It is the so called 'controllerism'.

Controllerism appears early in the mid 2000s as the creative application of musical controllers to build music upon mix, scratch, remix, effect, or any other technique. It has been developed mostly by digital DJs, whom have really created a theory and technique for this practice (figure 3.14b).

Controllerism means creating music with controllers but rejecting the traditional passive task of the laptop-performer. In the words of its pioneer DJ Moldover (2007) (figure 3.14a):

> *Controllerists use computer technologies as musical instruments, differentiating themselves from people who 'check their e-mail' on stage*

Controllerism is a clear interface effect (Galloway, 2012) produced by the introduction of musical interfaces into the cultural world of DJs. Since controllerism depends on the idiosyncratic selection of particular physical controller and software, there exists a considerable amount of uniqueness and customization in the

(a) The reactable (photo from reactable.com)

(b) The reactable

Figure 3.13: Two visions of the same interface

(a) Moldover showing some of his custom controllers for performing

(b) Raffi Zaki performing a controllerist session where we observe that controllers are inclined towards the audience

Figure 3.14: Two of the most important controllerists

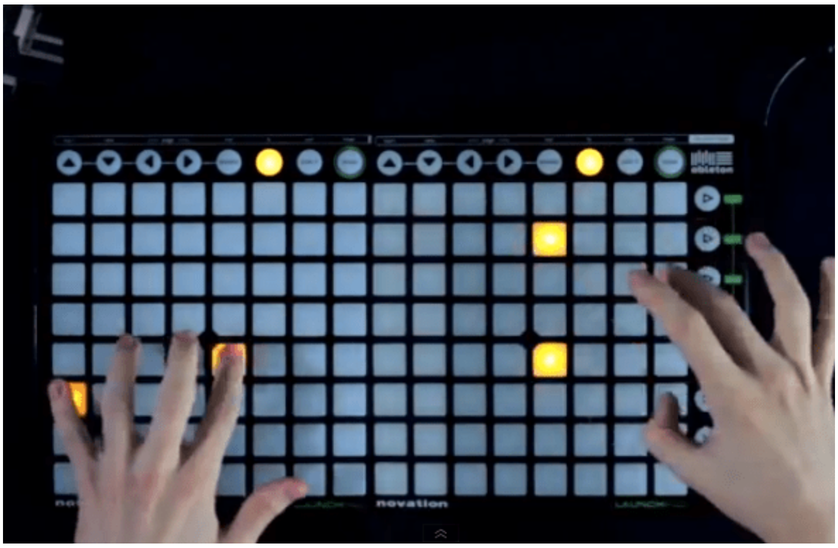


Figure 3.15: The launchpad interface, quite popular among controllerists

scene. Controllerists can hack available commercial controllers, modify and extend them or build their own technologies from scratch (figure 3.15).

NIMEs are often understood as continuing the developments done in Western contemporary music (e.g. classical music from Tudor or Stockhausen until today). However, controllerism is a practice primarily evolving from turntablism. Indeed, genuine controllerists battles have been regularly organized by Moldover and others in the USA.

The magic of controllerism does not come from technological constructs like fancy velocity sensitive pads or elaborated sensors. Instead, controllerism relies mainly on human skills to perform with expression. A good controllerist is one who communicates musically well with an audience during a concert. It is not only about the quality of the music played but mostly about engaging socially with others, an euphoria towards live expression. In short, controllerism has shown us how to bring 'liveness' to electronic music. As another post-digital practice, controllerism has shown us that it is possible to articulate a fruitful communication with other musicians on stage. This has resulted in a huge and international community of practitioners sharing their tricks, achievements and musicality mostly through the Internet. Where academic computer music has failed as a medium to communicate musical ideas to a mass audience, controllerism has taken the opposite direction: engaging from its liveness, making interesting and causal the relationship between gesture and sound produced.

In 2007 Moldover explained:

> *Right now controllers are where it's at, and so that's the name for the movement. Button-pushers, finger drummers, digital DJs, live loopers, augmented instrumentalists; we're all controllerists. The beautiful thing is that it's still new, it's still raw, and it's not about this or that style.*

Certainly, the success of controllerism resides in its perfect adaption to existing popular musical practices. Controllerists have developed techniques, methodologies for arranging songs and composed studies to learn technique. This material is stored in websites and shared through the Internet using channels like youtube, for example.

Interestingly, the popularization of controllerism has caused specialized companies to emerge (e.g. Dj Fighters), many fully dedicated to the production of interfaces for controllerists. For example, interfaces with rapid but silent arcade buttons allowing quick finger-drumming. But this popular character has also partially turned controllerism into another mainstream practice under the influence of social media. On a daily basis popular controllerists, just like youtubers, share videos of new techno-hit remixes (e.g. from Skrillex) using 16-arcade-buttons controllers.

As Phil Morse (2011) describes, although controllerism is highly present on the Internet, probably not many of us have ever attended to a controllerist concert or battle. If a concert like that would happen in our city, we would probably not be aware of it. Its presence on radio and other traditional media is absolutely non-existent and these are undoubtedly characteristics of cultural practices in the underground. I conclude this section with the words of Phil Morse (2011):

> *controllerism is here to stay, and it's only a matter of time before button pushing is the new vinyl spinning - and sooner or later, someone will tell you that you're old fashioned!*

3.3.7. Politics: Conclusions

The development of musical interfaces have mediated profound changes in the understanding of what is actually a musical instrument. After decades of technical and instrumental evolution, musical controllers have conquered our stages while they have even become a part of ludic capitalism. Indeed, we can even perceive them as 'objectified'. Whether our opinion about musical controllers stays linked to the negative consequences of digital industries or rather to the creative possibilities of emphasizing communication among people through technology, depends mostly on the political use of these interfaces.

Understanding the ideologies and politics ingrained at interface design is decisive: our interfaces are perfect trojan horses which promote or obscure specific uses. Therefore, the study of the interface adopted to produce music gets the maximum relevance. Interfaces not only affect at the functional and the musical level but they also define us within the political sphere of music production.

Within our democratic societies, the cultural task of self-identification with existing political options is usually based on a process of reflection about all available tendencies. In the sphere of musical interfaces, ideologies are highly influenced by popular trends and commercial interferences. Like in the case of real politics, we need to evaluate our experience with musical interface, comparing it to our personal artistic expectations. Unfortunately, the perfect interface or the perfect political party does not exist. Fortunately, we can still decide if we continue with our affiliations or not.

3.4. Contributions of this Chapter

- I contribute with a study of musical interfaces as technologies which irremediably get reconfigured by cultural and political aspects. In my opinion, studies about musical interfaces not considering the mediations produced by the cultural and the political are simply not complete.
- I present the apparatus of digital musical instruments. I build on Vilém Flusser´s notion of apparatus to contribute to an understanding of musical interfaces as symbolic machines. From this perspective, the designer's task is about programming the instrument apparatus. The role of performers is producing symbolic products.
- The effects of interface politics have been explained. How musical interfaces create a complex landscape of idiosyncratic identifications, relationships and dependencies with other agents. To illustrate how instruments and interfaces carry political messages I analyze the case of Chicks on Speed's *We Don't Play Guitars*. How this song created a discourse towards feminism and inspired the production of a musical interface.
- I have discussed how marketing and communication play an important role at interface design. For instance, how a digital musical instrument can generate certain structures of use and expectations with its audiences after a marketing campaign.
- Building on D´Errico, I suggest that musical interface design in music has two main political affiliations. Those who prefer minimalism -transparency, adaptability and flexibility building their own forms of interface- or maximalism -a sort of fetishization of accesibility with predefined forms of interface and interaction-.
- I discuss the existence of a certain disenchantment with musical controllers due to an inflation of the expectations and value of the digital. I propose that it is necessary to embrace a post-digital attitude to situate human sensibility again in the center of the field. A resistance against the commodification produced by the super abundance of digital products.
- I discuss how 'controllerism' has managed to gain popularity within our field with a fresh cultural attitude. Controllerism puts liveness and social engagement in the center of musical interface design. Therefore, I suggest that understanding the cultural mechanisms of controllerism can help the development of musical interfaces in other areas of our discipline.

4

Notation

5) Make a piece, not an instrument or controller

Perry Cook (2001), Principles for Designing Computer Music Controllers

The development of new approaches to instrumentality during the decade of the 1960s contributed to the dual perception of instruments as scores. For many performers, the instrument became the score of what they played. This artistic hybridization carries substantial questions about the nature of our scores and about the relationships among instruments, performers and musical works. This section contextualizes the historical origins of this instrumental development.

4.1. The Instrument - Score Duality

Over many centuries, Western music has developed sophisticated notational and representational systems. Within the ecology of music, scores and instruments are different categories. Scores represent a musical work. Instruments serve to interpret musical intentions, written or not. Are musical instruments totally independent things from scores? Does the duality instrument-score exist? Dualities serve well to define something when we can find something else in the world which is absolutely complementary. Human being have created many dualisms through our history . For some reasons dualism, the eternal binary opposition, has been useful. Fortunately many dualisms are being discussed and challenged in modern society and being eliminated. Like the mind and body dualism, male and female, good and bad, etc.

Under a dualistic vision, scores would never share anything with instruments. This chapter dismantles this duality showing that instruments incorporate aspects of compositions and vice-versa.

4.2. Notation Today

4.2.1. Notation and Live Electronic Music

The static representation of time is fundamental to traditional scores. It allows the ability to function doubly. First as a set of real-time instructions that will instantiate a musical performance. And second as an atemporal representation of the composition that can be used for analysis and overview.

How does this representational notion apply to live performance with digital instruments? Let´s think of a gestural controller like *The Hands*[1] . If we are decided to compose a work for this instrument we first have to define the gestures which will be part of the composition and those which are not. Yet, it is possible to filter

[1]The instrument of Michel Waisvisz which I have described in chapter three, see figure 3.5 (e)

and bias the gestural and sonic possibilities of every digital instrument. And once its instrumental language is constrained we could possibly create vocabularies of gestures and sonic mappings. But, why is this not a common practice among live electronic musicians and composers?

The issue of creating notational systems for digital interfaces is that our notation has to represent physical gestures. We have to explain that this or that sign means doing this particular movement or another. Only in the case of using traditional musical language, representations can be mapped into physical actions the player knows.

Digital instruments usually incorporate very idiosyncratic methods to map gesture into sound. And sound can be musical or not. For Alan Tornay (2012):

> *A notation that represents physical input rather than sonic output is unlikely to be able to retain its breadth of functionality, to be simultaneously prescriptive and descriptive, temporal and atemporal, performative and analytic.*

Without a stable sound-gesture correlation, a notational system must signify the physical input rather than sonic instructions. Likewise, since different instruments have different gestural practices, new notation systems would have to be developed for each individual instrument, or at least for families of instrument sharing a basic gestural practice.

As I will further elaborate in section 4.4 of this chapter, this issue is not new at all in the history of performative arts. Dance shares the same problem in regard to notational systems. Although there have been efficient notational systems for representing dance (e.g. the *Laban* system), choreographers do not use them generally. Fortunately, dance has found ways to develop itself without the need of scores. Would this be a possibility for live electronic music too? I see it as an opportunity to develop new languages. Through this chapter I will contribute to a vision of musical instruments as notational objects too. But a type of embodied-in-the-instrument notation.

4.3. What can be notated?

Jacques Derrida, the philosopher of writing, is one of the philosophers responsible for the linguistic turn in the humanities. This means the recognition of the importance of language in human meaning-making. For Derrida (1998), referring to Charles S. Peirce´s philosophy of notation (1883), "*From the moment that there is meaning, there is nothing but signs. We think only in signs*". This idea is central to my thesis. I interpret it as the power that a linguistic understanding of the world exhibits. Once the relationship with something is given with the possibility to support some meaning, our communication will be based on signs. Our thinking becomes 'framed' by those signs. If we want to see it from another point of departure, why do we see inscriptions everywhere?

Speech does not need writing to exist. Derrida would say that writing is a technological development. But for Derrida (1998) writing "is all that gives rise to an inscription, everything that is alien to the order of the voice: cinematography, choreography, pictorial, musical, sculptural writing." Writing is a technology. The inscription allows thinking on something with detail. It even affords thinking disconnected from the necessity of using speech, like in the case of mathematical notation which is clearly not phonological.

Even before writing, how does a speech appear? If analysis allows for isolation of that which repeats on multiple occasions, a lexicon or an alphabet can be created. This lexicon can vary, as different moving expressions would lead to particular ways of speaking a language. We soon learn the words of our language which discretize the infinite sounds which could be emitted by our mouths. And soon we get phonetically framed by the phonemes of our language. In our context, could anything like that be culturally created for notating body movements? For sure it would be possible. But what is the sense of notating movement? Or maybe is that the possibility of conceptualizing the many possible languages of the body, with all their many spoken vocabularies and dialects, would not be an overwhelming task leaving us little time to invest in creation?

Alva Noë (2013), a philosopher of mind, defines notation as a tool for thinking thoughts. As any tool, explains Noë, notation has significance only in the context of its embedding. Remove it from the context and it becomes nothing more than a thing. This is very interesting, because then writing doesn't represent language from outside, modeling sound and structures. We write 'cat' and we think that 'cat' spells out the word by spelling out its sounds. But we don't have any grip on the sounds prior to our model of how to represent them in writing. That's why we can write only those sounds that are already words and not halves of words, for example. You can't write down the floor's actual creek. We don't represent sound in writing, we represent speech, or language. We don't step outside language to write them.

Notation inscribes but it can be thought. This was the main concern of Wiggenstein regarding the use of language in philosophy. Cornelius Cardew (1961), inspired by Wittgenstein´s treatise asserted that "a musical notation is a language which determines what you can say; what you want to say determines your language".

In conclusion, 'writing' is invented by speakers to represent language to themselves. It is a meaning-make activity. It is a kind of research. We write the game down to think about the game. For Alva Noë (2013) if the musical work is tied to to the score, then the musical work is concerned with a problem: how to write itself. At various times throughout history composers had to invent new ways of translating into writing what they were doing. Nowadays interaction designers often need to notate bodily action. Their struggles are comparable to those of choreographers.

4.4. Dance and Notation

As I have explained in section 4.2.2, live electronics, interaction design and dance share the issue of notation. For this reason it is relevant studying how dance, such a long time performative art, has developed itself in regard to notation. The study of dance through notation includes an investigation into movement that not only enriches a dancers understanding of movement but also provides the possibility of creating new relations and innovative perspectives.

Developing a notation for dance has occupied many researchers for centuries. The oldest notational system we know is the *Manuscript of the Basses Danses* from Cervera and Tarragona, in Spain from 1495. In the book *Traces of Dance* (1994) Louppe informs us that the researcher Anne Hutchinson has described eighty-one systems for notating movement, including sixty-two for the modern age alone. Although many of these are good, workable systems and have been around for centuries, their use was never generalized.

The advent of film and particularly affordable video recording in the 1970s overshadowed the need for notation in dance. However, video also has its limitations. A video is a record of a particular performance. Learning from videos too often results in transmitting the personal mannerisms or mistakes of one dancer which are picked up and exaggerated by another. Thus it can easily distort choreographies. In contrast, a musical score is a record of the work itself which represents the work, not an individual performance. Nowadays we can say there is no single standardized notational system for dance.

Creating notational frameworks for dance is an overwhelming task. Various projects in the past (Bary, 2002) have suggested the assumption of computational systems able to record and convert movement into parameters. It is the field of 'dance technology'. In the 1970s there were several attempts to computerize the Labanotation and later the Benesh notation, two notations developed in the twentieth century. These attempts naturally evolved into attempts to translate the symbolic notations into computer models of the moving human body and further to computer-assisted creation of choreographies. One of the more recent and more versatile systems is the "RAM Dance toolkit" developed by YCAM (Yamaguchi Center for Arts and Media). This system (figures 4.1 and 4.2) uses various sensor technologies to recognize gestures and visualize spatial trajectories precisely.

4.4.1. Choreographic Objects

Investigating the notational problem in dance, the choreographer William Forsythe has developed an interesting approach, the concept of 'choreographic objects'. Since at least the 90s, Forsythe has faced the problem of using a generalized system for representing his choreographies. For Forsythe, the ephemeral act of dancing does not allow the static observation. Its materiality is only revealed when a choreography is being enacted.

In a conversation with Paul Kaiser in 1998 Forsythe explains (Salazar, 2015) that:

> *Shelley [Eshkar] and I have spoken about it as the search for a new art form, [...] I imagine that in this new form, performance and recording and notation 'three strands of the performing arts that have always been separate' will be fused. So that you can have the notation shaping the performance, the performance shaping the recording, the recording shaping the notation, and so on. Perhaps this new process, which builds on itself, can bootstrap a new way of making art.*

And Forsythe provides a starting point:

Figure 4.1: The RAM Dance Toolkit system

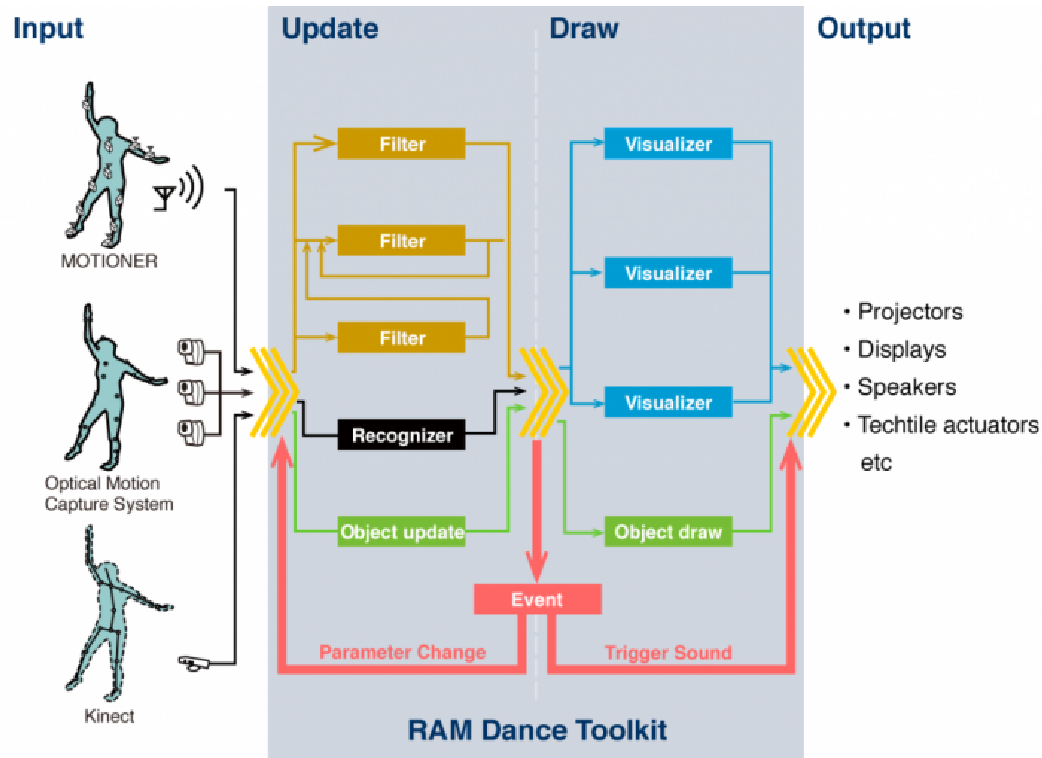


Figure 4.2: The schematic of a RAM Dance Toolkit system

> *Where I'd start is with the score. What's been missing so far is an intelligent kind of notation, one that would let us generate dances from a vast number of varied inputs. Not traditional notation, but a new kind mediated by the computer.*

For Forsythe (Forsythe, 2009) a score *"represents the potential of perceptual phenomena to instigate action, the result of which can be perceived by a sense of a different order"* . As well *"a score is by nature open to a full palette of phenomenological instigations because it acknowledges the body as wholly designed to persistently read every signal from its environment."*

Physical objects, of various types, are considered choreographic by Forsythe when they are able to enact particular behaviors and movements to people dancing. These objects reveal a choreography that is inherent to their physical materiality and to human's ability to discover and read these inscriptions. For Forsythe's every object is a source of possible enactments. Then, the choreographic object would be an equivalent to the instrument score.

For Erin Manning (2009), "choreographic objects are an affordance that provokes a singular taking-form: the conjunctive force for the activity of relation". Choreographic objects are inevitably morphophoric. This interpretation of choreography as a space of gestural affordances lead us to an enormous field of creative interpretations and phenomenological enactments. If classical music and dance was fundamentally about the use of fundamental and discrete morphophoric elements (e.g. notes, step, etc), nowadays we have adopted as natural the multimodal relation of actions. For example, cues for a dance choreography can be enacted from the visual analysis of an abstract physical object.

An example of the use of choreographic objects is the work *Nowhere and Everywhere at the Same Time, No.2* (figure 4.3) created for a solo dancer and 400 pendulums suspended from automatic grids. When activated they initiate a sweeping 15 part counterpoint of tempi, spacial juxtaposition and gradients of centrifugal force which offers a constantly morphing labyrinth of significant complexity. This setup privileges the unconscious choreographic competence induced by this special choreographic situation.

Choreographic objects have been traditionally considered a constraint. Forsythe develops an active stage, a composed reference frame suitable for performative enactments. If stage scenographies are usually representational, choreographic objects do not represent anything else than a potential to move. In the case of the work *Nowhere and Everywhere at the Same Time, No.2* , Forsythe gives a fundamental form to the space. Through this morphophoric affordance, the danceable space and all the possible movements are mediated by the inertial materiality of the pendulums. In this work, the dancing score can be found in the performative affordance of a myriad pendulums defining a composed space around them. Other examples of choreographic objects are *The White Bouncy Castle* (figure 4.4) and *The Fact of Matter* (figure 4.5).

Another part of Forsythe's efforts in the search for a notational system is the project *Motion Bank*, an online digital archive of dance scores[2]. The project was not intended for preserving original choreographies, but for collecting data acquired from choreographies in such a rigorous way that they can be reused for new creative uses. The result of this project was the development of physical and digital representations of the choreographies of various artists. For example Forsythe's *One flat thing* becomes various graphic objects out of the analysis the spatial relatioships between dancers. For Forsythe, these artifacts represent very well the algorithmic structure of the dance piece.

Another interesting question proposed by Forsythe (2009) that I will analyze later in this thesis is:

> *What else, besides the body, could physical thinking look like?*
>
> *Are we perhaps at the point in the evolution of choreography where a distinction between the establishment of its ideas and its traditional forms of enactment must be made? Could it be conceivable that the ideas now seen as bound to a sentient expression are indeed able to exist in another durable, intelligible state?*

I interpret Forsythe's insights unfolding an embodied-in-the object sort of representation, similar to that of tangible interfaces when data turns into some part of the physical materiality of artifact. In this case the original representation leaves its original status of information and becomes another trigger for enacting movement.

[2] motionbank.org/ last time accessed 21/4/2018

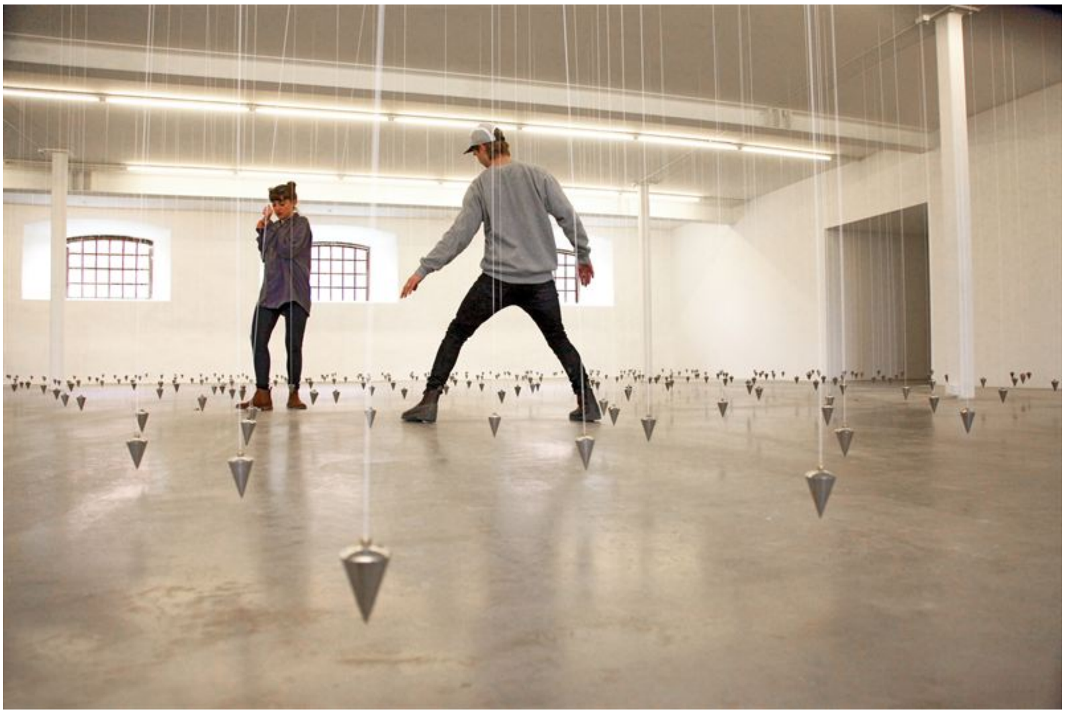


Figure 4.3: William Forsythe, Nowhere and Everywhere at the same time no 4, 2005. The Wanas Foundation, Knislinge, Sweden.

Figure 4.4: William Forsythe, White Bouncy Castle. Originally commissioned by ARTANGEL, London March 26. 1997,

Figure 4.5: Forsythe's The Fact of Matter, exhibition at MMK, 17 October 2015 — 13 March 2016

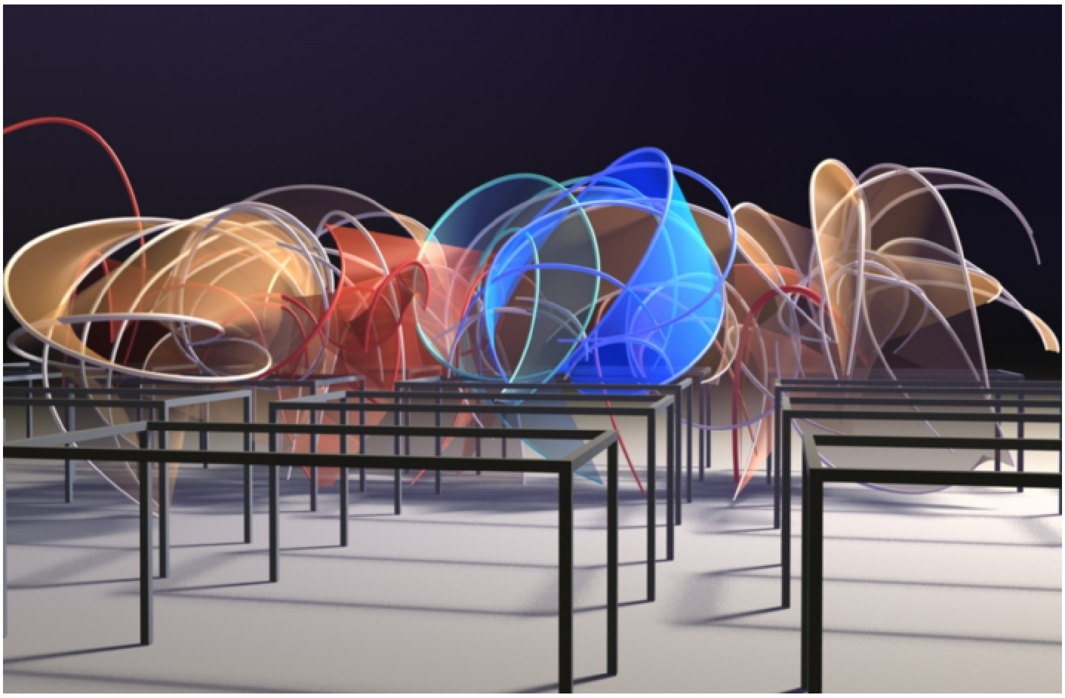


Figure 4.6: William Forsythe, Motion Bank. *One flat thing re-produced.* Graphic artifact after dance choreography.

4.4.2. Mallarmé, Dance and Notation

One of the most interesting precedents of post-structuralism was coined over the course of the 1890s by Stephane Mallarmé who dreamed of dance as "a poem unburdened of scribal accesories" (Louppe, 1994). A type of 'counter-writing' in which dance would liberate the poem from signs. Around these years, Loie Fuller would have revealed contemporary dance's representational realm to Mallarmé. For Louppe, Fuller revealed dance as a poetic state enclosing bodies into a concept.

Mallarmé unfolds contemporary dance as an art without a scribe. But more important, he shows us that contemporary dance can evolve along any trajectory, not only the physical. Can those trajectories be notated? How can one inscribe Fuller's masses of color in her *Serpentine* (figure 4.7)? For Louppe (1994):

> "*dance is not the formulation of another language. It is a transformation of representation itself. It is a trajectory between the real and the sign. This trajectory is perturbed by the presence of a living body, intervening as such. Representation supposes the absence of the object, the absence of being. Here life inhabits what will never be its icon or its index. Dance de-represents; it courses thought through zones of perception where meaning can only be invented amidst the debris of signification. To return danced movement to a site of inscription is therefore grave. It amounts to the reimposition of a figure fom which dance had slipped free. It also amounts to the reconstruction of a representational architecture whose restraints had been broken, whose frame had been burst...*".

It is often said that choreographers have fixed or written a choreography, when often not a single symbol has been drawn or written on paper. Choreography for Luoppe is above all "*a matter of an interior score, moving and intimate. This score is within all of us; it is the ensemble of breathings, pulsations, emotive discharges or mass displacements which are focused on our bodies*".

For René Thom (Louppe, 1994), classification and organization of movements in relation to a body's topology goes beyond any physiological possibility. The spatial positions of the body comprise a scope of two hundred dimensions, two hundred parameters, a number big enough to overwhelm any human in the quest for for a system of notation. And parameters are of no interest to a dancer. In conclusion, the technical classification of the body is not useful and the non-physical trajectories of dance cannot be represented. Fortunately dance exists to remind us in human computer interaction, that representation is not the most crucial factor. At least as far as when we communicate something with our movement.

4.5. The Circuit as Score

4.5.1. The Inherent Score: Origins of this Practice

The idea that a musical instrument can be considered a musical score too, or that the instrument is the score of what we play has come to the academic discussion partly in the field of interfaces for musical expression (Tomás, 2014), music notation (Maestri & Antoniadis, 2015) and performance of electronic music (Mooney, 2012). Certainly, when a performer approaches a musical instrument a number of limitations or constraints will be revealed. These characteristics of the instrument are often considered a score by virtue of its property of shaping the musical work.

During a conversation with Nicolas Collins[3], the American performer clarified how in fact this perception has a long history among performers:

> *As it happens, it's been an area of low-key speculation for me over the past year or so. It was very common in the 1970s (when I was a student) to spout the "circuit as score" mantra, but it was only recently that I asked myself, "Well, if its a true score then there should be a way to analyze it as such, rather than simply use it as a recipe to build an instrument."*

Interestingly, here Collins puts our topic on the path to research. Collins informs how for a long time the idea of "circuits as scores" was a more than an impression, it was a reality affecting musical instrument design. However, it seems that until now it was never recipient of philosophical inquiry.

It is widely considered that the creative interpretation of musical instruments as scores has its roots in the Sixties. Composers like Gordon Mumma, David Tudor or David Behrman built electronic music instruments that, once configured, can afford enough performative potentials to reveal a musical work.

[3]Email communication with the author during May 2016

Figure 4.7: Loie Fuller, Serpentine Dance (1890s)

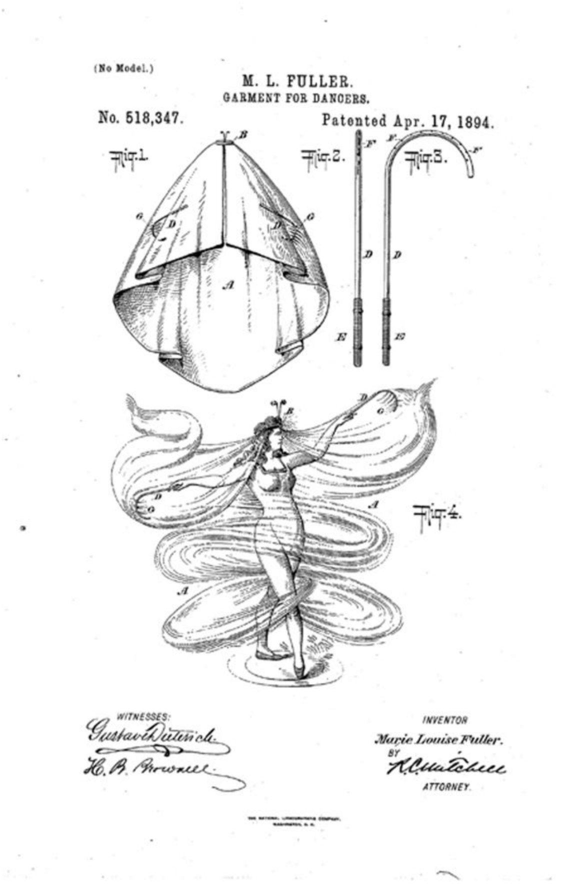


Figure 4.8: Fuller's patent for the Serpentine dance props

Alvin Lucier (1998) describes how within many of the works produced by the Sonic Arts Union *there were no scores to follow; the scores were inherent in the circuitry*. In David Behrman's Runthrough (1968) an undefined number of performers interact with the instrument by illuminating parts of a light sensitive audio mixer (figure 4.10). Conceived as an improvisational piece, Behrman allowed ample time for the possibilities offered by his circuit to unfold and explore the acoustics of the actual room used. In Runthrough performers are not provided with instructions about the type of sound sources to use, their durations, sections of the piece, etc. The general rules for performing are delegated to a player's musical exploration.

When Lucier exposes that "the score is inherent in the circuitry" we are facing the origins of a new compositional practice. Soon in the 1970s this practice originated the collective *Composing Inside Electronics* (CIE)[4]. In my opinion, it constitutes a new way of understanding instrumentality. Performers would not need an external cause, a precondition, to play the instrument. But in this case the musical work is also partially defined by the instrument which has agency to shape it. Thus, the performer's role would be to reveal instances of the musical work inherently integrated in the circuitry. This type of embedded-in-the-instrument scores I will call, like Lucier, 'inherent scores'.

It is during this decade intense research on alternatives to traditional musical notation was undertaken. In the same year, David Tudor composed Rainforest (1968). In this work, a set of sculptural speakers are suspended in the installation space and act as unique resonant loudspeakers with sound emanating directly from the sculptural objects (each having a unique sound source). In Rainforest the compositional idea is that if you send sound through materials, the resonant nodes of the materials are released. It is a kind of physical filter. Visitors are encouraged to wander around and physically interact with the work. Tudor's notation of the composition is, in a deliberate way, only a circuit diagram (figure 4.11). Like in Runthrough, Rainforest can be played without further instructions about durations, sound sources or number of sculptural speakers. Another seminal example is *Notations* (1969), a printed compendium of musical notation edited by John Cage and Alison Knowles. It is remarkable that among 269 compositions, in *Notations* we only find three musical works making use of circuit schematics as notation: Gordon Mumma's Mesa (1966) (figure 4.12), Max Neuhaus's Max-Feed (1966) (figure 4.13) and Fredic Rjewski's Piece with Projectors and Photocell Mixer (1966) (figure 4.14).

Through the concept of inherent scores it is easier to analyze the complex and mediated relationships among composers, performers and their instruments, especially in the case of electronic musical instruments. It has been often stated that electronic music instruments are open-ended systems (Tanaka, 2005) because it is difficult to define where the electronic instrument ends and the composition starts. Certainly, for defining the instrument it is necessary to implement some input to output mapping strategies. But normally these strategies are fully affected by the characteristics of the composition to which the instrument is dedicated. Remarking on this observation, Schnell and Battier (2002) described digital instruments as 'composed instruments'. This term serves to explain how our digital instruments equally "carry the notion of an instrument as that of a score" , in the sense of determining various aspects of a musical work itself. This is coherent with the fact that during the technical implementation of the instrument -hardware or software- we often incorporate many ideas of composition into the programmed system. Certainly, if circuits are configured in a specific way for their artistic use, the role of the composer, at an equidistant point among designers, composers and performers, would start with the configuration of the technical system behind the actual instrument. Indeed, performing becomes the creative exploration in freedom of the musical affordances, musical reactions or acoustic relations to the physical space performed, without the need of any kind of dedicated musical composition.

In a lecture-talk given at Oxford University James Mooney (2012) explains how within an interview to the English experimental music band *Gentle Fire* in 1970, Richard Bernas describes how he plays a custom sensor-based electronic music instrument called the *qHong*. Bernas assures that: "the instrument is the score of what we are playing". On his talk called "the instrument is the score" Mooney develops a framework where the relationships between instrument and score can be defined through shaping the affordances the instrument creates. The concept of affordance in musical instruments will be explained later in this chapter. In addition, Mooney recognizes performers as another active shaping element of the musical composition. Consequently, for Mooney performers would have a crucial role in defining the musical work. Later in this chapter I will return to Mooney's observations for proposing a theoretical framework for designing instrument-scores.

[4]CIE is a is a group of artists dedicated to live performance of electronic music using both software and circuitry designed by their own.

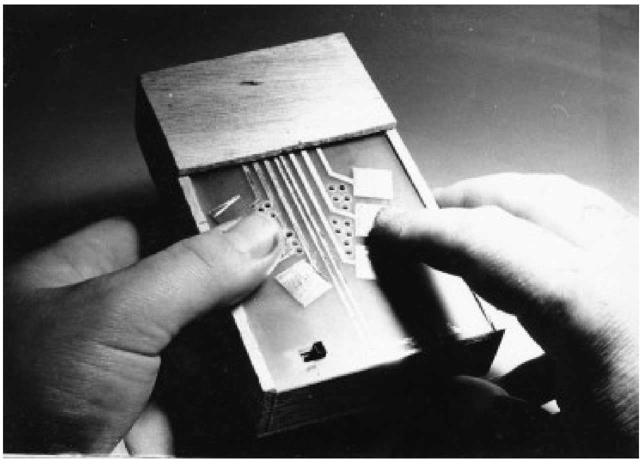
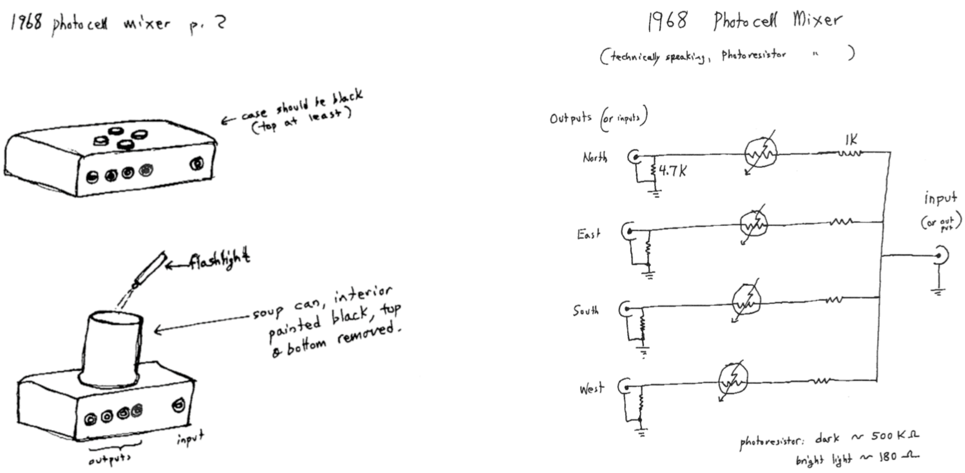


Figure 4.9: Cracklebox (STEIM)



(a) Runthrough instructions

(b) Runthrough schematic

Figure 4.10: David Behrman - Runthrough (1968)

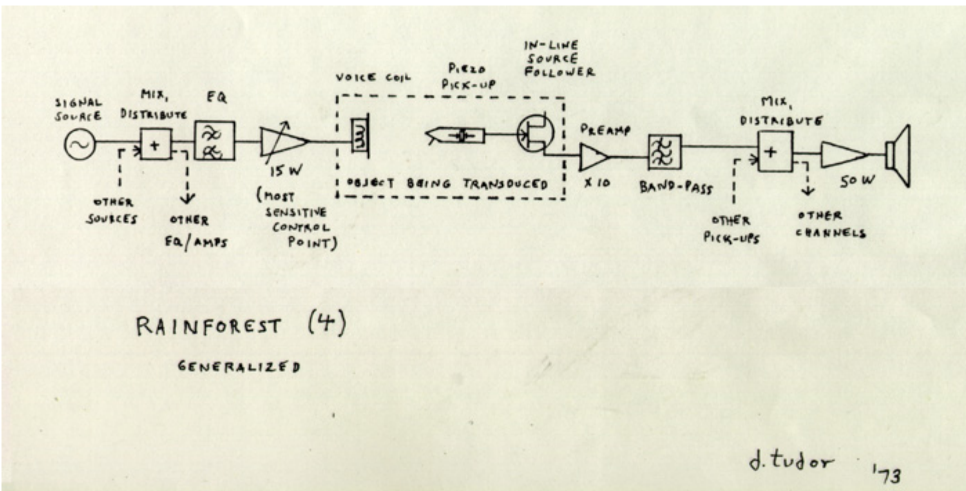


Figure 4.11: David Tudor - Rainforest

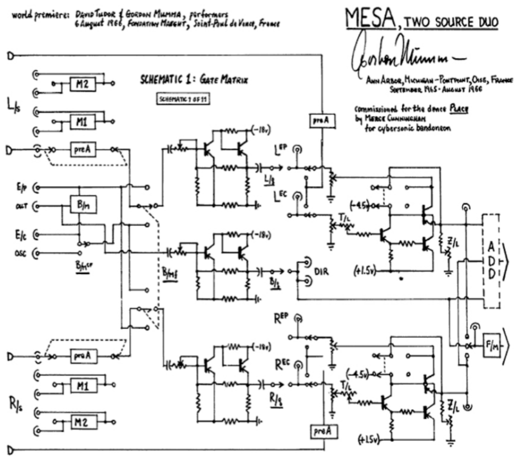


Figure 4.12: Gordon Mumma - Mesa

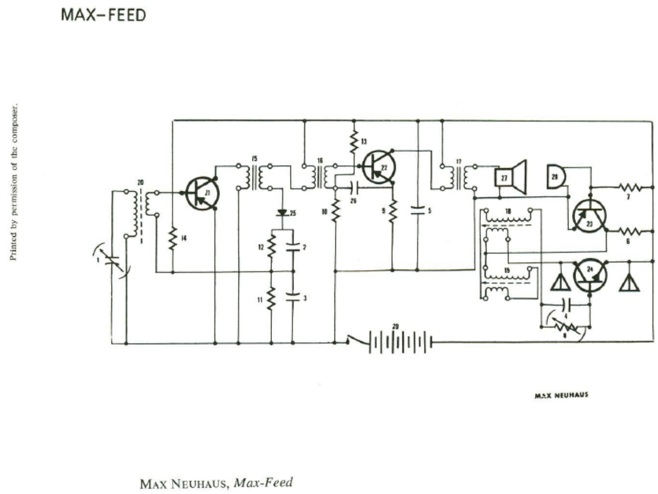


Figure 4.13: Max Neuhaus - Max-Feed

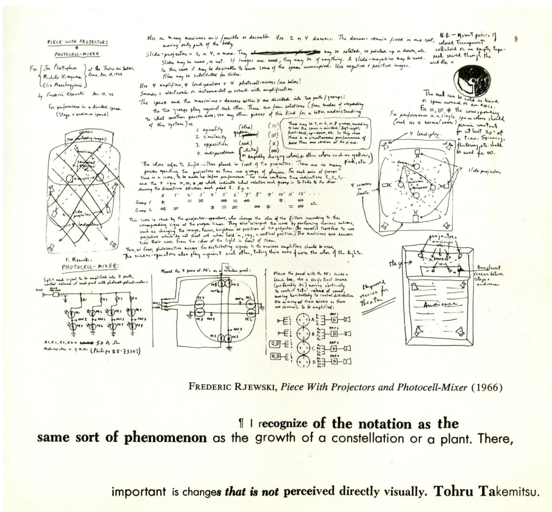


Figure 4.14: Fredic Rjewski - Piece with Projectors and Photocell Mixer

4.5.2. Composed and Self-Composed Instruments

The origins of this new musical practice -composing inside electronics- under the influence of electronics and the germinating attitudes of post-modernism, trace their roots mainly to the appearance of a new approach to instrumentality. It does not only rely on the mere evolution of an existing compositional practice. The introduction of electronic components in composition definitely changed the understanding of what until that moment was defined as ”playing”. Much of this electronic circuitry was able to synthesize sound or modify sound without the need of direct manipulation. Then, instead of playing, performers ”control” their instruments. John Fulleman, a frequent collaborator of John Cage, attributes David Tudor an ”ability to assert just enough control over the equipment to get through a concert” (Kuivila, 2001).

In 1966, during the *Nine Evenings of Experiments in Art and Technology* the first ever composition of David Tudor was performed, marking his transition from performer only to his new added role of composer. It was the premiere of *Bandoneon!*, a ’combine’ of programmed audio circuits, moving loudspeakers, TV images, and lighting. All controlled through the live sound of a bandoneon played by Tudor (figure 4.16).

From the program notes we read that Bandoneon! *"uses no compositional means, since it composes itself out of its own composite instrumental nature"*. Ron Kuivila (2001) asserts that we were in fact facing a new way of understanding instrumentality. In these self-composed instruments, Tudor acts as the interpreter and performer of a composition that "*composes itself out of these constituent parts*". Or using Lucier’s arguments, the composition is created from the inherent scores that can be found in the structural elements of a particular electronic configuration.

This concept carries extraordinary implications, the acceptance that an electronic instrument is an entity that can display itself without the need of a composer, composition or even a performer. Tudor’s aesthetics of ’composing inside electronics’ anticipated many modern concepts found in circuit bending, by DIY builders and sound hackers. But more importantly, he founded the principles of a new musical practice that has continued up to the contemporary use of digital instruments and interfaces. Like in *Bandoneon!*, we should understand contemporary digital music instruments as a combination of circuitry, software, logics and spatial relationships, exposing an inherent score that configures its instrumental and compositional nature.

It is my impression that both concepts, that of composed and of self-composed instruments, speak to the same notion but from a different aesthetic approach. For example, Tudor in an interview in 1989 explained that (Austin, 1989):

> *My experience with Alvin (Lucier) is that he approaches things more like a romantic, so that he’s an appreciator of these phenomena, and he appreciates their specific beauty. Then, when he goes to compose the work, he wants to display those characteristics, which seem beautiful to him. Whereas, in my case, I want to show it as something in nature. You know, I don’t want to display it, I want it to display itself, you see.*

We can discern two families of electronic music instruments builders. The first, those closer to Tudor’s intentions, in which circuitry is given the agency to display itself as another element in nature. This agency can inspire creative relationships and performers may respect it ’as it comes’. These instruments can even perform without the need of a performer. Many times they can evolve or generate music sensing environmental conditions, as a new kind of electronic *being-in* the world. It is the case of many Tudor’s works, like *Pepscillator* (1970) or *Untitled* (1972), or Nicolas Collins’s *Pea Soup* (1974) and *A Clearing of Deadness at One Hoarse Pool* (1982), where electronic processors are arranged in a feedback circuit to create an autonomous electronic system with “no input". As both Tudor and Nicolas Collins (the American composer) have several times commented, these instruments only need some initial excitement. It is clear that in this case, instruments display themselves.

On the contrary, the other family of builders would work under the guidelines of an opposite aesthetic principle: looking for interesting phenomena in circuits or software and instead of showing them ’as they come’, these characteristics are filtered out of anything else not related to that. Circuitry become instrumentalized towards a function. Often these phenomena are also parametrized and revealed through some musical process. It is the case of Lucier’s *Music on A Long Thin Wire* (1977) or *Music for Pure Waves, Bass Drums and Acoustic Pendulums* (1980),

How can this understanding to instrumentality and composition affect our practice with digital instruments? In fact, the same methodology can be applied to digital instruments. It is possible to navigate along the field of characteristics a digital instrument incorporates. One could read from the instrument, not only as a mere catalog of potentials or affordances, but as an inherent score. It is then a performer's decision to choose among these two possible aesthetic paths, giving a final form to the work.

4.5.3. The Inherent Score of Acoustic Instruments

Finally, an important question arises from the assumption of the inherent characteristics of electronic instruments which I have called the 'inherent score'. Is it possible to apply this notion to traditional acoustic instruments like a cello or a piano?

In 2015, deeply engaged in this inquiry, I decided to endeavor to answer this question through practice-based research. The impetus was a prior invitation from an experimental music off-space in Linz (*MEMPHIS - Nomandenetappe*) to play a concert with a pipe organ. My initial response to this invitation focused on clarifying that I was useless as an organist. Indeed, that my skills on a keyboard were very vague. Soon I discovered this was the main interest of the organizers, if I could try to find a way to play a church organ 'in a few hours'. I accepted, and the program was fixed: a virtuoso organist playing Bach, a famous electronic keyboardist playing electro-pop, and me, trying to find the inherent score of this instrument in five hours, two nights before the concert. During two nocturnal sessions of encounters with the organ, I actively explored it as an artifact with agency to suggest to me me a performance. Obviously, I rejected the idea of composing or improvising using any note. The organ's characteristics were explored from a much more open point of view. I explored the sonic and acoustic affordances of such a great instrument.

Some findings came quickly, like how different timbres colorize specific frequencies or how the bass pedal influences sound, creating beatings and amplitude modulations at very low rates. Additionally, I found many physical parts of the pipe organ interesting. They could produce beautiful noises, like when I percussed the wooden keys or the furniture supporting the keyboard. Once I recognized I had enough control over the instrument I was prepared to proceed with the concert.

During the concert, my improvisation was a real time composition where I felt the instrument itself displaying the composition it contains. I structured twenty minutes of improvisation in four parts using contrasting sonic materials, exploring very limited parameters at each part. For example one part explored the last few notes of the organ in the last octave using only two delicate timbres. Very interesting acoustic artifacts were produced in the room. Another part explored how the bass pedal could almost work as a low frequency oscillator (LFO). A third part explored frequency beating at various octaves. And the last part, more interested in the physical affordances of the organ, explored a catalog of noises through various rhythmic patterns supported by bass notes. Of course, I had to make a lot of decisions. I had to give a form to the concert, like the length of different passages, or the shape of the intensities during the performance. But many were induced from the acoustic response of the instrument in the room, like its resonating properties in a reverberant space which I had to respect. Also other decisions were totally subjective and idiosyncratic: the personal and specific way of presenting me in front of the instrument and the audience, the inspiration or flow that I established, my sonic intentions, etc.

The example above exemplifies my personal impression about the inherent score in regard to acoustic instruments. In my opinion, inherent scores can be found in any type of materiality we are committed to understand as being musical.

Finally, I want to add another example showing how much the concept of inherent score can help for describing non-traditional musical practices. In this case showing the result of playing the instrument's inherent score. At figure 4.17 we can observe Tomaž Grom's contrabass. Tomaž Grom is a contrabassist, composer, producer, pedagogue and researcher working in the field of improvised music, acoustic and digitally processed sounds. His musical practice explores actively the physical affordances of this instrument. Escaping from a traditional musical languages he explores the physical nuances of his contrabass as 'the composition'. He finds ways of playing the whole body of the instrument, bowing not only the strings but any other part of the resonant box. His instrument visualizes and gives us a map of gestural symbols pointing to the inherent score he explores during performance. The bass, after so many performances, becomes a visual and tactile score too. Grom knows where certain sonic symbols can be accessed.

4.5.4. A Material Account of Scores: Performative Materiality

In contemporary performative arts, scores can take diverse forms and materials: graphic scores, action scores, computational, sculptural, etc. Then, can anything be a score?

As I have discussed in section 4.4, the choreographer William Forsythe (2009) defends that:

> *a score represents the potential of perceptual phenomena to instigate action, the result of which can be perceived by a sense of a different order*

Following this argument, we can say that in traditional Western music a score would be the instigator of a transition from the visual to the aural via our body.

However, in the case of non-traditional notation, how does a score define the way we interpret a musical work? Forsythe explains:

> *a score is by nature open to a full palette of phenomenological instigations because it acknowledges the body as wholly designed to persistently read every signal from its environment*

Interestingly, Forsythe lays more importance on the embodied explorations afforded after the interpretation of a score and less on the original representational ideas. For Forsythe, dance cannot be analyzed as another static matter. In dance, scores would only exist in the exact moment when a performer finds the performative potential of something. And because every object can be interpreted as an inscription of something else, scores can be found everywhere.

Under this generalized vision of what can be a score, I defend that any object can have the potential of being interpreted as a score. For example, in Merce Cunnigham's piece *Solo Suite in Space and Time* (1953) the accompaniment for the dance (composed by John Cage) used a chance process in which the notes or tones corresponded to "imperfections" in the paper upon which the piece was written. Cunningham adapted this procedure for his choreography too.

Definitely our musical instruments incorporate this potential to afford interpretation. If musical instruments are perceived as scores that is essential by virtue of their physical or performative property, as well as their high evocative power to instigate musical actions. This characteristic is what has been called 'performative materiality'. The theory and application of performative materiality within Human Computer Interaction has been extensively studied by Johanna Drucker (2012). Drucker suggests that the materiality of a system *"only occurs when we action it, and only and at that moment we perceive and discover it, always distinct in each instance."*

For Drucker, *"material conditions provide an inscriptional base, a score, a point of departure, a provocation, from which a work is produced as an event."* Certainly, as Brown and Duguid (1994) have emphasized, material features, in their peripheral, evocative, and referential function, provide border resources for interaction. Jacucci and Wagner (2007) have explained why the materiality of electronic musical instruments is not only a mere support for acoustic or digital sound machines. This materiality is performative too: "material artifacts have a history, emerge as part of specific events in time and become part of performative action". Physical materiality always has a performative potential. For instance, James Mooney (2012) attributes the creation of improvisations out of found objects to composer Hugh Davies, who *"re-purposed (objects) as musical scores, in a way that any visual stimulus can be interpreted as a set of instructions that shape the development of music."*

But can these features be considered scores?

I defend that under this generalized definition of score, it is possible to interpret electronic musical instruments as scores. Not mainly from the fact of being musical instruments, but essentially from the performative materiality they engage. Finally, the inherent score would be a result of the performative materiality an instrument incorporates.

It is very important to remark that inherent scores only exist by virtue of a performer's commitment on interpreting some type of materiality as performative, being of physical, virtual or mixed origin.

Additionally, I may clarify that the physical (tangible) materiality is not the only one in charge of shaping the inherent-score. Nowadays, a great part of our digital instruments are based on graphical user interfaces (GUIs). In this case, their performative materiality cannot be expressed through physical artifacts. But from Thor Magnusson's research (2010) we understand better how the inherent affordances and constraints of the constituent elements of a graphical interface mediate on screen-based musical instruments. In a certain way, GUIs and tangible user interfaces can be unified by the theory of performative materiality.

And a final question which is often discussed at my presentations: can we give the name 'scores' to inherent scores?

A recursive question at various presentations and lectures has been, why do you call it 'score' if in fact it is so different from what we know as a score? My answer to this question has been also recursive. First, I have clarified that many musicians before me have called it the 'instrument-score'. I share this terminology because I think that it really helps to communicate the concept it carries to both specialists or newcomers. I have detected although that it creates certain tensions among the musical community. I am convinced of the utility of traditional scores. I am myself a musician who daily reads pentagrams and plays the music inscribed on them. Defending the existence of inherent-scores does not mean that scores are old-fashioned. In my opinion calling them inherent-scores or instrument-scores just gives a name to an artistic and philosophical project. It gives a phenomenon a name, serving it to explain better the message as well as for developing new creative relationships.

4.6. Formalization as Notation

4.6.1. Preliminary Questions

The idea that an instrument can be also a score affords creative relationships. But, it also carries very substantial questions waiting for some formalization. For example:

- if an instrument is a score, is it true that a score is an instrument too?
- If an instrument is a score, is it possible to separate instrument and score?
- Where can we physically find the inherent score within the instrument's body?
- How is an instrument-score interpreted or shaped by its performers?

For answering these questions, the theory of notational systems can help us. Along this section, the theories exposed are built on Nelson Goodman's notational principles, taken from his opus *Languages of Art* (1968). The hypothesis and research questions are:

- If inherent scores are scores, it is because they manifest their symbols to their readers.

What are those symbols?

Nelson Goodman' s Languages of Art has been described as one of the most important books against the persistent tendency of philosophy to create dualisms:

> *Like Dewey, Goodman has revolted against the empiricist dogma and the Kantian dualisms which have compartmentalized philosophical thought. . . . Unlike Dewey, he has provided detailed incisive argumentation, and has shown just where the dogmas and dualisms break down. (Richard Rorty, 1979)*

4.6.2. Notational Systems

A symbol in a notational system refers to something (literal, metaphorical, indirect) and its interpretation depends on the system of symbolization. Furthermore, the sort of symbol it is -linguistic, musical, pictorial, diagrammatic, etc.- will be by virtue of its belonging to a specific system. A symbol system, say, the English language, consists of a symbol scheme -i.e., of a collection of characters with rules to combine them into new, compound characters associated to a field of reference. For Nelson Goodman, symbol systems are notational when:

1. the characters are correlated to the field of reference unambiguously (with no character being correlated to more than one class of reference, or compliance class)
2. what a character refers to -the compliance class- must not intersect the compliance class of another character (i.e., the characters must be semantically disjoint)
3. it is always possible to determine to which symbol an item in the field of reference complies (i.e., the system must be, semantically, finitely differentiated).

Languages like English have a notational scheme but fail to be a notational system because of ambiguities (in English, cape refers to a piece of land as well as to a piece of clothing) and lack of semantic disjointness (man and doctor have some referents in common).

Figure 4.15: Gentle Fire playing the qHong

Figure 4.16: David Tudor - Bandoneon!

Figure 4.17: Tomaž Grom's contrabass, full of traces, visualizes the inherent score its performer plays.

Finally, let's apply these definitions to our artistic field. Sculptural or pictorial systems fail on both syntactic and semantic grounds so they are non-notational systems. Within Goodman's approach, a musical score is a character in a notational system only if it determines which performances belong to the work and, at the same time, is determined by each of those performances. Given the notational system and a performance of a score, the score is recoverable. This is ensured by the fact, and only by the fact, that the language in which a score is written must be notational, so it must satisfy Goodman's stated requirements.

4.6.3. Inherent Scores Notational Scheme

For bearing out the notational scheme of an inherent score we need to examine its symbol system and rules. If musicians consider that instruments, through the active exploration of their constraints and affordances, are scores too, then some kind of symbols and rules must exist. In this section we will first clarify where these symbols can be found. This analysis will help us to conclude if this system is notational or not.

It is important to remark that our task here is not showing if it is possible to create a Goodman's notational system for electronic instruments. Our focus is on understanding what kind of notation is the one of an instrument, the notation of an inherent score.

The initial and probably main complication consists in the total absence of rules within the field of reference. Normally, within instruments materiality (i.e. a cello), elements are not discretized. One could in principle touch the instrument without constraints and play all the physical components, and not only the ones producing musical notes. Therefore the space of affordances against materiality is continuous. For this reason, traditional Western musical notation establishes a radical discretization on this space of affordances: playing musical notes.

For example, in Western musical notation, the space of frequencies has been entirely discretized with the use of notes and scales. Or as another example, among all the possible sounds that i.e. a cello can produce, our traditional Western notation has filtered out all kind of noises. It is centered on the production of tones.

Additionally, within this continuum of materiality, if a constituent is defined as a symbol or not, it is a decision left to the actual performer of the inherent score. Goodman explains that these kinds of systems are *analog systems*. For every character there is an infinite amount of others referring to the same mark. We cannot possibly determine that the mark does not belong to all other characters. A system like of this kind is obviously the very antithesis of a notational system.

4.6.4. Non-Notational Systems and Musical Graphs

In the search for the defining properties of an inherent score and its symbols, there is a clear lack of terminology to apply here. For this purpose, I propose first analyzing the notational scheme of graphic scores, which nowadays are an accepted format of scores while they have been extensively studied within the ontology of music. From these results it would be easier to extrapolate some parts of our analysis. Although graphic and inherent scores are not the same thing they share many instrumental similarities. Later in this chapter we will explain some interesting differences applied to instrumentality.

Graphic scores appeared in the musical avant-garde of the mid-20th century as a way to release composers from the constraints of writing their music using the traditional Western notation. Consequently the representation of a musical idea opened to the personal and subjective selection of graphic figures that could inspire new and imaginative ways of interpretation. One of the first examples of graphic scores is Earle Brown' *December 1952* (figure 4.18).

Are graphic scores notational systems? Earle Brown did not specify how his graphical symbols should be interpreted. Therefore, depending on just how the symbols are interpreted, syntactic and semantic disjointness may be lacking. In cases like *December 1952*, composers are using systems that only slightly restrict the performer's freedom to play what and as he or she pleases. The system furnishes no means of identifying a work from performance to performance. Furthermore, we can say that the system of *December 1952* is non-notational (like inherent scores).

An early but fundamental contribution describing, illustrating and classifying the symbols used by modern composers was Erhard Karkoschka's *Notation in New Music* (1965). Karkoschka developed the following typology of musical systems (I am using here Karkoschka's literal definitions):

- Precise Notation: where every note is named
- Range Notation: where for example, only the limits or the ranges of notes are set
- Suggestive Notation: where at most relations of notes, or approximate limits of ranges, are specified.
- Musical Graphics

Certainly, musical graphics are non-notational because they lack both syntactic or semantic articulation. We should note Karkoschka's intuition in not calling them musical graphics notation.

In Languages of Art, Goodman explains that Musical Graphics are another example of analog systems. For every character there are an infinite amount of others referring to the same mark. I must state that musical graphics -as they were coined by Karkoschka- are non-notational systems but they are still scores. The implication of classifying traditional Western scores as notational systems and musical graphs as non-notational does not restrict us from saying that *December 1952* is a score. The appreciation of -what is- and -what is not- a score has changed historically with the introduction of new musical poetics. Finally, it is a fact that Earle Brown's *December 1952* has inspired hundreds of musical realizations. Thus it must be a score.

An important property of graphic scores is that they are usually not created with the interest of substituting a ”normal” score. As discussed by Rebelo (2015) or Vlagopoulos (2012), and by Earle Brown himself in his seminal *On December 1952* (2008) , graphic scores are usually created as improvisational scores. They appear with the mere intention of guaranteeing an unique way of performing. But graphic scores are not ”the performance”. Furthermore, the graphic score is a trigger for the interrelation among performers in the rehearsal phase, if it exists. A graphic score is a provocation to solve a musical challenge with our own poetics of communication. This strategy would be congruent with the practice of musical improvisation. For suggesting an open improvisation, certainly a non-notational system can be a very valid creative trigger. Any effort in the direction of discretizing the system of symbols used during a performance (e.g. with a notational system) would lead to discretization of the musical response as well.

Therefore, and updating Karkoschka's typology, nowadays our musical graphs can adopt any form and any dimension. It is remarkable that historically a large percentage of these graphic scores have mainly used paper as their medium, in an inexplicable and unnecessary conceptual analogy to the format of the traditional score. We had to wait until the advent of digital interfaces to see musical notations that can be interactive, dynamic, fragmented or non-linear.Examples would include the animated scores of Miyashita [(2003) or the three-dimensional scores of Berghaus (2011).

4.6.5. Instrumentality of Graphic and Inherent Scores

Graphic and inherent scores are non-notational systems manifesting interesting differences in their instrumentality. The first difference we can observe is that graphic scores exist in physical or virtual forms. They can adopt diverse forms. They can even be virtual or dynamic. But they are always perceived through our senses and they can be analyzed before we start playing the instrument.

On the contrary, inherent scores display themselves through the creative exploration of the constituents of a musical instrument. And this happens only at the moment of performance. Therefore, inherent scores cannot be formally understood as objects. They are a purely embodied activity enacted from the interaction of a performer with an instrument.

Interestingly, when an author or a performer declares that a visual composition should be considered as a graphic score, the original graphic object extends itself towards music in a non-physicalway. It acquires a new abstract dimension able to enact musical compositions. The graphic object becomes a new embodied category, in a similar way to inherent scores.

However, conceiving music from a graphic score demands some rationalization. Performing a graphic score means giving visually perceived content a musical meaning. As we remarked, graphic scores do not substitute traditional scores. They are a kind of musical provocation.

But this translation from the visual to the aural needs an interpreter, be it an individual, a collective or even a technological device. To this reason many external elements can be added: in-situ possibilities, sociocultural influences, etc.This plethora of information makes the realization of a graphic score an unique musical work, intimately connected to its performers.

On the contrary, there is nothing to translate when performing inherent scores. The decision-making process during performance is normally intimately connected with our creative exploration and the resulting sonic reinforcements. Understanding the specific performative potentials of an instrument is a posterior process. It happens once we have already started playing. The performer of an inherent score does not need a translation from the physical to the aural. Even more, many times the instrument can sound without our interaction.

Therefore, the performer's task is closer to the role of embodying and modifying this continuous flow of sound. Indeed, many times, these sonic affordances are not predictable. They can change or evolve during a performance with the conditions of the room, the situation of the performer or the instrument configuration. In contrast, the sounds created when playing a graphic score are usually produced after some cognitive process of interpretation from the graphic elements found in the score.

4.6.6. The Form of an Inherent Score: A Hybrid Art Form

Another substantial problem is the artistic form of the musical work that an inherent score affords. And how it functions in relation to other visual or physical elements existing in the instrument. Acoustic instruments are primarily defined by their physical materiality. Electronic music instruments consist of hardware and software. Both the visual and physical parts of an instrument can be specifically designed to infer some kind of limitation or, in other words, to shape the musical work. Inherent scores are the combination of existing forms resulting in a kind of hybridization.

Within the ontology of arts, philosophers have studied the identity or nature of the art object in physical arts (painting, sculpture, etc) and in the so called non-physical arts (mainly music and literature). In the latter, there is no particular ”thing” to be considered the artwork itself. The score of a musical sonata or the printed paper of a novel are not considered the art object itself but its representation.

Some authors like Croce (1992), have suggested that music and literature are purely mental. In philosophy, there is a wide-spread consensus that a musical work is a variety of abstract objects, a structural type or kind. Scores are the mere representation of the musical work. They are the symbols to concatenate during a performance plan.

But scores do not make or produce sound. Thus, they cannot be the musical work. The musical work is what we actually hear when the score is played.

Introducing the wide debate on the identity of the musical work would require a longer extension. But because there are artists claiming that their instruments are scores, we need to at least introduce the problem of defining a musical object. It is now my intention changing focus to talk about clarifying the form of inherent scores

An interesting approach for deducing the form of inherent scores can be taken from Jerrol Levinson's theory of hybrid art (1990). Levinson notes that not all kind of arts are pure, some are hybrids. Examples like kinetic sculpture or interactive audiovisual installation show us that independently of their complexity, these forms of art show elements of multiple art forms. A kinetic sculpture would be the encounter of sculpture and dance. An audiovisual installation would consist of multiple media: cinema, music, sculpture, etc. On the contrary, we perceive a traditional figurative painting as an instance of its category.

However, Levinson asks himself if even pure forms of art have been hybrids at some moment in the history of humankind. For Levinson the hybrid status is primarily a historical thing. An art form is hybrid ”only in virtue of its development and origin, in virtue of its emergence out of a field of previously existing artistic activities and concerns, two or more of which it in some sense combines”.

For us, the most important feature that this theory exhibits is that if an art form is hybrid then it must be understood in terms of the combination of its original components. Levinson extends his theory of hybrid art to the combination of existing art forms and technological processes. For example, laser sculpture, computer music, computer graphics, video installation, etc would be a result of this combination. Thus, Levinson features clearly the plausibility of new art species creation from the hybridization with technologies. The resulting possibilities for this process are three: juxtaposition (or addition), synthesis (or fusion) and transformation (or alteration). In all three of these cases of process, Levinson explains that the hybrid combination of art form A and B to produce C, will change the properties that A or B exemplfied in the joint context. These properties would be relative to what one of the original forms would exemplify on its own, or at least affect the prominence of what each exemplifies after combination.

Inherent scores are good candidates to be considered hybrid forms. At this stage of the explanation, we could describe them intuitively as the mixture of a musical work and the performative materiality enacted from an embodied interaction with physical or virtual objects.

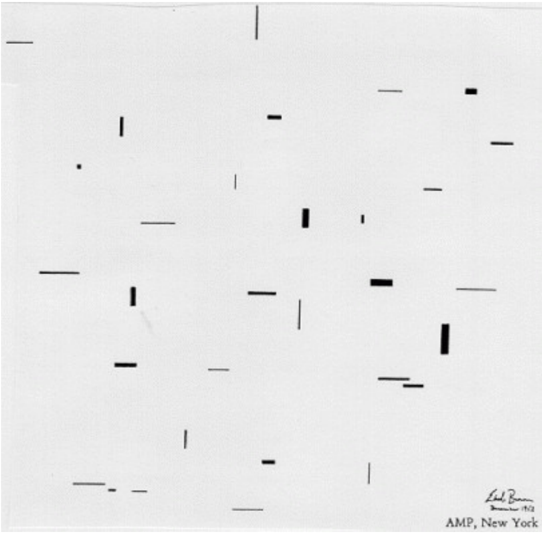


Figure 4.18: Earle Brown - November 1952

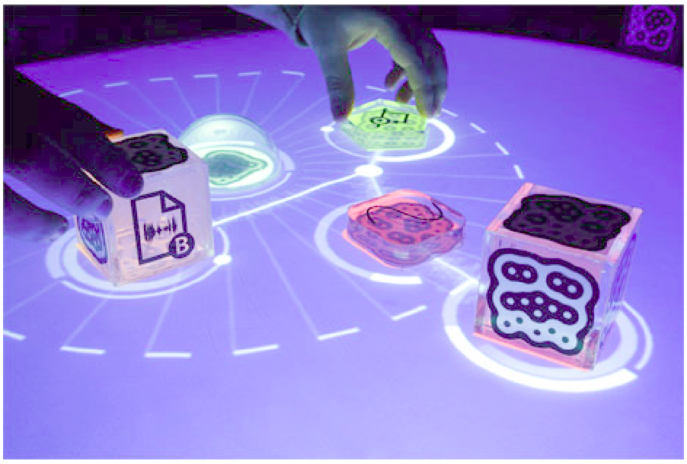


Figure 4.19: Extrinsic Symbols of a reacTable Interface are those digital representations incorporated to the physical artifact.

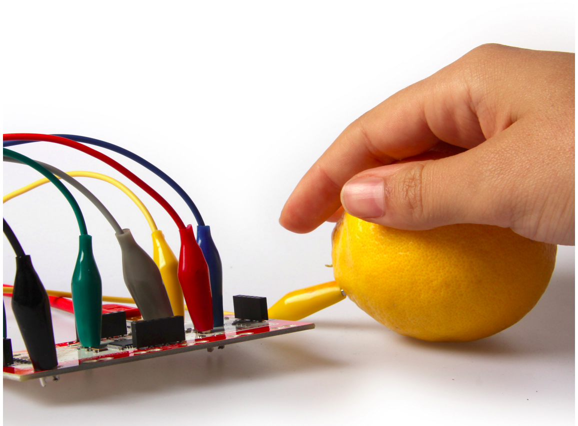


Figure 4.20: Intrinsic Symbols of an interface, the physical affordances that the interface offers to its performers.

As we have discussed before, artifacts do not change their physical configuration if they are approached as inherent-scores. The consideration that an instrument is a score is produced at the symbolic level. Therefore, this hybridization affects the symbolic apparatus of the instrument (that I have described in chapter three), extending its symbolic realm towards the realization of a particular type of embodied practice.

4.6.7. Inherent Scores: Typology of Symbols

For the analysis of this hypothesis of hybridization I suggest here a typology of symbols that we can identify within our musical instruments. Due to the important role that technology holds within many of our actual digital musical instruments, I will focus the attention on those instruments incorporating some kind of computational system fundamental totheir configuration.

The first type of symbols are intrinsic. These would be inherent to the affordances of the physical or virtual interface. Furthermore, we talk about intrinsic symbols when their affordances determine various features of what is aurally enacted. For example, a Theremin affords playing glissando and a reacTable's round form affords collaborative performance. In the case of virtual systems, the latency of response of a network protocol implemented in Pure Data affords performing with this delay as temporal material. Through this specific intrinsic property, the instrument's intrinsic materiality shapes the particular ways the instrument can be played.

The second type of symbols are purely extrinsic. These would be mainly representational. They give us information about the computational status of the musical instrument being played. For example, the visual composition of tokens on a table-top interface like a Reactable 2005 (figure 4.19) is an example of extrinsic symbols. They represent the status of the algorithms anuser is running. In this case, the systems affords less on the materiality of these tokens (e.g. form, color, material, texture, etc.).If instead of using these original acrylic tokens we use other ones made of wood, the sound mapping or the overall sonic output will not be affected.

We can find both types of symbols within instruments and combining them is possible. For example, a modified reacTable incorporating the same type of representational tokens but also taking into account the physical properties of these tokens. Measuring the stretch force applied to a token made of rubber could modulate the volume of an associated sound synthesis. In this case the extrinsic composition of tokens can be affected by the properties of the intrinsic physical materiality.

4.7. Preliminary Conclusions on Inherent Scores

In the previous sections, I have described a possible theoretical framework for defining inherent-scores. This hybrid art form, the inherent score, would be the mixture of a musical work and the performative materiality enacted from an embodied interaction with physical or virtual objects. The result is a new kind of synthesis.

The existence of this hybrid form would explain the perception described by many performers of playing a score when they improvise with their instruments.

Certainly, performers have the perception of playing a specific form. Inherent-scores are perceived as the artifact's performative potential to inspire specific embodiments. Certainly, the result of this fusion alters the perception of the original forms. Instrument's materiality gets extended towards a compositional object, acquiring a new symbolic nature. In the same way, the performative materiality ingrained in the embodiment with the artifact gets reconfigured, it manifests a new kind of order.

It is now possible to answer some of the preliminary questions:

- When an instrument is perceived as a score, our question was if one part can be separated from the other. Having concluded that an inherent score is a new abstract object synthesized from the fusion of two already existing ones, I can now assert that this separation is not possible. There is nothing to separate. The instrument still exists but a new abstract musical object appears on stage as a symbolic attribute in the system (of its apparatus). There is no possibility of explaining the inherent score to others without experimenting with the instrument itself. Additionally, this inherent score is eminently a subjective concept, embodied in interaction, that can be interpreted differently by different performers.

- Another question formulated was: if an instrument is considered as a score, would the score be an instrument too? Every artifact affords performative potentials to be perceived as a score. On the contrary, scores are representations of musical objects which do not feature sound production. Therefore, generally scores are not perceived as instruments.

4.8. A Framework for Composing Inherent Scores

4.8.1. Affordances and Constraints of an Instrument

For composing the inherent score embedded within every instrument we will follow the principles proposed by James Mooney (2012): shaping its ranges of affordances and constraints and designing the reference frame.

Affordances, as they were defined by the psychologist J.J.Gibson (1966), are "the properties of the relationship between the environment and an agent". In our case, the environment would be the musical instrument as a reference frame. The agent would be a performer. Between agent and environment, infinite relationships can be created, but the potential of performing some events are less probable than others. Sometimes even impossible. A violin affords playing sounds, but it does not afford traveling. A remarkable characteristic of affordances is that they are highly dependent on the reference frame where they are inscribed. For example, cultural contexts or personal backgrounds. What an object affords to a person can be different to another, even living in the same sociocultural environment (Norman, 1999). Therefore, affordances could be essentially subjective perceptions influenced by our social constructs. And this condition can reach the maximum in the case of performative arts.

The study of musical interfaces from the perspective of affordance and constraint has been studied by Thor Magnusson. The author explains (2010) how Margaret A. Boden defines constraints as one of the fundamental sources for creativity:

> *Far from being the antithesis of creativity, constraints on thinking are what make it possible. ...Constraints map out a territory of structural possibilities which can then be explored, and perhaps transformed to give another one.*

This assessment points to the potential of constraints as a trigger for creative enactments. Constraints would be characters in the performative materiality of an object, be it physical or virtual. Within the discipline of improvisation with electronics, the instrument's affordances take the important role of shaping the way an interface is played through its unique constraints.

As we have seen before in this paper, this inherent score can afford interesting performative enactments. Mooney (2012) supports the idea that a musical instrument can be designed from the perspective of which kind of musical relationships it affords. Also, Mooney identifies the possibility of defining the spectrum of musical affordance. This can be achieved by establishing a range of musical practices the instrument can support. For example, although very complex textures of sounds can be played and controlled with a Reactable, it would be rather difficult to play *Mary had a little lamb* with it. It is then noticeable that the spectrum of affordance is not comparable to the difficulty of playing the instrument. Affordances are fully mediated by the embodied relationship between instrument and performer. Even if the performer knows the musical notes of *Mary had a little lamb* it would be impossible to play them correctly on a reacTable. Therefore, an instrument's performative affordance and other types of affordance, like musical affordance, expressiveness affordance, sonic affordance etc do not necessarily match.

4.8.2. Performer's Embodiment with the Instrument

As we have seen, performing with an electronic music instrument means the creation of embodied and meaningful structures between their inherent scores and their enacted audiovisual outcomes. But these are always mediated and shaped by our embodiment.

This evidence was used by Mooney (2012) to introduce intuitively the 'performer' as another shaping parameter of the musical work. If the instrument is the score, then many of the decisions taken, although shaped by the instrument, will be result of a performer's freedom to act. Although Mooney did not develop this argument further, he introduced another variable in the equation: the performer. In particular, a performer's reference frame, embodiment and intentions.

The sociocultural context of the performer, even the actual mental conditions at the moment of approaching a performance will shape its result. For example, the expressiveness of a first musical approach with a reacTable can depend highly on knowing the elements of computer music in advance (what is a synthesizer, a sequencer, etc). Then, more objective factors connected with the type of embodiments created can definitely conduct the musical outcome. For example, if playing an electronic musical instrument well depends highly on the ability of scratching, but this cannot be done by a specific performer, all the designed performative affordances will be hidden. Thus, we can conclude that design models centered only on defining constraints and affordances must include 'the performer' as an central parameter.

4.9. Conclusions and Contributions of this Chapter

This chapter has contributed to another key element of this thesis: notation. Understanding it well as another type of technology was mandatory. I have also explained the mechanisms of creating vocabularies for notation. I have discussed why dance does not actually need a generalized notational system to produce choreographies. Yet, dance and live electronic music are at odds with notation because there is no intention of limiting among all bodily interactions available.

These are the main contributions:

- I defend that the duality instrument vs. score does not exist. Both instruments and scores are part of the ecology of music and they do not feature a complementary nature: many aspects of composition have informed instruments and vice-versa.
- I build on Lucier's notion of 'inherent scores', Gentle Fire's 'instrumental score', The Hub's 'software as score' and Collins' 'circuit as score mantra' in order to defend the existence of a dual perception of instruments as scores, which has its origins in the decade of the 1960s.
- I have explained that 'inherent scores' are a consequence of the active embodiment with an instrument, a way of exploring its performative potentials through an embodied activity.
- I defend that any artifact has the potential of being interpreted a score.
- I have shown why acoustic instruments also incorporate an inherent score. I have described how I turned an invitation to play an organ concert into a practice-based research project which helped me to understand the inherent score which every acoustic instrument has.
- Notation in dance is studied in order to gain experience on well established cultural practices. Forsythe's choreographic objects are described and discussed in the context of a dual perception of artifacts as scores. Mallarmé's description of dance as a poem disregarded by scribes is used to demonstrate the impossibility of finding an unifying notation for all types of musical interfaces.
- I propose an analysis of the notional scheme of inherent score based on Goodman's notational systems. Inherent scores are analog systems which cannot be notational. I have compared them to traditional scores and graphic scores.
- I propose that inherent scores feature two types of symbols -intrinsic and extrinsic- which can be intuitively found and interpreted by performers. Intrinsic are physical and virtual aspects affording an action. Extrinsic are aspects representing symbolic information.
- A framework for designing inherent scores/interfaces is described making use of the notions of affordance, constraint and personal embodiment. Thus, this framework opens the door to explore materiality in a much broader way in order to design the instrumental and notational aspects of digital instruments.

5

Tangible Scores

"The final source of any sound, and thus of the musical sound, is a vibrating body. [...] So, the less foreign bodies are interposing themselves between the human body and the vibrating body or, the longest the time during which the human body controls the vibration is, the more the created musical sound will be immediate and, so to speak, human."

Belá Bartók, The mechanical music, 1937

This chapter describes the conceptualization and physical implementation of *Tangible Scores*, a novel paradigm for musical interface design which is also the central artifact of my artistic research production.

5.1. Tangible Scores

5.1.1. Objectives

Inspired by the mediated relation between musician, instrument and musical performance, I decided to design a novel instrument which could emphasize the notion of inherent scores. Hence my research objectives were twofold:

- Working on the extension of the inherent score concept towards creating a new digital instrument which could incorporate some kind of musical notation within its physical configuration.
- Studying if while adding a tangible score to the physical layer of this instrument, I could conduct or suggest specific types of user's interaction with the instrument.

Therefore, as a proof of concept I decided to build a tangible instrument that we (in fact Martin Kaltenbrunner proposed it) called *Tangible Score*.

5.1.2. Definition

I define a tangible score as the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements.

A composer could then conceive a musical idea and incorporate it to the instrument body encoding it in a physical manner. A performer can explore the tangible score and navigate through its materials as another element of the inherent score that it contains.

A tangible score determines only the gestural constraints and as such does not define any sonic results. Therefore, just as with a traditional score, it encodes a musical intention and delegates the decoding part to other agents. A tangible score can make use of any material and can extend to two or three-dimensional artifacts.

In a tangible score the musical composition and its representation is integrated into the instrument at the physical layer. Making use of a physical score we can:

1. Inspire or conduct a musical performance. As it is incorporated physically within the body of the instrument, a performer can be intimately inspired, conducted or constrained without looking at any other score.

2. Define and suggest the production of physical gestures through the instrument's physical affordances. The instrumentalist will approach the performance in different ways depending on the physical configuration of the instrument.

3. Modulate and design the control signal that feeds the sound synthesis. The tactile activity will be used as the expressive input for sound synthesis. The material qualities of the interface will define and modulate this flow of information.

On a technical level a tangible score can make use of processes for the analysis of gestural behaviors of a performer. Although the technical implementation chosen during this thesis uses the acoustic analysis of the gestural impact on the instrument's surface, other additional or alternative techniques, such as computer vision, capacitive sensing and further sensing modalities may be incorporated.

5.1.3. Graphic Scores

During the process of looking for a physical design language for a tangible score I got inspired by graphic scores. Graphic scores appeared in the musical avant-garde as a way to release composers from the constraints of writing their music using the notation of a traditional score. Consequently the representation of a musical idea opened to the personal and subjective selection of graphic figures that inspire new and imaginative ways of interpretation.

In the world of improvisation, graphic scores are often used for structuring the evolution of the performance. They are also useful for the analysis of electroacoustic music and as a parallel notation for composers. We can thus consider that graphic scores are living in the same musical environment as our new interfaces for musical expression. Graphic scores are useful when traditional notation fails, as with complex or novel musical conceptions including indetermination or extreme parameterization of the musical variables.

Additionally, the musicological importance of graphic scores is that we can sometimes have a closer approach to the original ideas or aesthetic intentions, although other representations are also possible, like using texts and symbols or even electronic circuits, as we have seen in previous sections. For instance, in an interview with Victor Schonfeld (1972), David Tudor is critical of the notation of Stockhausen's *Klavierstucke* (1952):

> *All his works of those days were composed as theoretical forms, structures dealing with numbers, and whenever it can to making a score he had to translate his original material into musical form. Many's the time I would ask him why he didn't publish the original idea instead of the realization he had made from it, but he always refused.*

Graphic scores have been traditionally hand-written or painted by composers so we can extract valuable information about the work, just like from traditional music manuscripts. It is interesting to note that graphic scores can adopt any form and any dimension, although historically almost all of them have been published on paper. This is an inexplicable conceptual analogy to the traditional format of the score. We had to wait until the advent of digital interfaces to see musical notations that can be interactive, dynamic, fragmented or non linear. Examples include Nathalie Miebach's sculptural data scores (figure 5.1) and the animated scores of Ryan Ross Smith (figure 5.2).

With the aim of exploring and extending the field of graphic scores, I decided to use them extensively in my first conceptual experiments towards the production of *Tangible Scores*. Although my current implementations are therefore physical representations of graphic scores, this approach has to be understood as the further evolution of one possible score concept into the physical domain. Future implementations may extend to the idea of sculptural scores.

Figure 5.1: Hurricane Noel. 3D Musical Score of the passing of Hurricane Noel through the Gulf of Maine, Nov 6-8, 2007. Meteorological data comes from two weather stations in Hyannis, MA and Natashquan, Quebec as well as an off-shore buoy anchored on George's Bank in the Gulf of Maine. Data translated includes wind, air temperature, barometric pressure, wave height, cloud cover, historical hurricane data and solar azimuth.

Figure 5.2: Ryan Ross Smith Study no. 43 for 5 players. Each player is assigned one of the 5 single-line staves. Each player predetermines two sounds, one short and percussive, the other sustained with a soft attack. Players must be able to play their respective sounds simultaneously, as well as separately. Each time the attack cursor crosses an event node, play the short, percussive sound once. Each time the attack cursor crosses a horizontal line, play the sustained, soft attack sound. This sound should begin as the circle crosses into the line (left side), and end as it passes it (right side).

5.2. Physical Embodiment of Digital Information in Tangible Scores

One of the core features within the genre of Tangible User Interfaces is the embodiment of digital information within physical artifacts, which can be shaped through the direct manipulation of the interactive object itself (Ishii, 1997). My design approach for *Tangible Scores* borrows several concepts from this field and merges them with ideas from graphic scores and musical instrument design. As Verplank (2009) has suggested an inverse relationship between Piaget's development psychology (1953) and the history of human computer interaction, we can equally observe a similar development in the history of musical score systems.

While a traditional score defines a highly symbolic notation language for the description of a musical system, a contemporary graphic score relies mainly on an iconic language that couples a rather versatile visual representation language with a corresponding musical expression. Therefore the analogy of a tangible score or a physical representation of a musical piece and performance practice seems to provide an appropriate method for an embodied musical encoding. This unification of score and instrument provides the representation and control within a single musical artifact, fully concentrating the performer's attention on the interaction with the musical composition in a physical form.

5.3. Design Aspects: Design Objectives of Tangible Scores

In order to facilitate the design process, we have established some prior constraints to our definition of tangible scores:

- Diversity. A tangible score design should promote a diversity of forms and materials. There is no unique identity for tangible scores and they can be designed in any color, form and material.
- Replicability. A tangible score should be easy to share, copy and replicate, transform or adapt. This suggests the use of rapid prototyping technologies such as 3D printers, CNC machines or Laser Cutters.
- Modularity. Traditional scores are modular, in order to allow the use of them in parts. Tangible scores should offer the possibility of being extended or reduced.
- Embodiment. The musical idea should be embodied into the instrument as its physical representation It should be defined through its materiality but not affected by the used technology.
- Discrete and Continuous Control. Our instrument should incorporate the qualities of an acoustic instrument, with discrete and continuous dimensions.
- Intimate Expression. The instrument design should promote an expressive performance, allowing a big dynamic range of gestures, from subtle tactile interactions to more energetic behaviors.

5.4. Design Iteration Loop with Tangible Scores

The iterative process of design and evaluation is explained here. This process is characterized by three phases.

For each iteration:

1. Selection of the number of design patterns to study, adding, removing or combining them: what do I want to change.
2. Taking decisions for each of the design patterns: how to act.
3. Implementation of the artifact
4. Comparative evaluation taking into account my design objectives: has it worked well?

Each iteration can produce a new artifact or combine new parameters into precedent versions. Every artifact has been evaluated through:

- Inside of the lab evaluation: if the objective, functionality or intention is fulfilled
- Outside of the lab evaluation: if in a real world context the same objectives, functionalities and intentions makes sense

5.5. Design Patterns

The parameters chosen for creating patterns of design for *Tangible Scores* were:

1. Physical Materiality: all the materials I am interested in using for fabrication: wood, paper, metal, concrete and silicones.
2. Number of Spatial Dimensions: two or three dimensional
3. Discrete Controller. If Tangible Scores would implement feature featuresof a discrete controller like buttons or specific discrete values.
4. Sound Content. The possible types of sonic aesthetics I am interested in working with: noise, digital glitch, human voice, etc
5. Sound Synthesis: the types of sound synthesis which I find interesting for this project: concatenative synthesis, wavetable synthesis and sample-based synthesis.
6. Musical Language vs Textural: if the interface will allow playing musical content, with particular notes, or will it be a textural interface.
7. Freedom of Sonic Configuration: if the sonic content could be configurable by potential users or will it befixed by me indesign phase
8. Interaction Spatial Tracking:will user's fingers be tracked when touching the interface.
9. Temporal Structure: if the instrument would allow itself to be reconfigured over time.
10. Homogeneous vs HeterogeneousPhysical Structure: if the interface is uniform in respect to materiality or more a collage of materials.
11. Level of Control: if the instrument should be deterministic or or guided through random properties (e.g. a piano or a cracklebox).
12. External Tools: if the instrument is designed for being played with the hands or with other tools like mallets or scratchers.

Thus, the process of designing different versions of Tangible Scores was guided and limited by combinations of those patterns. Later in this chapter, the final decisions taken regarding these parameters will be explained.

5.6. The Tangible Score Instrument

For the initial implementations of *Tangible Scores* I decided to create some ad-hoc surfaces and two dimensional forms that could function as interfaces for tangible interaction and incorporate a physical score in its configuration. The main hypothesis to prove was if I could suggest a particular type of movement to a performer who interacts with my instrument. Thus, the question was, which graphic scores are better for suggesting particular movements?

A first set of instruments would serve as a proof of concept of my hypothesis. I chose wood as their material since it is easy to manipulate and affordable. Also because it is used commonly in the production of acoustic musical instruments.

My first idea was engraving some tangible design intuitively to observe my own reactions when I touched it. I took a 40 centimeters piece of wood and engraved some basic patterns with the help of a gouge and a hammer (figure 5.3). I engraved four different designs to see if they would afford different tactile interaction.

After touching the new instrument for the first few hours, I annotated the following results (written in present tense):

- For some reason, I look at the object and I feel my brain is almost sending signals of... 'touch it'. I am not interested in seeing it closer. I have a need to touch it and to complete the mental idea of the object.
- If I touch it with my eyes open and looking at the object, I naturally prefer following the lines I see with my fingers. With one or maximum two fingers. My tactile stimuli seems to complete what I see.

- If I touch it with closed eyes, I prefer using all my fingers to grab some kind of spatial reference and then touching more precisely with one or two fingers. I observe myself touching more into detail, trying to understand what is under my fingers on a small scale. I do not navigate the forms so easily as I dowith my eyes open. Probably the same test, if done by a blind person, would result in a different conclusion.
- If I understand the surface as an interface, I begin imagining various sonic mappings which are always intimately related to the tactile gestures I am making. I do not imagine that the interface would trigger samples, for example.

For the first time in my life, I realized the huge dependence between the tactile and the visual when something has a profile, when something is engraved with a motif. This simple design triggered a kind of tangible attraction, which indicated an additional layer of tactile information apart from its visual content. This perception is further explored and my finding expanded upon in chapter seven of this thesis (section 7.3).

This experience inspired further experimentation with more patterns. As I was not really skilled at working with gouges I decided to use a laser cutter to engrave graphic scores into the surface of the wooden panels. This also allowed the systematic production of tactile patterns and the easy replication of my designs.

5.6.1. Implementation as Acoustic Interface

For interfacing with the synthesis level I decided to interpret these surfaces as tangible acoustic interfaces. The tangible interaction with the tactile footprint of the engraved score produces vibrations on the surface that can be captured through contact microphones. The variety of produced sounds provides an enormous vocabulary of signals that can be used for direct sound synthesis and for extracting information that can be used for discrete or continuous control.

Acoustic interfaces are based on the idea that when users interact with surfaces they modify their acoustic properties. For example, users will create new sounds or absorb acoustic energy in a degree which is proportional to the pressure of their contact. This sound can be analyzed and converted into information suitable to be used: frequency, loudness, timbre, location, etc. The acoustic information can be easily captured by microphones attached to the surface or body of the interface. Vibration propagates well on rigid components and thus these microphones can be also hidden at interior parts of the interface.

An interesting possibility is, for instance, transforming any object into an interface with the use these technologies. The project *Mogees* (figure 5.4), has explored this medium extensively. Using a contact microphone and a smartphone app which resynthesizes captured sound, *Mogees* transforms common everyday objects into musical instruments. The engine behind *Mogees* learns an object´s harmonics profile when plucked in different ways and it is able to recognize which object has been played and in which way. *Mogees* allows only triggering samples so it did not fulfill my needs.

According to Polotti and Crevoisser (2005) tangible acoustic interfaces have the characteristic of recovering a clear correspondence between a physical gesture and the sound response produced by it. It is also-possible to conceive the interface according to a desired gesture instead of adapting the gesture to a given interface.

Therefore, I decided that the technology behind tangible scores should be an acoustic interface. Among the many technologies which could help for sensing tangible interaction, analyzing the acoustic pattern of the interface resulted in the most expressive findings. The reason for adopting this technology was that the sonic result of touching a surface contains a great deal of of information about the tangible interaction:

- The envelope of the signal gives information about its temporal evolution and it also informs about gestural aspects. For example, the energy envelope of scratching can be used to recognize a gesture, an aspect studied by Harrison (2008) at his Scratch input interface (figure 5.5).
- Touching is an universal action that any observer can decode. As external observers of an action of touching we need to understand also the pressure actuated, the possible texturing and the rigidity of the object touched.
- There exists a multiplicity of computer hardware and software for audio analysis.
- Contact microphones hidden beneath the surface leave all a user's attention free to navigate the score and for expressive action.

Many other composers and performers have used sound as the control signal in a digital system. It is intuitive and natural. Probably Béla Bartok anticipated it when he claimed in *The mechanical music* (1937) that:

> *"The final source of any sound, and thus of the musical sound, is a vibrating body. [...] So, the less foreign bodies are interposing themselves between the human body and the vibrating body or, the longest the time during which the human body controls the vibration is, the more the created musical sound will be immediate and, so to speak, human."*

Finally, I would like to remark that the equipment for my first implementation of my instrumentas an acoustic interface was a 10 euro cents piezo microphone plugged to a 40 euro pre-amplifier, which was connected to the sound input of a computer running Ubuntu. Thus the use of specialized technology or the cost was not a problem.

5.6.2. An Engraved Graphic Score as Controller

I first explored the possibility of defining acoustic patterns engraving materials. It was not difficult to engrave a graphic score on the surface of a wooden panel. This decision was influenced by artistic wood-carving techniques, known as xilography, where an image is carved into the surface of a wooden block.

Therefore, the engraved score had to be designed to have an acoustic impact. It would drive the sound synthesis. Inspired by percussion instruments like an idiophone, I created various examples and mock-ups to test, if for example, scratching an engraved parallel line pattern would create a vibration with a harmonic component dependent on the distance between the lines. This would be definitely a parameter which could be used to control the synthesis engine.

An idiophone is any musical instrument that creates sound primarily by scratching or hitting its resonant body, without strings or membranes. For my interface I was inspired by friction idiophones, like güiros, which are rubbed to increase vibration and sound intensity. Idiophones are made of materials that give off unique sounds, thus materiality was also an important aspect that I had to analyze.

In our case engraving patterns accomplished the following feature set:

- It influences the characteristics of the sound controlling the synthesis. Tactile interaction on dedicated parts of the engraved surface produces different sounds and reinforces specific components of the control signal spectrum.

- It conducts and constrains the gestures of the player. Performers follow intuitively the visual contours of the engraved forms.

As a starting point I engraved two graphic designs in panels measuring 30 by 20 centimeters. With a standard laser cutter I was able to create surface patterns with depths ranging from microns to 1mm. The results can be observed at figures 5.6, 5.7 and 5.8.

Again, my gestures on the surface were naturally induced by the visual design that I had engraved. Afterinformally testing this phenomenon with several lab members, I noticed that all had the same tendency to follow the visual design.

5.6.3. Sound Synthesis

Having evaluated different types of synthesis, I decided to implement Corpus Based Concatenative Synthesis (CBCS) (Schwarz, 2006), since our objective was to facilitate dynamic adaptation to any tactile gesture. When CBCS is applied to a live input signal, it creates a very intimate relationship between the physical gesture created and the sonic gesture perceived. As Altavilla, Caramiaux and Tanaka explained (2013) for the design of sonic affordances in new digital instruments, it is important to consider the tendency by audiences to describe sound production in terms of causality.

CBCS is a type of granular synthesis with the goal of imitating an input signal. Generally CBCS involves two processes. First the mathematical classification of a database of samples, extracting specific descriptors during small windows of time or grains. The objective of this first step is building what it is known as the space of sound characteristics, a comparative representation of descriptor values in the database. Second, for creating the synthesized sound, an input signal is analyzed with the same procedure and the grains within a sound corpus with similar descriptors are selected and concatenated. Usually there are multiple grains

Figure 5.3: First ever tangible score created

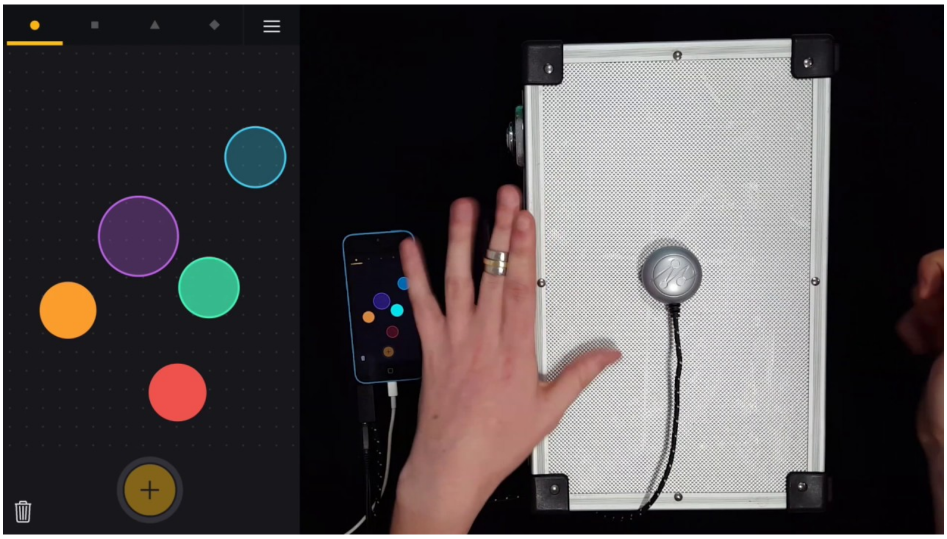


Figure 5.4: Mogees (2014) by Bruno Zamborlin

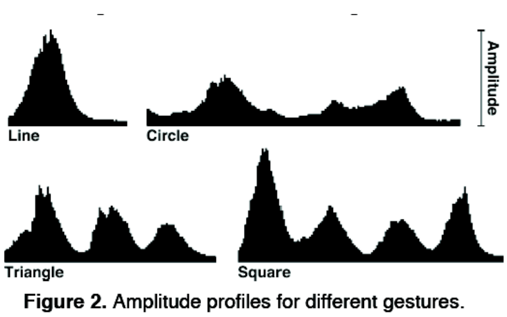
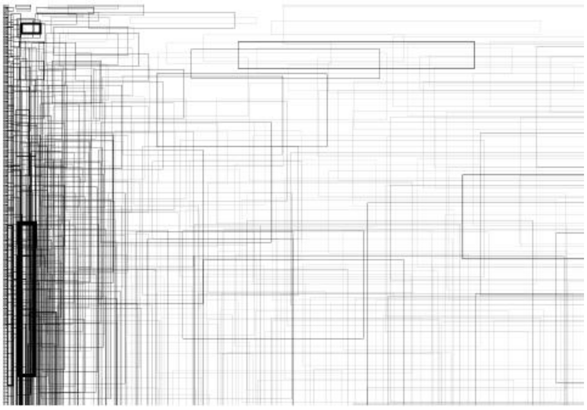
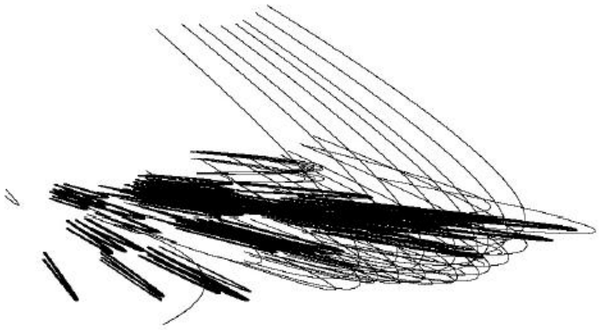


Figure 5.5: Harrison Scratch gesture envelope recognition.



(a)



(b)

Figure 5.6: First graphic scores to engrave

Figure 5.7: First graphic score engraved from (a)

Figure 5.8: First graphic score engraved from (b)

matching the input signal and the user defines the maximum number of audio snippets to be used in the synthesis.

The interest of using concatenative synthesis in digital music instruments was explained and discussed by Schwarz (2012). Playing a CBCS instrument consists in navigating along the space of descriptors, or in other words, projecting the input data on the multidimensional space of the descriptors. In theory, it is possible to pick single or multiple grains and play them back for creating different sonic gestures. As it is discussed in (Polotti and Crevoisier, 2005) using a live sound signal as input "the final objective seems to be the re-encounter of the acoustic energy of an excited surface with the synthesized sound generated". In other words, we can assume causal effects between tangible interaction and sound produced.

According to the online concatenative synthesis survey[1] we see that CBCS in combination with live input has not been explored enough. This motivates our present use of concatenative synthesis for the design of tangible acoustic interfaces, in particular after the promising results obtained in combination with acoustic interfaces and scratch input (Harrison, 2008).

Schwarz (2012) also has introduced a first taxonomy of controllers for concatenative synthesis:

1. Positional control
2. Audio Control
3. Additional Parameter Control

Positional control is probably the most straightforward method for mapping 2D or 3D values to the timbre space to an equivalent dimensional space of descriptors. To this type of control we can associate X-Y controllers, multitouch surfaces, motion capture systems and accelerometers. Audio control is the second category of this taxonomy, and it is probably a more natural way of navigating the sound space because the live input audio is used as the target for sound synthesis. Finally a third category is introduced, it is called additional parameter control. It consists of controllers using a large number of parameters in parallel, as with multi-fader surfaces.

In this taxonomy, we see that the first and third categories show a disconnection between a physical gesture produced with the controller and its sonic response. Only through mapping ofthe timbre space are sonic gestures produced. Live audio control appears as a more a more natural way of creating sound gestures.

Finally, the result of using CBCS is often described as an audio mosaicing (van Nort and Navab, 2014) because the result of a sonic gesture is a granular version built from audio snippets. Using envelope followers and attack detectors, is easy to recognize causal effects on scratching or hitting a surface.

5.7. Hypothesis: Synthesis Controlled by Acoustic Patterns

Once CBCS was implemeted and a few more wooden panels were engraved, my research turned to answering the following technical hypothesis:

Can I design and fabricate tangible patterns on the interface surface in such a way that the sonic result of a performer´s tactile interaction could control with certain precision a concatenative synthesis program?

I can advance that the answer is 'yes, it is possible'. The following subsections are dedicated to explaining how and under what conditions this is true.

5.7.1. Analysis of different engraved patterns

We can think of these engraved tangible scores as a kind of complex idiophone. Since it is played with our hands, these scratches and finger attacks are generally imperceptible outside of the material but they can be easily acquired with contact microphones.

For testing my hypothesis, I decided to make an exhaustive analysis of the sound signals produced in the wooden material. For that I fixed an observation system which:

- recorded audio and video.
- analyzed sonic spectrum values of every acoustic interaction recorded.

[1] http://imtr.ircam.fr/imtr/ accessed on 24/11/2017

I prepared a battery of tests with these patterns:

1. First select an area of engraved pattern to test. Only interact on that section until the next steps are fulfilled.

2. Second choose a type of movement among scratching, tapping and caressing. Only test this movement until the all combinations with the following step of this process is finished.

3. Third choose a part of your fingers to interact finger nail or fingerprint, now repeat for one, two and three fingers simultaneously.

I expected that all signals would be centered around the same frequency. That is the resonant frequency of a particular piece of wood. It depends on the wood size, form and material. This is the principle for creating tongue drums, for example.

Therefore, for a particular wooden panel we expect two types of signals:

- the first as a result of the finger attack on the panel.

- the second as a result of the finger gestural evolution on the panel.

In figure 5.9 it is possible to observe the engraved panel used for my analysis. In order to afford an easier interpretation of my observations, I defined four areas where I could perform interactions with my hands. These four areas are identified in the same figure.

In figure 5.10 the results of a very simple interaction (among the combinations of patterns I have described) are shown. The interaction was scratching with the nail of my right index finger during a short attack of approximately 150ms. All sound files were analyzed with an FFT (Fast Fourier Transform) with the software Octave.

In figure 5.10 we see how:

- It is easy to perceive that every spectrum is different. It shows different formants of frequencies. Apart from the possible deviations in minimum amounts of energy employed, the spectral envelopes are different for each area.

- All spectra are centered around the same central frequencies independently of their engraved pattern. One around 700Hz, 1200Hz and 2200Hz. There is a final harmonic around 3400Hz which is not important for us to consider. There are unimportant low frequencies to be taken into account (at least for this scratching movement) and spectra look situated in the form of three formants around the described central frequencies. This allowed my analysis to be centered on the range between 500Hz to 3000Hz without loss of information. This also suggests that the live input signal can be filtered and re-sampled as it would not modify substantially the analysis.

- The engraved area 1, can be served as a point of departure. Formants look like bells, with rounded and regular form. Readers can easily reproduce this sound on any piece of wood without varnish. Its sound can be described as a band filtered white noise.

- The engraved area 2, made of parallel lines, features a prominent peak in the spectrum at 2400 Hz and it lacks information between 1000 and 1250 Hz. Sonically, it sounds more empty that on the engraved area 1.

- The engraved area 3 is a flat surface with grainy content. It sounds similar to area 1 but with significantly more bass. At its spectrum we see that its envelope is similar to the spectrum of area 1 with the exception of a prominent peak around 700 Hz.

- In engraved area 4 we find deep short lines which are not parallel. Interestingly we see how it combines elements of the other three areas: lower harmonics and information around 2400Hz, but also information around 1200 Hz. This spectrum reinforces the impression that the sound produced here was the richest in timbre.

These results point to the finding that for a particular gesture, playing on different areas modifies the shape of the audio signal produced in a recognizable way.

There, as a conclusion to our hypothesis:
"Yes, we can design tactile patterns to control a concatenative synthesis engine".

The natural question to this answer is now:
"How much do the different types of scratching or tapping gestures affect this analysis?"

In other words, we have seen that it is possible to design the signal used to drive the system. But how much does this signal vary and how sensitive is it to human variability?

The natural answer is saying that it affects it completely. Every person would acknowledge that the sound produced if we scratch or tap is different. And this can be also recognized and classified by computers. However, let's examine in the following sections its limits.

5.7.2. Analysis of different gestures

In this section we center our analysis on understanding the spectrum envelope produced by various attacks made by different parts of our hands and fingers. All the examples were performed at the same location in the same wooden panel (the one of figure 5.9).

In the figure 5.11b the spectral analysis of three different gestures is presented. On top one finger was actuated as a leverage and attacked with the nail. In the middle two fingers played a short tremolo with fingerprints. Below one finger slidits fingerprint on the surface.

As it was expected, all these examples show quite different results. Indeed, they feature many more different profiles than the ones produced by different engravings.

This analysis suggests that human variability will be a huge factor that will totally modify our expected results. Developing a deterministic digital instrument looks then quite difficult.

5.7.3. Idiomatic Design: Designing from Imperfections

The variability of possible patterns to engrave, summed to the expected human variability and error, and also summed to all the combinations of gestures, attacks and materials, suggested that it will be very difficult if not impossible to predict and parametrize all the possible signals which could be produced. For accomplishing the mission of mapping input signal to final concatenated audio I would need to know all these combinations. This is not surprising. We work with non-restricted materiality and human beings.

How one depends on the other?

Rethinking this design process from an artistic standpoint solved many of these logical issues. Did I need to create deterministic instruments or expressive instruments? In other words, I assumed a certain level of imperfection in the system. We can say it is the instrument's personality. The most important is that the instrument, used in a real musical situation, produces interesting sounds.

The process of tuning the digital instrument from its imperfection is an idiosyncratic decision which depends on the particular performance and its performer. The most important aspect of this process of design is not the discretization of the solutions but the affordance of musical means in freedom.

I discovered that the best option for continuing with the design of the instrument was fixing a sonic content and testing its sonic result in combination with many types of attacks and gestures. As many as I could try. Then, changing the various parameters controlling the synthesis (range of descriptors, grain size and probability of jump, as we will see later), we can tune the instrument until the texture obtained fits specific musical intentions. Through this process, that we can call 'tunning', the instrument is given a sonic personality.

My impression is that while doing this, what I was actually configuring was the inherent score of the instrument. One part was already fixed with the physical engraving, after which I defined my embodied interaction with it. The other part, the electronic system (software), also had to be designed. However, this electronic design cannot be done without regard for decoupled from the other parts. It has to be designed through embodied interaction, through practice, taking into account seriously the other constituents forming the instrument's inherent score.

5.8. Relations between Tangible Score and Sound Synthesis

In order to clarify the relationships between engraved patterns, score and sound synthesis a few more elements have to be included. In particular it is necessary to include the analysis of the sound corpus used at every interpretation.

The easiest way to explain these relationships is describing the mechanism for creating a Tangible Score:

1. The specific material used has to be acoustically analyzed: its resonant frequencies and other filtering capabilities that it may show.

2. A graphic design is proposed. It is designed from an aesthetic intention but also taking into account that it has to effectively produce specific acoustic patterns when touched. From an initial design, various iterations are usually needed to produce interesting graphic elements with identifiable acoustic marks, always informed by the specific acoustic properties of the material studied.

3. A set of audio files are selected for being part of the sound corpus. This decision is taken analyzing the spectral characteristics of those sounds.

4. A pattern of tests must be created. The easiest is modeling it as a three dimensional problem. In one axis are the possible attacks which can be played. Then the locations of the surface with different acoustic marks. And finally the candidate sound files. Then a three dimensional space of possibilities is created and it must be explored.

5. These possibilities are limited through sonic tunning, testing different configuration of the parameters in the synthesis (range of descriptors, grain size and probability of jump). This process is informed by the musical and embodied intentions of the performer.

6. These configurations are saved as presets which can be recalled by performers at every moment during performance.

5.9. Fabrication

5.9.1. Construction: Important Aspects of Materiality

Certainly, another component of design is matter. Our interaction with matter defines many aspects of the work to play. And matter suggests interaction too. In regard to the technical system supporting the implementation of *Tangible Scores*, matter mediates vibration and can critically improve or reduce our possibilities for musical expression. I decided to work with materials which are rigid enough to transmit vibration but also which are easily malleable to create prototypes. For that reason I chose wood, plastic, silicone and paper as the first options. Then I explored additionally metal, stone and casted concrete. The following subsections summarize my experiments with these materials.

5.9.2. Wood

As I have explained, the first demos of tangible scores were crated out of wood. The reasons are simple: this materialis cheap and malleable.

The first demo profile can be observed at figure 5.3. It is a wooden piece with holes and scratches created with a drilling machine. The first series of designed instruments were built using 30 by 20 cm flat plywood panels with attached piezo microphones. This can be observed in the figures 5.7 and 5.8.

The second generation of wooden tangible scores were 70 by 40 centimeters panels with much more complicated engraved profiles. They can be observed at figures 5.13a to 5.15b. The laser cut time required varied from twenty minutes to four hours for the more complicated designs. These wooden panels were presented at an exhibition in the Kunstuniversität Linz and later traveled with me to many concerts and exhibitions around Europe over the last three years.

The benefits are clear: they are rigid andeasy to transform into artistic objects. At various exhibitions and workshops, may users also noted negative aspects of wood in regard to tangible scores:

- They are too rigid to play: one has to scratch with quite a lot of energy (e.g. compared to paper) and it is often necessary to play with long fingernails.
- Users often declare that they would like to explore the artifacts in three dimensions. But wood does not afford depth, so it creates only interaction at the surface.

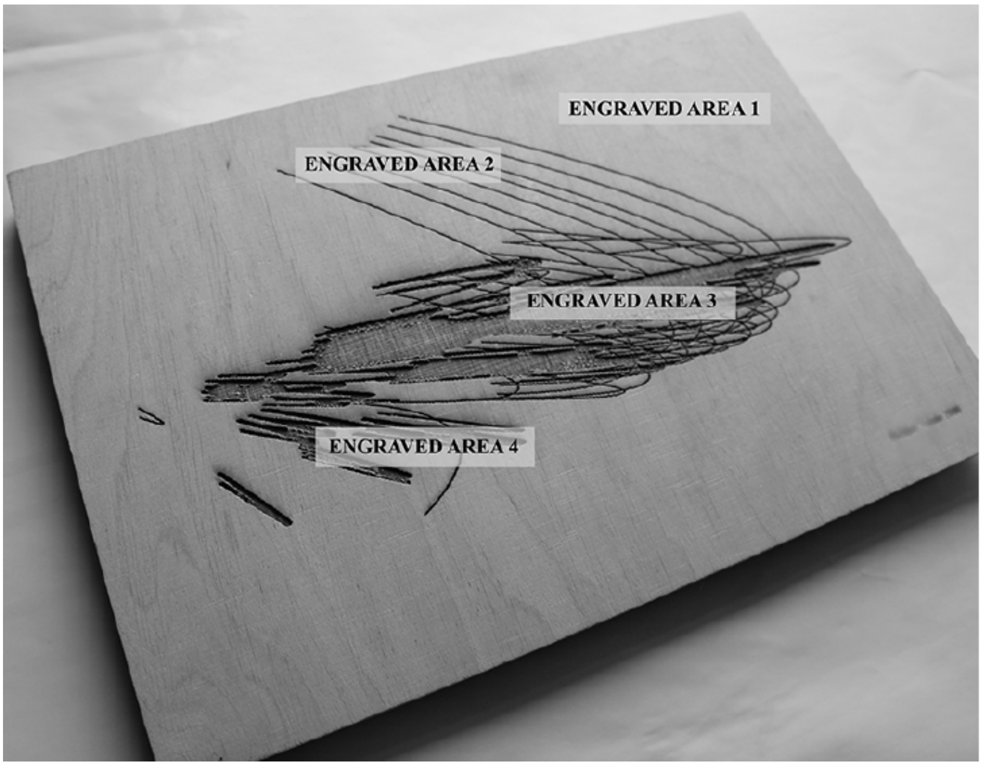


Figure 5.9: Locations of the tests in the engraved object

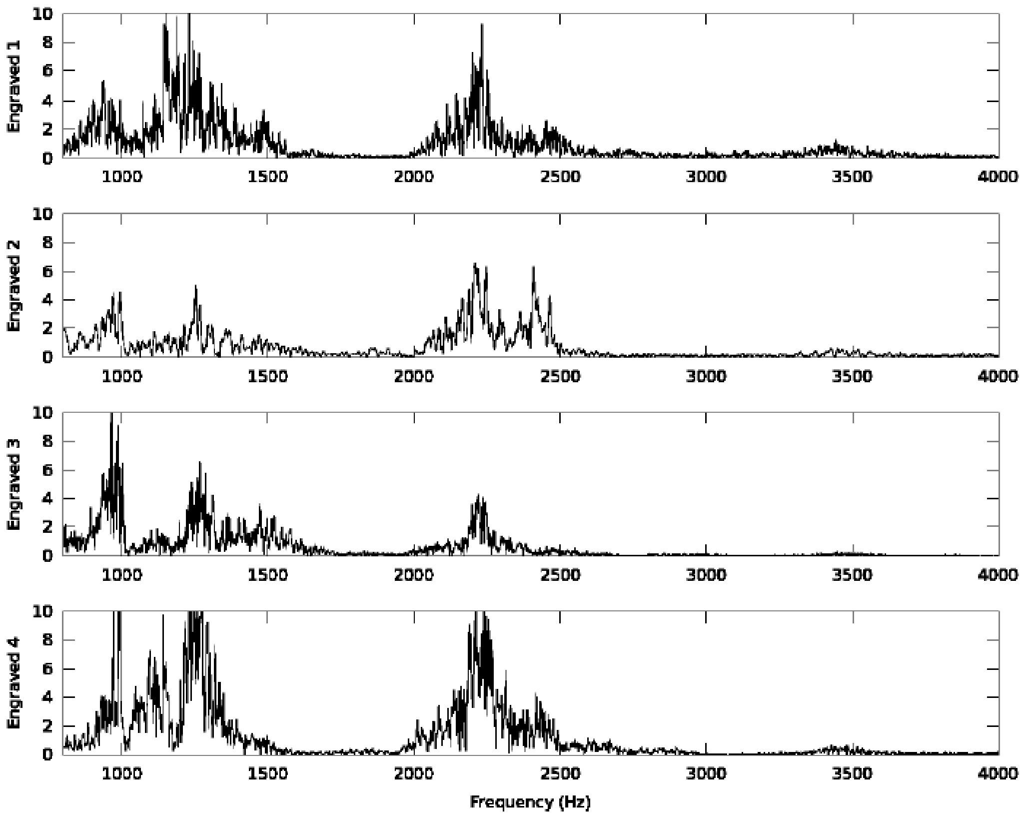
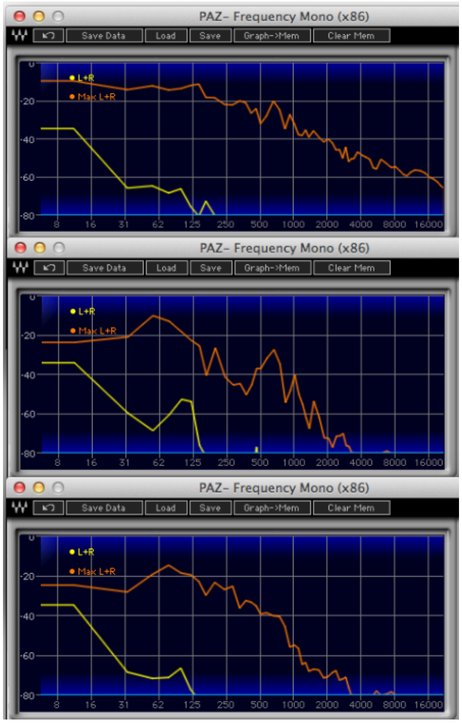


Figure 5.10: Spectral Analysis of the same gesture (scratching) at different locations



(a) Spectrum at three progressive distances to the mic

(b) Spectrum of three different types of hand attack

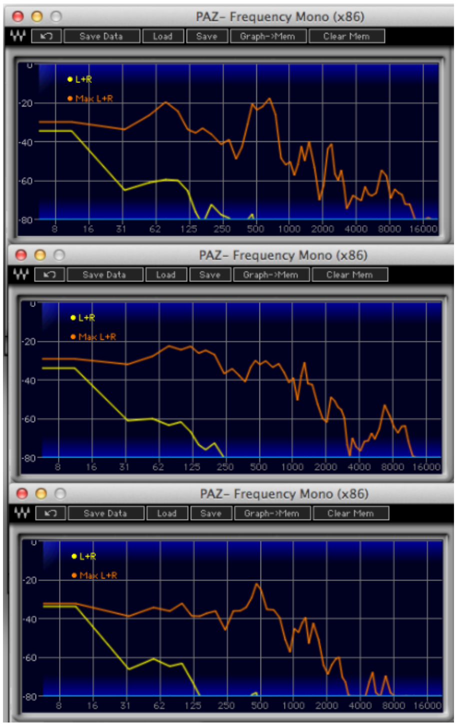
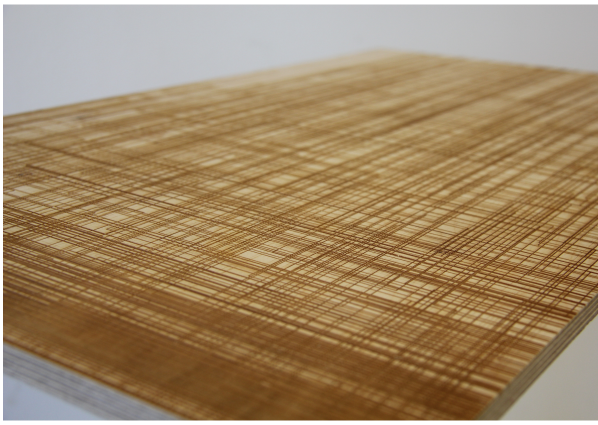


Figure 5.12: Spectrum of same scratching on three parts of the surface

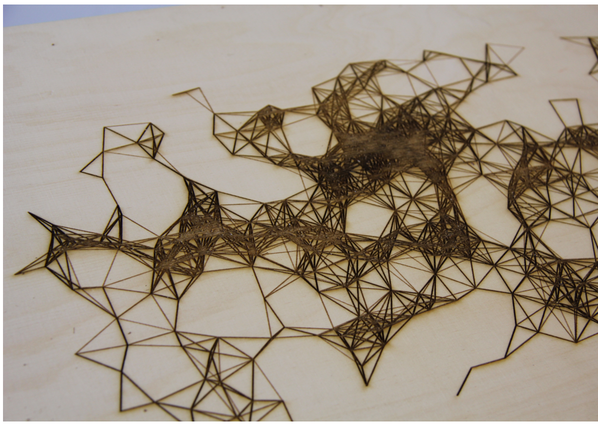


(a) Tangible Score one

(b) Tangible Score two

(a) Tangible Score three

(b) Tangible Score four



(a) Tangible Score five

(b) Installation Space

5.9.3. Paper

Graphic scores are usually drawn or painted on paper. But, a tactile or tangible score on paper had to be something different. Therefore, my intention was producing some paper scores where all the information could be observed in its tactile profile, without any written or drawn mark. The texturing of paper has an important attraction for the human touch.

Two techniques were used for creating these profiles within paper: paper casting and paper embossing.

The process for casting paper can be summarized as:

1. Digital Design of the profile
2. Fabrication of the cast with a CNC, usually with Styrofoam.
3. Casting process with a conglomerate of paper.

The outcome of casting paper is a tactile profile with the typical irregularities of hand-made objects. Therefore, with the CNC I could create very complex patterns which finally looked as if they were crafted by hand.

That was a positive result for me. The profiles I created were up to two milliliters high. A series of these tangible scores was created. Some can be observed at figures 5.16a to 5.17b.

For embossing tangible scores:

1. I created a digital design of the profile
2. I embossed the profile with the use of a CNC to which I had connected an embossing tool.

The outcome of this embossing with CNC was also very interesting. It resulted in very complex but clean textures on the paper. I used water coloring paper of 250gr/m2. However, the process of embossing with a CNC is a difficult task. The paper, when it is embossed, flexes and is no longer flat. If the tool touches it laterally it breaks the paper and the piece is destroyed in seconds. After many tests and iterations I engraved a series of eight designs. Some can be observed at figures 5.18a and 5.18b. Three were used for the performance "A Moment of Transition" which is described in chapter six.

5.9.4. Flexible Silicone

My intention in this case was the production of flexible tangible scores. I wanted to adapt their form to other objects or to even produce wearables. A few tangible scores were produced with CNC fabricated casts. I decided to use a thickness of around 8 millimeters. Some examples can be see at figure 5.19.

The main issue with flexible silicone is related to the transmission of sound and vibration. In order to have a good sensibility for user's interaction, it is necessary to incorporate many contact microphones under their surface. For this reason, combining contact microphones with other types of sensing technology is always necessary. My first solution was incorporating a new layer of capacitive sensing within the silicones, but my silicone was a too good an isolator and didn't work well. The next choice was using pressure sensors, which was a much better option.

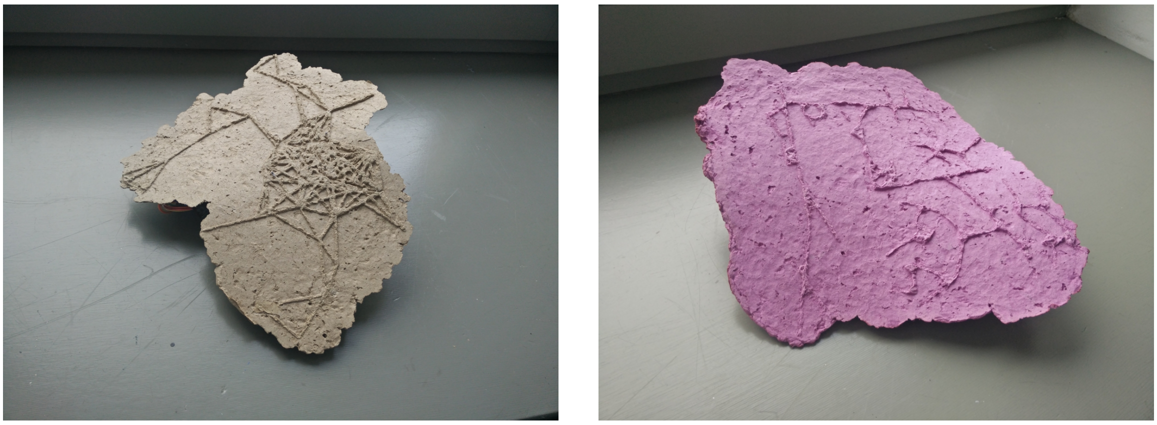
The use of silicones is an option affording interaction in deepness. The exploration of the tangible score created a great expectation of control with pressure. Unfortunately, I was not able to find an affordable technology for sensing larger surfaces(more than 20 by 20 centimeter). Then, I wish to explore this material much further in the future. Recent sensing technologies, like the Sensel morph[2] are still not affordable but show interesting technical possibilities.

5.9.5. Conformed Thermoplastic

A series of tangible scores made of thermoplastic was produced during the workshop "Diffractive Interfaces" in 2017. The idea was rapidly texturing the surfaces with the help of DIY conforming machine made by Fabricio Lamoncha, a research colleague at Interface Cultures with whom I collaborated.

Thus, participants of this workshop would be able to create profiles in minutes. The materials used were termoplastic sheets. We decided to give them the same size (20 cm x 20 cm). To these surfaces we also incorporated contact microphones. Finally, we created a mural with all of the scores created (figure 5.21 to 5.23).

[2] https://www.kickstarter.com/projects/1152958674/the-sensel-morph-interaction-evolved accessed 25/11/2017

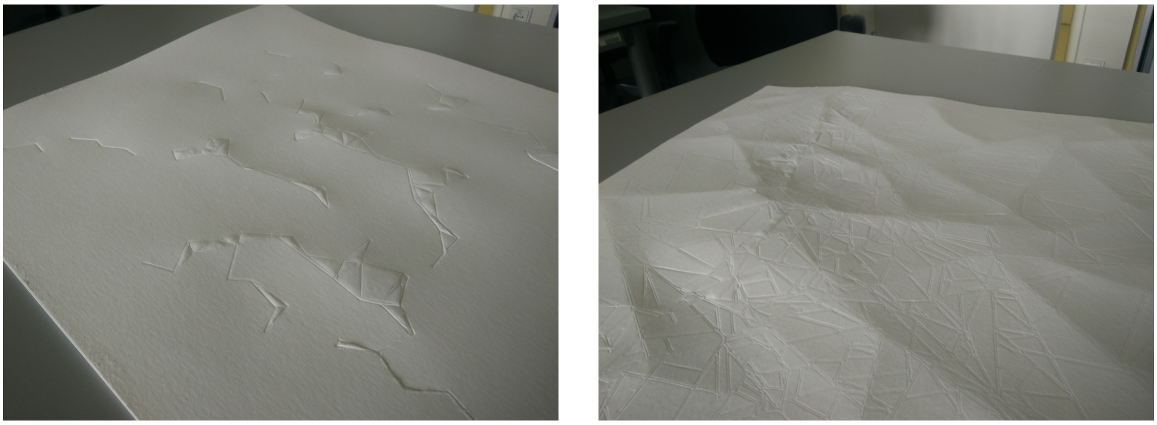


(a) (b)

Figure 5.16: Examples of casted tangible scores

(a) (b)

Figure 5.17: More examples of casted tangible scores



(a) (b)

Figure 5.18: Embossed tangible scores

The main differences of using thermoplastic were:

- We could tighten the plastic once it was conformed, and even tune it, so we were able to control a bit the frequency of the sounds produced.

- Thermoplastic is very homogeneous in structure and it usually looks to be of little value. Thus, visually it is not the most attractive material. Yet, conforming interesting textures onto surfaces made from this material contrasted well and was appropriate to my needs.

- Thermo-conformation is a very intuitive and rapid process. One can take an object and use it very quickly for conforming a sheet of plastic without other technical complications. During a session of four hours we were able to create almost twenty tangible scores. Thus, this process afforded quick experimentation and prototyping, a feature that other materials didn't allow.

5.9.6. Casted Concrete

Casted concrete is quite popular at hobby shops. It is used to cast pieces of jewelery and some other artistic objects. I created a concrete tangible score with a profile of 4 millimeters.

The main issue regarding concrete is that although it isrigid, it is very difficult to transmit vibration through it too. It is quite a heterogeneous and heavy material, with many small stones mixed with sand. The transmission of vibration again turned into a problem to solve.

In spite of these problems, concrete tangible scores are aesthetically appealing. This material opens great possibilities for use in future projects.

5.9.7. Three Dimensional Tangible Scores

A recurrent question during this project was why the *Tangible Scores* were all flat. Would it be possible to create sculptural tangible scores?

To answer this question, I produced a small prototype. I designed a digital three dimensional object and exported it in a way that it could be fabricated out of thin slices of wood. These slices had to be glued in a pile (figure 5.20). The decision for adopting this fabrication method was only because my CNC didn't allow three dimensional carving. This fabrication technique produced and interesting form affording tactile interaction between slices. It was like a sophisticated güiro. Additionally, a piezo-electric component was embedded into the object and I incorporated a female jack connector, making it very intuitive to hold and use.

My findings after exploring this sculptural score were very important for the development of this project:

- Navigating the profile and texture of this three dimensional score was radically different. First the object afforded being touched with my hands and not only with my fingers. This score created large expectations about our interaction. For example, users who tested it explained that they expected other ways of interacting apart from playing with object's surface (e.g. sensing the movement, inclination, pressure, etc). This suggests the need to incorporate additional layers of sensors to afford this control.

- When touching the object, one has the impression that its 3D materiality becomes much more dense. Our eyes are not good at decoding volumes and we cannot understand hidden parts without touching. Thus, touching is a key to seeing the other part of the object. As a result, the tangible becomes crucial. It has to complete what the other senses cannot afford.

In conclusion, the creation of three-dimensional tangible scores supposes more than the simple addition of one degree of difficulty in the system. It is a huge step in complexity that has to be studied in detail. For this reason I decided on constraining my tangible scores to two-dimensional artifacts (at least during this thesis). A future funded research project (called *embodied gestures* in which I am involved) will allow for research into the possibilities of three-dimensional tangible scores.

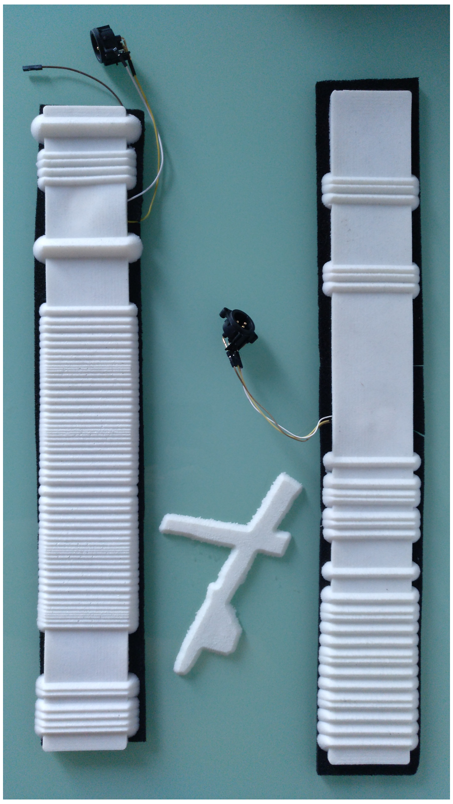


Figure 5.19: Tangible Scores made of flexible silicones

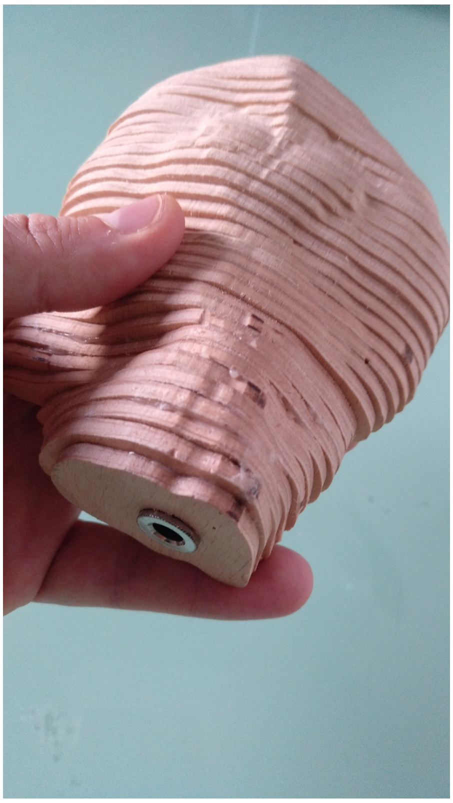


Figure 5.20: Tangible Score made in three dimensions

Figure 5.21: Conforming DIY machine

Figure 5.22: Students using materials to conform

Figure 5.23: Some final tangible scores at the exhibition in Sonar 2017

5.10. Technical Implementation

5.10.1. First Implementation

The first implementation of *Tangible Scores* I programmed runs on a 2.3 GHz, 8GB RAM Mac Mini(year 2012) with OS X 10.8.5. After considering various CBCS implementations, we decided to use William Brent's library timbreID (Brent, 2010) for Pure Data (PD). A preamplifier improved the audio signal sampled at 48KHz by an RME Fireface UCX.

An important consideration with concatenative synthesis is the selection of the mathematical descriptor for the analysis. As I have explained we expect specific spectral profiles for scratching, while percussive gestures will feature different information in the lower part of the spectrum.

After analyzing the spectral components of multiple gestures, I decided to use the descriptor *Mel Frequency Cepstral Coefficients* (MFCC), which represents the spectral envelope of the live input signal through a bank of filters distributed along the spectrum. In particular I used a version called *Bark Frequency Cepstral Coefficients* implemented in the PD object *bfcc*. In this case the separation between the bands of the bank of filters is the *Bark weighting parameter*. Since it emphasizes the low frequency components, it achieves a better classificationof percussive gestures while it also is still robust for high frequencies.

I invested part of the year 2013 developing and testing this implementation. At the end of 2013 I was able to test this system in various local concerts and in 2014 it was ready to be presented at academic conferences (NIME, ICMC and SMC) and festivals (Sónar and Ars Electronica). Through these experiences, I was able to debug and test many parts of this implementation. The outcome of this artistic practice was a flexible and modular framework for controlling a multi-channel concatenative synthesis.

5.10.2. Second Implementation: Embedded Instrument

The second technical implementation started in 2017. Public interest about *tangible scores* grew and many interested people asked me how to purchase one of their own.

I also got an invitation from the intra-sonic duo based at IEM Graz to play my *Tangible Scores*. This was a great opportunity. However it created new problems. I had to re-implement *Tangible Scores* to be more robust and user-friendly. I was sure that this was the only possibility to distribute my instruments. I didn't want to rely on every person's individual computer characteristics.

There are many minicomputers available with which to create embedded systems. After testing my software with the family of raspberry Pi and Beagle Bone Boards I discovered that these computers did not feature enough CPU power for implementing my synthesis. Finally, I found a solution, an Odroid XU4 with a Samsung Exynos5422 Cortex™-A15 2Ghz and Cortex™-A7 Octa core CPUs and 2Gb LPDDR3 RAM PoP stacked. Withthis system it was possible to compile and run my Pure Data code flawlessly.

I decided to embed all electronics, including pre-amplifiers and computer into a wooden frame underneath the physical score. Users only need to switch on the system and play.

The interesting aspects of this implementation were:

- As the Odroid featured Wifi connection it was possible to configure and even debug or update the system remotely.
- The embedded wooden frame served as a support for the scores. It could be left on a table or hung on a wall.
- The nature of the system finally created the impression that tangible scores, as a whole, was a digital instrument and not only an interface. Every score had a different design and a sonic character. But more importantly, this configuration was fixed and it could not be changed by the user.

5.11. Performance Aspects: How Does it Sound?

After having implemented Tangible Scores I obtained the following subjective conclusions [3]:

In terms of expression, the produced sonic gestures are recognizable and suggest a causal relationship to the tactile input gestures. The instrument reacts to very subtle interactions, which makes the performance process very expressive and intimate.

[3] A number of videos of the instrument in action can be watched here: http://interface.ufg.ac.at/tmg/projects/tangible-scores/

The sensation of playing is fluid. Latency is not an issue, since I chose an adequate buffer value of 32 samples and no glitches or dropouts were observed. The CPU was not used above 65 percent with five channels of analysis and synthesis.

Those results show how using concatenative synthesis in combination with physical scores, is a promising way of creating expressive instruments. The main constraint of the acoustic nature of the interface is that the spectrum of the control signal is usually centered around the resonance frequency of the material used.Therefore I have assumed this sound characteristic, creating performances and compositions of spectral music, making use of the multiple parameters that concatenative synthesis offers to modulate sound, such as the range of the used corpus and the grain size.

5.12. The Tangible Score Paradigm Adopted and Interpreted by Other Researchers

As I have defined in section 5.1.2, a tangible score is the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements. My personal implementation of the tangible score paradigm is an acoustic interface controlling a concatenative synthesis program. Therefore, this should be considered one of the multiple options for producing tangible scores. In this thesis, I have centered my efforts in developing a robust and expressive system around this configuration, but I do not reject other technical and creative possibilities pushing the boundaries about what a tangible score can be.

Fortunately, after presenting the first paper about tangible scores in the NIME conference 2014 (Tomás and Kaltenbrunner, 2014), a few other researchers have adopted this paradigm and have developed other interesting interpretations. To this point in time (May 2018), these are some academic publications describing digital instruments which have been inspired by tangible scores:

- A Flexible Platform for Tangible Graphic Scores by Simon Alexander-Adams (Alexander-Adams and Gurevich, 2015) and (Alexander-Adams, 2015) of the University of Michigan. The author credits in his dissertation (supervised by Michael Gurevich) Tomás and Kaltenbrunner (2014) for describing that his first instrument, called soundCanvas (figure 5.25)"*soundCanvas, is my own first inherent score, which nearly constitutes a tangible score. In soundCanvas, the viewer uses an electromagnetic transducer to amplify a circuit embedded into the surface of a painting. Photocells in the circuit create sonic variation as viewers cast shadow on the piece, reacting dramatically when hit with a flashlight or bright source of light*".

  This is how the author explains that his final implementation of a flexible tangible score: *A textured panel would be used as the basis for a multi-touch surface, allowing for both textural and visual compositional tools to be utilized in tandem. This method would be distinct from Tomás and Kaltenbrunner's engraved scores. A sketch of tilting touch surface interactions its use of visual sensing instead of acoustic, and the addition of dynamic visual feedback and stimulus*". This instrument uses four laser emitters and a camera underneath the surface to detect tactile interaction, like the place where users are touching. The tactile panels incorporate different patterns engraved and are interchangeable. The whole system can be observed at figure 5.24.

- Diemo Schwarz, Gregoire Lorieux, Emmanuelle Lizere, Ariadna Tarres, Frederic Bevilacqua. A Topo-Phonic Table for Tangible Sonic Interaction. International Computer Music Conference (ICMC), Oct 2017, Shanghai, China. International Computer Music Conference (ICMC), 2017.

  It is a project closely related to Tangible Scores but giving more emphasis to gesture recognition from a real time sound stream. The authors have created "*an interactive sound installation project consisting of a specially designed table with a patterned surface that allows rich and expressive tangible sonic interaction by rubbing, scraping and hitting it with the hands or objects*" (figures 5.26a and 5.26b). In this case, the inquiry is focused on recognizing gestures from a database of classified movements. The tactile interaction is then sonified depending on the actual gestures recognized. Although the authors do not explicitly name it "tangible scores" they explain that *"Tomás uses specially engraved wooden panels as controllers to drive corpus-based synthesis in an instrumental or installation context"* citing my papers.

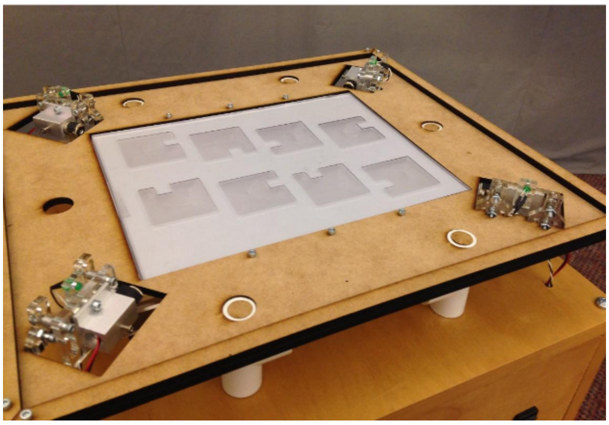


Figure 5.24: Flexible tangible scores by Simon Alexander-Adams

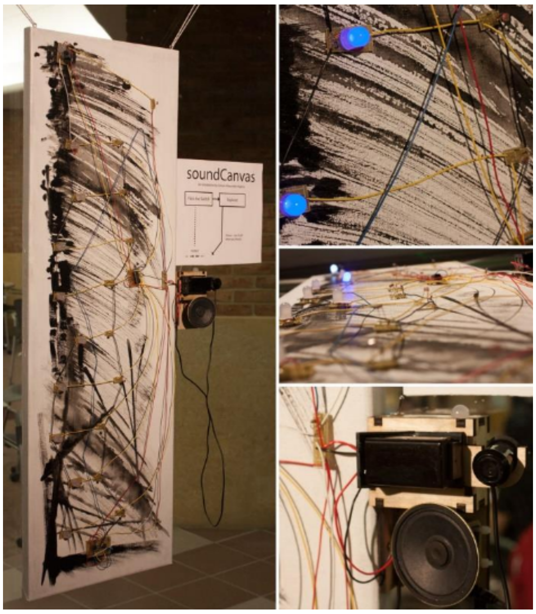


Figure 5.25: sondCanvas tangible score by Simon Alexander-Adams

(a) (b)

Figure 5.26: A Topo-Phonic Table for Tangible Sonic Interaction by Schwarz et al.

In conclusion, the tangible score paradigm is open to any type of technical or creative interpretation. Thus, my personal and specific implementation in the context of this thesis should not reduce or obscure the many other ways to explore the artistic possibilities of creating music through tactile content. In future work planned after this thesis, my intentions is exploring new implementations for the tangible score paradigm.

5.13. A Toolkit for Creating Tangible Scores

After having implemented a robust software system, it was necessary to program a toolkit for allowing others to create or configure *Tangible Scores*.

The toolkit had to overcome many of the technical difficulties and offer an user-friendly software environment. That was necessary, for example, for developing workshops.

With this toolkit:

- Any musician can independently create a Tangible Score without my guidance.
- We can evaluate the instrument in terms of its creative and functional use at different compositional situations.

For the creation of this toolkit I established several design constraints:

- It must be multi-platform (Linux, MacOS, Windows, etc.)and developed with open source technologies.
- All internal functions should be controlled by graphic based elements like sliders, knobs and buttons.
- Its control component must be decoupled from its sound engine (already programmed using Pure Data)

For these reasons I decided to develop the graphic layer under Processing (processing.org) using the GUI library *controlp5* and connect graphic layer and sound engine with the protocol OpenSoundControl.

The actual toolkit (figure 5.27) has the following sections:

- Performance Screen: it contains a visualization of inputs (microphone values) and output volumes at the sound engine. It incorporates all the necessary controllers for choosing a predefined scene.
- Composer Screen: it is in charge of loading a specific soundfile (corpus), analyzing it on-line and offer an interactive navigation through the space of mathematical descriptors obtained from the analysis. It allows saving a scene as a "preset".
- Sequencer Screen: this screen offers the possibility of sequencing already saved presets in time. Thus, in a real live performance the change of parameters in the instruments can be totally automated.

In conclusion, this toolkit is a key feature for the distribution of the instrument "*Tangible Score*" and the generalized use of this instrument by other composers and performers.

5.14. Tangible Scores as a Discrete Controller: Machine Learning

5.14.1. First Implementation: Sound Analysis

After having implemented *Tangible Scores* as an instrument for concatenative synthesis, I decided to add a new feature. I also needed it to work as a discrete controller. For example for selecting a specific setup or scene of the time sequencer, or to use it as another variable in a composition.

Instead of incorporating some buttons or other type of discrete sensor, the objective was extracting specific information contained in the sound input and interpreting it as discrete parameters. For instance, for classifying and recognizing specific sonic contents like scratching or tapping.

First, I decided to implement a machine learning algorithm. In particular, my objective was recognizing six different types of percussive timbres when they were produced. With that intention, I used the same Pure Data *timbreID* library of *Tangible Scores*. Then I added a classification algorithm (also available with *timbreID*) after obtaining the *Bark-frequency Cepstrum* descriptors with an audio window of 2048 samples. The Pure Data object *bfcc* outputs a vector with 47 spectral components but only the first 20 were analyzed after noticing that our percussive gestures did not contain differentiable components above the spectral median.

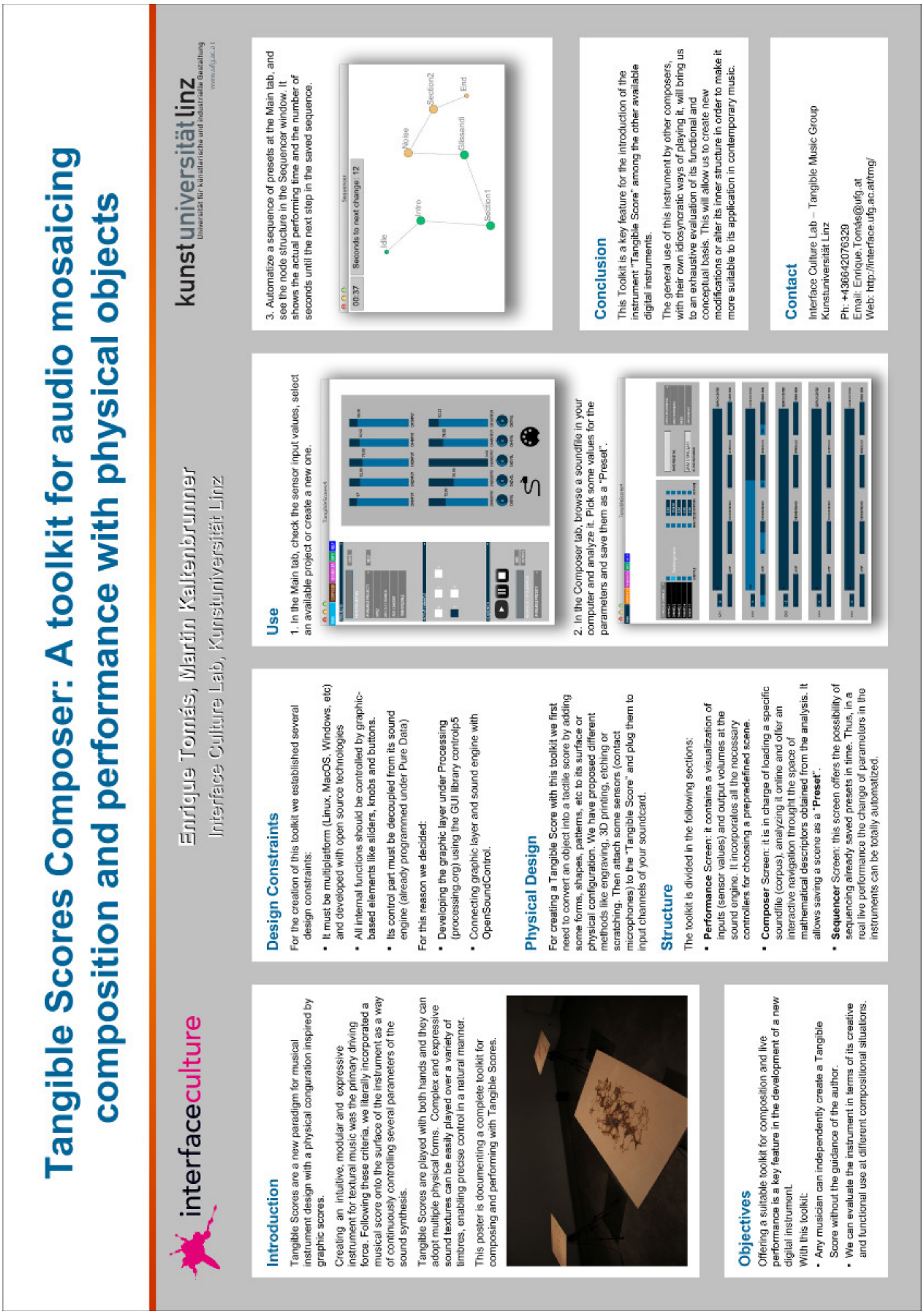


Figure 5.27: The Tangible Scores Toolkit. Poster of PhD Kolloquium 2015

The process of selecting six candidates for robust recognition was more difficult than expected. Initially I chose six different percussive hand gestures. The system was trained playing the same gesture twenty times after informing the program that I wanted to classify a new timbre.

Having trained the system, I tested it and around eighty percent of the gestures were well recognized. The big discrepancies appeared when I tested the system in a live situation. During performance, the variability of human expression and the noises surrounding the action disturbed the recognition process, which was no longer robust. I didn't do a quantitative analysis but my perception is that the system recognized my sonic contents less than half of the times I tried. This fact indicated the need of implementing a more robust strategy, maybe combining it with other sensing technology.

5.14.2. Second Machine Learning Implementation: Wekinator and Capacitive Sensing

One of the most common feedback comments I received was that it was not easy to repeat sonic contents while playing a Tangible Score. This triggered the idea of incorporating a new layer of sensors to my surfaces. In particular, I chose to detect the place where users touched the surface.

I decided to attach a layer of capacitive sensors under my surfaces. Capacitive sensing is a technologybased on capacitive coupling that can detect and measure anything that is conductive or has a dielectric measure different from air. In other words, it can measure if a conductive object has touched another. It can also recognize if any user is touching the material on top of a metal plate. Usually, capacitive sensors use metal contacts attached to the material where users touch as a reference to detect changes. In our case, this technology was quite attractive, as the contacts or metal plates used as a reference can be installed under the surfaces.

The easiest was testing this layer in the tangible scores made of paper, using conductive ink as our material. Thus, it was very easy to fabricate them as I only had to paint the back side of these surfaces with conductive ink and connect the cables to a microcontroller. As a sensor I used the capacitive sensing inputs that the *Teensy Low-Cost* microcontroller features. Programming this device it is possible to measure the capacitance of thirteen capacitive inputs in parallel. Finally, this information was converted into MIDI messages and transmitted to the computer with an USB cable. The main constraint was that I could only detect thirteen areas on the surface. For these 40 by 20 centimeter paper Tangible Scores, this number of detectable areas was acceptable.

The next step in this design was mapping my surfaces to the different areas covered with conductive paint. An issue was that due to the irregularity and complexity of my physical designs, various combinations of detected touched information would need to be calculated to decide in which part there was actually tactile interaction. Explained it different, various combinations of touching were allowed for the same discrete solution. Thus, I decided to implement a strategy for classification and recognition using a machine learning algorithm. I chose *Wekinator*, as it is an educational software useful in the production of interfaces.

The process of training the classification algorithm took less time than programming the structure of data I had to send to *Wekinator* from the microcontroller. Once it was trained with all the combinations, the results were very efficient. Wekinator implements the protocol OSC (OpenSoundControl) for managing inputs and outputs. That helped to interconnect it with the components of my software.

After this implementation, Tangible Scores had two new layers, and now four in total:

1. Capacitive Sensing Module
2. Classification of Touch Information
3. Audio Input Sensing
4. Sound Synthesis

5.15. Source Code Repository

Programming Tangible Scores involved hundreds of hours coding Pure Data, Processing, Arduino, Python and C++. All the source code for reproducing Tangible Scores can be found at my github repository:

https://github.com/ultranoise/tangible-scores

This source code has been released under a Creative Commons Attributions Share-Alike 4.0 International.

5.16. Conclusions

This chapter has described the decisions taken for the creation of my central artistic research object: *Tangible Scores*. The process for defining different patterns of design is clarified and the solutions adopted are explained. I have summarizes many technical and conceptual decisions adopted to improve expressiveness and robustness. A practice-based process of tests, demos, workshops, concerts, etc.will be explained in the following chapter.

After having implemented and evaluated the instrument in a concert situation, several research questions emerged:

- What are the aesthetic, cultural and musical implications of using sculptural objects as scores?
- Which materials and shapes are most suitable for the design of Tangible Score instruments?
- Which other sensor and synthesis technologies can be used for the technical realization of Tangible Scores?

These questions are answered in the following two chapters of this thesis.

6

Tangible Scores in Practice Evaluation and Critique

"para saber de esto (flamenco), hay que trasnochar"
(to understand flamenco, one has to stay up late)

El Sordera de Jerez

In this chapter I will describe my practice with Tangible Scores. It is a journey of five years which begins with the first practical experiments in the late 2012. It covers the experience gained at musical festivals, exhibitions and workshops during these years. It concludes at the point of releasing the instrument for use by other musicians, no longer exclusively in my own performance practice.

From experience, as I will explain, I have been able to gain a considerable amount of embodied knowledge about playing musical interfaces. Those activities have also been crucial to evaluate my design decisions. In this chapter, I will focus mostly on the aspects affecting the instrument design. In chapter 7, I will give emphasis to other notions, more related to my embodiment that developed out of my practice with the instrument.

6.1. Practice-Based Research

As it has been explained in chapter one (section 1.4), a considerable part of my methodology is built on the analysis of my own artistic practice. In fact, the notion of inherent score is eminently practical as it cannot be induced from the mere theoretical study of a musical instrument.

Therefore, it is crucial here to define 'practice' in the context of this thesis. Mainly because 'practice' has often become another empty and undefined space in artistic research. I understand 'practice' as:

1. The targeted work done towards the creation and preparation of a musical performance or an installation with *Tangible Scores*.
2. The work done during a musical performance or an exhibition with *Tangible Scores.*

Why is being 'targeted' so important? In my opinion, there are two entirely different ways of approaching the design of a musical instrument. The first happens after having a target, a concert or a composition one has to give. The instrument in this case adopts the form and configuration that the performance needs. In this case, instrument and musical work are often inseparable, one cannot exist without the other. The second is designing an instrument without a target. Design becomes an activity centered in the instrument.

Instrument design can become a scientific activity in which the political and cultural values of a society define many elements of their creation, as we have seen in chapter three, but they can be scripted with variable intensities.

How is it possible to evaluate my practice? Most of the knowledge gained in this thesis (which will be discussed in chapter seven) comes from a process of reflection after action with the artifact. These interactions have happened both in the safe environment of the lab and on stages of music festivals and galleries.

During my research, two main types of practice-based activities have been developed:

- Evaluation Studies: studies aimed at evaluating the validity of some assumption or hypothesis, obtained through formal observations of a phenomenon under specific conditions allowing to extract patterns of analysis. In my case, exhibitions and workshops organized in controlled environments to study and understand how users interact with *Tangible Scores*. In particular, the results of formal studies helped to confirm (or not) personal, ad hoc impressions. It proved to be beneficial, not only in providing substantive outcomes for the thesis, but also for understanding better the nature of my own work. By taking an objective view of how a person might interact with my work, I could better address other's experience in practice. I was able to strengthen my understanding and acquire more detailed knowledge as well as being aware of the potential for unexpected events. Finally, these studies helped me also to substantially support the existence of the instrument-scores in the case of *Tangible Scores*.
- Reflection in Practice: learning from my own professional experience as researcher-practitioner, rather than from formal learning or knowledge transfer from others. It is the ability to reflect on one's actions so as to engage in a process of continuous learning. Reflection in practice, in my opinion means the complete personal evaluation of the results and outcomes after having developed some activity e.g. a concert or exhibition. Many activities which could not count or be prepared as evaluation studies became valuable after a systematic analysis and reflection.

  Reflection always began after questioning if the decisions taken for the particular activity were beneficial for my objectives. After that, new alternatives for improving weak points of my artifacts, practice or theories were always imagined and explored.

  Both my 'evaluation studies' and the most relevant activities of 'reflection in action' will be discussed in the following section.

In the search for clarity, these evaluation studies have been developed:

1. The first exhibition of *Tangible Scores* (Kunstuniversität Linz) in April 2014 (18 months after beginning my thesis)
2. The production a dance piece (Flamenco Biennial Netherlands) with *Tangible Scores* in January 2015 (PhD´s second year)
3. An experts' workshop (Kunstuniversität Linz) in March 2016 (PhD´s third year)
4. A concert (IEM Graz) where other performers played *Tangible Scores* alone in May 2017 (PhD´s third year)
5. A collaborative-design workshop developed with students of IEM Graz in May 2017.
6. A workshop on critical interfaces (Sónar Festival 2017) in June 2017 (PhD´s fourth year)

The following events brought relevant reflection to the development of my thesis:

1. Concerts: LAC Conference (2013), NIME Conference (2014), ICMC+SMC Conference (2014), Ars Electronica (2014), IRCAM (2016), MEQ Festival Montpellier (2017), Alte Schmiede Wien (2017)
2. Exhibition: Sónar Festival (2014), Ars Electronica (2014), TEI Conference (2016), CTM Festival (2017).
3. Talks: IRCAM (2016), Sussex Univ (2016), CTM Festival (2017)

Figure 6.1: Concert at Linux Audio Conference 2013 at IEM Cube (Graz)

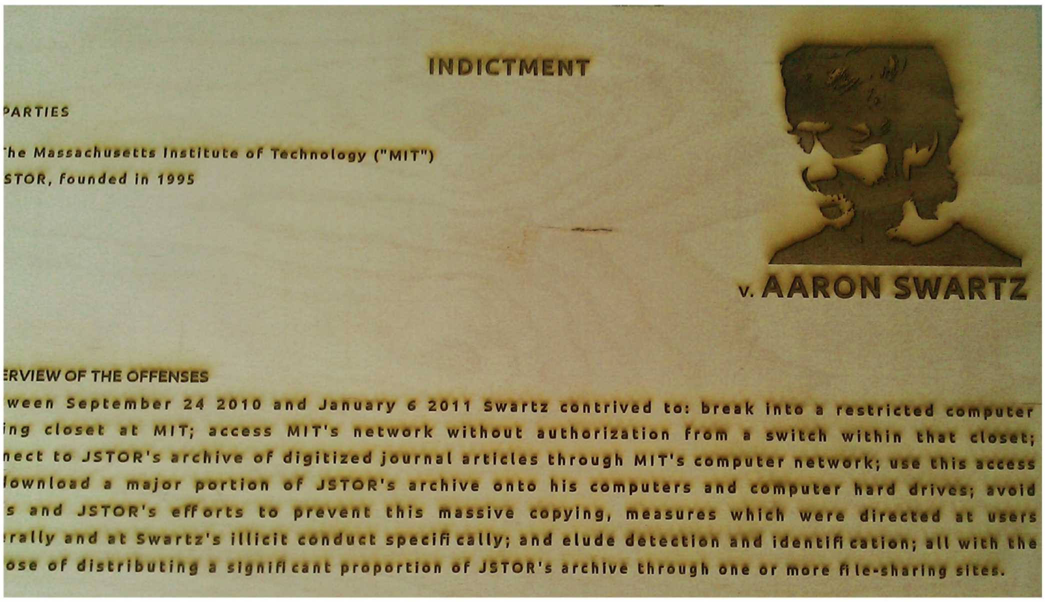


Figure 6.2: Surface Engraved for concert at Linux Audio Conference 2013

6.2. Description of Practice-Based Activities and Their Evaluation

The following activities are presented in chronological order:

- **Concert at Linux Audio Conference 2013, IEM Graz, May 2013. [REFLECTION IN ACTION]**

  As it was crucial to evaluate my initial hypothesis about the musical possibilities of the instrument I was designing, I prepared an improvisation for a first surface. Therefore, I proposed a concert to the Linux Audio Conference (LAC) 2013 organized by the *Institut für Elektronische Musik und Akustik* (IEM) in Graz. It was accepted for its public presentation in May 2013, eighteen months after beginning my PhD. The objective was also evaluating the real expressive possibilities of playing with a surface with the technologies and concepts I wanted to explore in the future (many still unknown at that moment).

  This performance, called *With intent to defraud*, was prepared for the trio Endphase (Alberto Bernal, Joao Pais, Enrique Tomás) which had to be reduced to a duo after the inability of Alberto Bernal to be in Graz on those days. The work is inspired by the last days of *Aaron Swartz*[1], and his efforts towards information openness on the Internet.

  The indictment and trial report was audio recorded and its text grammatically and semantically analyzed. Each word in the audio was marked with one of the eight possibilities parts in English speech (nouns, pronouns, verbs, adjectives, adverbs, conjunctions, prepositions, and interjections). Treating each word as an individual element, this pre-recorded audio was re-composed during the performance using generative algorithms controlled by my first *Tangible Score*, a wooden panel where Swartz's indictment and face was engraved (figure 6.2).

  The action on the surface, captured by contact microphones and analyzed by a machine learning algorithm served to change the category of the words triggered and spatialized in a cloud of sounds. In parallel, the sonic activity on the surface was sonified using concatenative synthesis. Joao Pais controlled the form of the performance and the spatialization of the work in the ambisonic space of the IEM Cube (figure 6.1). This work problematized the discrepancies found between the aesthetic appreciation of electroacoustic music and the harsh reality of the textual content. This sound performance had a duration of ten minutes.

  My concert was well received by this audience. Some of the comments and questions:

  - *How many sensors do you use? Are they pressure sensors? Where are the sensors?*
  - *Wow, it was really good, Aaron becomes a musical instrument and you played him.*
  - *How does the sound change playing at different parts of the panel?*
  - *What were you actually controlling in the performance?*
  - *Is the sound generated in real-time?*

  This performance along with the audience reception was systematically analyzed and its consequent reflection written down in my thesis notebook:

  - Those comments showed that the instrument structure, a combination of an acoustic and digital instrument, is expressive and can afford plenty of musical possibilities which I had to explore.
  - The audience did not understand well how the sonic content was controlled or how much the sound did or did not depend on that surface. Obviously, that was a weakness in my design. I could have used any other object, not this engraved panel, and the result would have been similar. An important question arose: How can I make the surface more connected with the musical work I improvise? In this case, the engraved text or photo did not suggest any tactile trajectory in particular. Can I compose that too?

[1] On January 6, 2011, Swartz was arrested by MIT police on state breaking-and-entering charges, after connecting a computer to the MIT network in an unmarked and unlocked closet, and setting it to download academic journal articles systematically from JSTOR using a guest user account issued to him by MIT. Federal prosecutors later charged him with two counts of wire fraud and eleven violations of the Computer Fraud and Abuse Act, carrying a cumulative maximum penalty of one million dollars in fines, thirty-fiveyears in prison, asset forfeiture, restitution, and supervised release. He committed suicide while under federal indictment for his alleged computer crimes.(source Wikipedia: `https://en.wikipedia.org/wiki/Aaron_Swartz` accessed on 26/11/2017.

– Unexpectedly, the visual aspect of the instrument represented an important factor for the success of the performance. Audience members directly understood that the artifact was artistic and critical. It was not only seen as a neutral controller. This marked a very important step in Tangible Scores. The interface itself, even if de-instrumentalized, should also be perceived as artistic.

– The way I performed it, scratching and tapping directly on Swartz´s face and indictment, resulted in a very communicative and embodied performance. I touched a cultural object and it communicated a political act.

– I did not incorporate any external controller (pedals, keyboards, MIDI controllers in general) to the instrument, and that was a positive fact for me.

– At this performance, only one channel of concatenative synthesis was implemented. This resulted in the creation of a monophonic instrument which could not perform harmonies or contrasting parallel textures. That was a technical constraint limiting the musical possibilities. This suggested the implementation of a polyphonic concatenative synthesizer.

- **Exhibition at Kunstuniversität Linz, May 2014. [EVALUATION STUDY].**

The celebration of the *Lange Nacht der Forschung* event in Linz was a great opportunity to develop my first evaluation study. I wanted to see how audiences perceive the tactile score and how they physically interact with the instrument. In particular the main objectivewas testing the validity of one hypothesis: if designing the engraved surfaces can suggest particular movements.

My plan was presenting a set of *Tangible Scores* in a dedicated space where audiences could play them. I recorded continuously the activity in the room as well as detailed interactions with a video camera and a photo camera. The event was open to the public, then then expected audience could be anyone. Anyone could come and play, regardless of musical education, age or cultural background.

Therefore I decided to design and engrave five tangible scores with very different (almost complementary) tactile patterns. That would allow me to explore three different aspects of this study: tactile and visual appearance, semantics of the engraved patternsand their sonic mappings. I created all the graphic designs using the *Generative Gestaltung* library in the programming environment *Processing*. Then, they were engraved with a laser on 70 x 40 cm plywood panels in the *Kunstuniversität* Linz.

VISUAL ASPECT	SONIC CONTENTS	PATTERN DEEPNESS	SCORE FIGURE
Orthogonal Complexity	Sound Collage	Varied and combined	6.3a
Punctual Cells	White Noise	Varied and combined	6.3b
Moving Threads	Water torrents	Evolving	6.4a
Text Following a Form	Human Voice	Similar	6.4b
Neural Network	Artificial Tones	Similar	6.5a

Table 6.1: Design parameters chosen for the Tangible Scores built for the Lange Nacht der Forschung

The following tangible scores were created:

– One exploring complexity in scale. It is made of orthogonal lines separated at various distances, from a tenth of milliliter until two centimeters. I also used various various depths (6.3a).The sonic content used for the corpus was a thirty minute performance of John Cage´s *Fontana Mix*, mostly a collage of many radio recordings.

– One exploring very punctual patterns distributed randomly over the surface. It was created out of a generative algorithm simulating living microorganisms (6.3b). The corpus was a noise performance played by the author of this thesis. Timbre could vary substantially but sonority would stay always noisy.

– One built especially for testing the semantic relationship between visual and sonic contents. I created multiple lines with sinusoids, in the form of threads, suggesting horizontal movement (6.4a). The sonic contents used was water torrents recorded in Iceland. Timbre was quite limited in this case.

- One based on textual contents. I engraved the first sentence of Goethe´s *Faust* following complicated trajectories and sizes (6.4b). The sonic contents are a vocal recording of Faust taken from archive.org. Sonority would be thus always stay related to standard vocal frequencies.
- One for exploring structural complexity, based on a network visualization which creates a star-like pattern (figure 6.5a). The aim was testing if users would follow the local and global complexity of the network. Sonic contents were recordings of tones produced when old modems called providers to connect to their Internet networks. Timbre was similar but frequencies could be very different.

These patterns are summarized in table 6.1.

In addition for this exhibition, I had to develop and deploy my first version of a polyphonic concatenative synthesizer. However, each of the boards would incorporate one microphone and produce an independent but monophonic (in terms of synthesis) outcome. This was a limitation but this study was built for testing the hypothesis of whether it is possible to inspire particular movement from the exploration of a tactile content. Therefore, this limitation was acceptable.

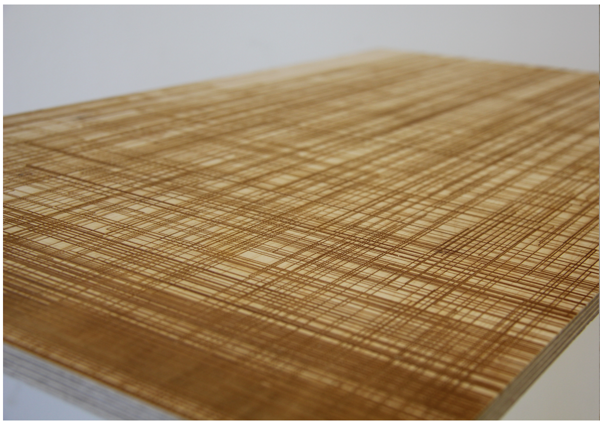
The tangible scores were mounted on camera tripods and presented tilted and forming a circle. That helped visitors to understand from where they had to play the instruments and emphasized communication while they performed.

These were some of the conditions of the evaluation study:

- An info trainer was hired to inform people about the project but with the important condition of not training our audience how to play. His role was more about giving background information and only directing the visitors that they were allowed to touch the surfaces of the objects, as it is normally not allowed to touch artifacts being exhibited in a gallery.
- A video camera was installed in one corner of the room and the author carried a photo camera (also with recording capability) to capture detailed interactions.
- The info trainer asked the public about their level of expertise in music. That was captured by the camera.
- The session lasted five hours.
- The five *Tangible Scores* were presented almost in a circle for increasing communication among players. Every *Tangible Score* reproduced sound through a different speaker in the room. Thus there were five speakers (Yamaha Msp5).

These were my results:

- From the video:
  - 327 persons entered the room
  - 181 persons (55.35%) actively engaged with the instruments (they played two minutes or longer), and of those, 42 visitors (23.204%) had experience in music or playing instruments. Five children engaged with the instruments, all younger than eight years old.
- From the video analysis, users played every score following the tactile patterns engraved and in a very similar way. The Tangible Scores were able to suggest or inspire gesture. This validates my hypothesis. Users understood that the tactile information was relevant was relevant along with following the patterns. They read the the choreography of movements inherent to the artifact.
- In tangible score one (orthogonal line patterns), users created ample gestures towards the horizontal and vertical, never in diagonal. Visitors followed the structures of these lines and decided their trajectories at the intersections of the lines, never in between. In the tangible score two (granular tactile material), visitors explored very short sonic gestures, jumping from one part to the other randomly, playing more with the borders of the granular forms as there was no connection between the engraved material. In the case of the tangible score three (sinusoidal threads), visitors played following the lines

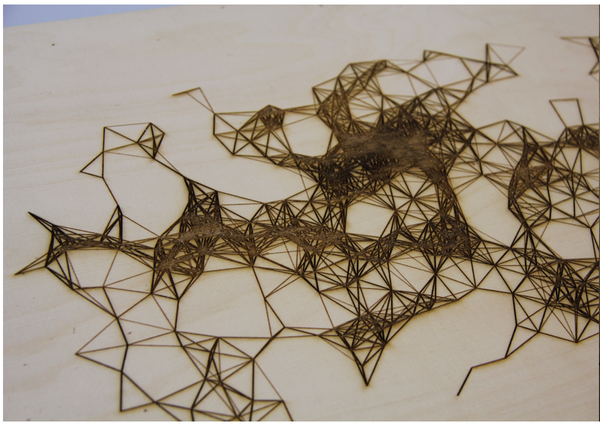


(a) Tangible Score one

(b) Tangible Score two

(a) Tangible Score three

(b) Tangible Score four



(a) Tangible Score five

(b) Installation Space

Figure 6.6: Visitors informed by the info trainer (in blue t-shirt)

Figure 6.7: Child playing a score. They all showed difficulties to play with their fingers benefiting playing with their hands

but also explored them vertically, as if they were strings. In the case of the fourth score (Faust's text) visitors played both with the contours of the letters and with the graphic shape given to the sentences. Finally, the fifth tangible score (network) visitors played with the lines but also with the most complex nodes, even destroying some part of the engraved material.

- Visitors usually began the exploration touching first the center of the engraved patterns. From there, they followed intuitively the patterns. Once they gained experience, they started to touch other parts of the panel.

- From studying the videos, it is my impression that the eye controls many of the movements of the hands.

  Visitors looked over the panels, almost like they were reading them, following the lines with their eyes. Then, movement is reinforced by sound with a causal relation (a tactile gesture creates a sonic gesture which is recognizable). But the tactile is not only another type of feedback. It also produces decision-making. When visitors' hands are on the wood, they cover the pattern and it is the haptic which informs what to do at a smaller scale: continuing or stopping, changing direction or keeping it, etc. The haptic creates 'accidents' in the trajectory that the eye wanted to follow.

- Visitors understood the causal relationship between touching and sound produced. But they did not understand the difference between playing on one part of the panel or at another. As there was only one microphone per panel for analyzing the sonic input, sound was only controlled by the timbre of the overall sound within all the panel.

- Visitors were not so used to scratching instruments or surfaces: for many of them it was not easy to produce sound at the beginning and the info trainer helped them. Wood was evaluated as too rigid for many visitors.

- Many participants asked if they could play notes or scales. In general they understood the sonic identity of every surface, but they also wanted to have some capacity to change the frequency of timbre. This suggested again the need of some technology to detect the area of interaction.

- The aesthetic of the sonic contents was too too abstract and sometimes too harsh. This was not well received by many visitors who were not used to listen to this type of sounds. This suggested that, in the case of open public presentations, the contents would need to be designed artistically taking into consideration other more popular aesthetics as well.

- Often, when visitors started to play, too loud sound textures were synthesized without correlation with the energy used to touch. The response was like playing a piano which has highly sensitive keys. Thus, it suggested a logarithmic control of amplitude which was still not implemented and the incorporation of sound compressors.

- In general, the format of presentation, with the scores on camera tripods, was found interesting and useful. But after two hours they became less stable and I had to reattach the structures. That suggested a re-design of these score stands.

- The graphic scores were well received and attracted visitors to engage in performance. Many visitors were interested in knowing how the scores were designed and fabricated. Many emphasized that it was an appealing idea mixing complex digital designs with fabrication on wood.

- Many users requested the possibility of playing long sustained textures without the need of being always touching. They suggested the implementation of an attack, delay, sustain and release (ADSR) envelope of sound.In these iterations there was no reverb effect applied to the sonic results which were often perceived as too dry.This suggested the incorporation of reverberation potential

In conclusion, the hypothesis that these artifacts could suggest specific gestures was validated. The instruments were quite well understood but quite a lot of work had to be done in order to make the instrument more interesting sonically and in terms of interaction. Finally, I discovered that the materiality of the artifacts had to be further explored.

- **Exhibition at Sónar Festival 2014. [REFLECTION IN ACTION]**

  In the context of an exhibition of Interface Cultures projects at Sónar Festival in Barcelona, I was able to exhibit Tangible Scores. Because of the greater number of visitors to Sónar, the objectives of my evaluation were:

  - testing the project with a larger audience scale (thousands of visitors)
  - testing the polyphonic control of the synthesis.

  The festival lasted only three days, and the project was exhibited from 10h to 20h, each day. It was impossible to count the number of visitors, but surely at least two thousand people could see and play the project (approximately seventy visitors per hour). I presented only two tangible scores which were exibited at Sonar. For this setup, I incorporated three microphones to the first score and two microphones to the second. Each of these channels was independent and controlled by a separate concatenative synthesizer. Then, when playing closer to a microphone, the synthesis associated to that channel would sound louder than the others. It produced a kind of natural panning effect. Without having to locate a performer's hand, timbre changes depending on the distance to these microphones occurred.

  In Barcelona, I used the same sound materials as in Linz, but I changed the synthesis parameters to make the sonority more attractive to the visitors. I also added reverb to the signal generated through Pure Data with the internal effects of my sound-card.

  These were the conclusions:

  - Instrumentality: again, many people could not play well because the material was too rigid. Only those with longer nails could better activate the instrument.This reinforced the use of other materials for the future.
  - Multichannel configuration: the addition of more channels per panel added a new axis, a new dimension. Timbre changed along the surface. Visitors explored the surface and compared the sounds produced at different locations and inspired very interesting mini concerts. This fact suggested further exploration of this design strategy.
  - Performativity: in the context of Sónar, many visitors were musicians or at least, not newbies to electronic music. Thus, many people played tangible scores as an instrument to create rhythms and beats. I was then tested as a valid percussive instrument.

  Additionally, I also gave a concert at the the Sónar+D stage (figure 6.8). It was a short improvisation with the scores presented at the exhibition.

- **Concert at NIME (New Interfaces for Musical Expression) Conference, July 2014. [REFLECTION IN ACTION]**

  In 2014 I submitted a paper and a concert to the NIME Conference 2014 organized by Goldsmiths University in London. My publication was accepted as a long-paper format and I would play at the University theater. I decided to play the same two scores I had at Sónar Festival as I was not able to bring them all (five) to London. I prepared a live improvisation as in Sonar, but one surface had three contact microphones and the other two microphones. This concert would allow me to test how much the use of a polyphonic input could inspire musical ideas.

  This prepared improvisation was structured in three parts with durations of two minutes, five minutes and three minutes respectively. The system was programmed to automatically change the parameters of the instrument at specified moments and without my intervention.

  I prepared the improvisation during a period of eight weeks. There were days which were dedicated entirely to performance practice and many other days dedicated to programming and configuration. When one works towards preparing for a particular concert, many musical intentions and expectations collide with the instrument's actual possibilities. This serves to develop the instrument towards a specific musical use. Then, my musical plan guided the programming. This process helped to design new features of the instrument. In particular:

  - Sequencing parameters in time

  - Saving configurations of the instrument as presets
  - Triggering other sound materials (audio files) with the instrument
  - In general, modifying the synthesis to my needs, forcing it to behave as I wanted in particular moments of the performance.

  As I would play Tangible Score on a larger and elevated stage, it became necessary to film my performance with a camera and project it on a big screen (figure 6.9). The concert went well and I could improvise during those ten minutes appealing musical contents. The impression after this event: I was personally happy with the musical result of the improvisation. The fact of structuring the performance allowed me to use less material and to refine it, contrasting one part with the others. My strategy was choosing one sound gesture and repeating it with variations during each part. I was able to suggest interesting profiles of form using dynamic range and density. Many attendees of the conference commented to me that my performance was very expressive and interesting in terms of sound content.

- The introduction of the polyphonic synthesis allowed ample possibilities for improvisation. Depending on the distance to the contact microphones, different textures were naturally mixed and merged in an organic fashion. This suggested that it would be also possible to spatialize the output of a score.

- Some issues with software complication resulted in my having to restart my computer when I was to start my performance.This suggested the need to simplify my software structure which had been using two instances of Pure Data.

- Another weak aspect was that the instrument was still mostly a prototype and it was not prepared for traveling and setting it up quickly on stage. Mounting the tripods and surfaces took too much time. This suggested adopting new solutions for the physical design of the electronic components and the stands.

- **Exhibition and Concert at Ars Electronica Festival, September 2014. [REFLECTION IN ACTION]**

  In the Ars Electronica Festival 2014 I was able to exhibit *Tangible Scores* as an installation and also give a concert (figure 6.10).

  The installation format was quite similar to the one prepared for the exhibition in the Kunstuniversität Linz. However, the system in general had evolved a lot since that moment. The quality of sound, the sonority of the instruments and the stands were improved. Also the sonic identity of the installation was changed towards producing sounds which could be combined better in harmony and volume. This allowed the installation to be better understood by the audience.

  The concert was in essence, quite similar to the one given in NIME two months before. However, I could improve a few aspects of the instrument and my performance. In particular:

  - the physical stability of the stands and scores on stage
  - my performance was structured in time differently, allowing a deeper development of the gestural motifs which I could play.

  The concert, again ten minutes, was presented at the Raumschiff space in the main square of Linz (Hauptplatz). The installation would run for five days at the facilities of Raumschiff in a dedicated room.

  These were my conclusions:

  - Instrumentality: again, many people could not play well the scores because they are not used at playing an instrument with their nails, as a guitarist would. Those who could, engaged well with the instrument.
  - Sonority: the decision to change the sound material of the installation evaluated as positive as the visitors engaged with the scores over a longer period of time and more intuitively.
  - Performativity: Playing of the instrument was very expressive as I was able to develop my musical plan. The software and hardware operated flawlessly for this performance.

Figure 6.8: Concert at Sónar Festival 2014 in Barcelona

Figure 6.9: Concert at NIME Conference 2014 at Goldsmiths London

Figure 6.10: Concert at Ars Electronica 2014

Figure 6.11: Performing at ICMC+SMC 2014 in Athens

- **Concert at ICMC+SMC (International Computer Music Conference + Sound and Music Computing Conference) in Athens, September 2014. [REFLECTION IN ACTION]**

  At this performance, only two weeks after Ars Electronica Festival, I decided to repeat the setup. But this concert was very helpful to reflect about many aspects of the previous performance. The big stage of ICMC at Old Stock Market of Athens had an over-sized PA system (figure 6.11). My performance was prepared to be shown together with a video projection in the background but for technical reasons, the equipment of ICMC could not connect my video camera to their projectors.

  The main reflections after this event:

  - Tangible scores were now more solid but quality of sound became my problem. After playing through powerful audio systems, I realized that the quality of my sound could be much improved. I was missing bass and sometimes a better feeling of the sound material. It was mandatory to add mastering effects, beyond the basic equalization which I had implemented.

  The months that followed were dedicated to checking and improving the sound quality of the instruments. checking and improving the sound quality of the instruments.

- **Tangible Scores in Dance. Bagatelles, a flamenco dance for the Biennial of Netherlands, Amsterdam and Rotterdam, January 2015. [EVALUATION STUDY]**

  In context of the Flamenco Biennial of Netherlands, I was invited to create a full spectacle for flamenco and electronics together with the dancer Ana Morales. I called it *Bagatelles* and it would have a duration of twenty five minutes. In Flamenco, dancers tap with special shoes on wooden floors creating complex rhythms which counterpoint live music.

  I decided to convert the flamenco floor into a tangible score for exploring new types of embodied interaction. The floor was going to be explored from two approaches: rhythmic tapping and textural expression using any part of the body. Therefore, the main question was how could I bring a tactile score to the floor. Then I thought, instead of creating a fixed tangible score like the engraved wooden panels, it was more interesting creating a space of dynamic and generative tangible scores. For that I decided to use a material often used in theaters: white sand. With the sand, we could create dynamic tangible scores on top of a normal flamenco floor. The dancer would follow this score for dancing. Her movements would be captured by contact microphones and converted into sound using my concatenative synthesizers. And finally, the dancer could re-build these scores at any moment (figure 6.14).

  Eight contact microphones were distributed around the dancing area (6.13). In the second part of the performance, five kilos of white sand were distributed onto the dance floor. The dancer improvised movements out of the physical and sonic affordances of the sonic and tangible space created.

  From a researcher's point of view, I had the possibility of recording, writing down and later, analyzing the process of production. I was able to annotate dancer's impressions during four weeks of rehearsals. The on-stage performances were also video recorded.

  At each step of the production, Ana Morales had complete freedom to create different choreographies and sonic patterns. Her comments and impressions were critical to develop the interactive system and also for evaluating it.

  During the production of this work I faced some difficulties which are interesting to note:

  - The dancer explained her difficulties to me, playing the dual role of music player and dancer. Her choreography of movements was created from her embodied relationship with the sand. But these movements also made sound. Therefore, there was no possibility of dancing to the music that was being produced. She commented to me that usually she gets inspired by music for developing a choreography. But in this case, sound was produced at the exact moment of her movement (or a few milliseconds after). For this reason, we decided that it was necessary to add another musical voice to this section. I decided to play the sruti box for suggesting a musical and expressive direction in parallel to Ana's interaction with the floor. Therefore, my music created a musical atmosphere that also inspired her movements.

Figure 6.12: Performing Bagatelles at Muziekgebow Amsterdam

Figure 6.13: Stage for Bagatelles, contact microphones are installed in the front of the wooden floor

Figure 6.14: Tapping with flamenco shoes and sand

- Improvising with the physical affordances of sand only worked well when the dancer had a good ability to hear. Without it, the causal relationship between movement and sound was broken. On big stages, where monitors can be located far away from her, we had to install additional hidden monitors.

Since 2015, we have performed *Bagatelles* several times on important stages like the Muziekgebouw Amsterdam (figure 6.12), at festivals like *November Music* and venues like the national theater of Ljubljana. This section of the piece, when sand is incorporated, has become the most introspective. Ana Morales always saw it very intimate and sensual. The circle of sand around her creates a private space for her imagination. Instead of trying to draw or represent anything on the floor, the sand becomes the visualization of her movement. She uses all her body on the floor, which seems to resonate with the materiality of the sand and the abstract sound textures she produces. When the section finishes, the sand becomes the trace of her movements and her body. And Ana intuitively decided that the perfect end for this section was tapping aggressively on top of those traces.

In the context of this research, this work has shown the possible application of both the notion of tangible score and my particular technical implementation in the field of dance. Like in the case of Forsythe's *Choreographic Objects* the material afforded enaction in the form of movement and sound.

- **Exhibition at TEI (Tangible, Embedded and Embodied Interaction) Conference 2016 in Eindhoven, February 2016 [REFLECTION IN ACTION]**

For the Arts Track of the tenth Tangible and Embodied Interaction Conference (TEI) 2016 I submitted a paper describing the installation *Tangible Scores*. As the paper was well reviewed, the installation was presented at the Senate Hall of the technical university of Eindhoven (TU/e) together with other six artistic projects.

The objectives in this case were:

- Receiving feedback from experts in the field of tangible and embodied interaction. In fact that would be the first time presenting in a strictly academic context.
- Improving the sonic contents of the installation. In this case I implemented it through the incorporation of intermediate software adding compression, equalization and limiting of the sound output. This intermediate software was *Ableton Live* which received the sound synthesized with *Pure Data* via a sound server called *Soundflower*.

The installation was a success in terms of attention and interest generated. The Conference chair, Caroline Hummels did not stop recommending and bringing visitors to my installation, often guiding them personally. Hiroshi Ischii, director of the MIT Tangible Media Group also wanted to share opinions. We had met at the previous Ars Electronica Festival too and he evaluated that he engaged better with my installation this time.

In conclusion, the sonic quality improvement could not be compared by most of the conference visitors, but I realized how this actually benefited to the overall experience. It was like upgrading your first study guitar to a concert one.

- **Experts Evaluation Workshop, Kunstuniversität Linz, March 2016 [EVALUATION STUDY]**

In 2016, after having already performed, lectured and exhibited this project at relevant academic conferences and art and music festivals, I thought it was necessary to think of an evaluation from another perspective. Usually, in the context of a concert or an exhibition, feedback about my project came from people who could only experience the instruments for a few minutes. It was then crucial to gather another type of input, more specialized and profound. For that reason I organized a one day workshop with experts in my University.

This workshop had been the most in depth evaluation of *Tangible Scores* from external viewers until that time (March 2016). Five experts (Thomas Gorbach, electroacoustic composer; Volkmar Klien, composer and sound artist, professor or composition; Fadi Dorninger, live electronics performer; Andi

Kurz, sound artist; and Günther Gessert, live electronics performer) were invited to a double session of five hours. The objective of this workshop was presenting the state of the art of tangible scores as well as four different configurations of the instrument-score which could be played by the participants in different rooms. In particular, I wanted to obtain inputs on:

- their perception about the concept of inherent-score
- how they personally would approach tangible scores when performing or composing
- which parts needed to be improved or further developed
- artistic applications

The whole workshop was recorded on video.

The sessions started with a one hour presentation on the theoretical background of tangible scores. It served to trigger the first discussions. The paradigm of the tangible-score and inherent-score were understood and approved. They were recognized as inspirational for themselves and potentially for other practitioners. They also commented that the instrument-score was a notion that they also had perceived at some moment of their practice.

Then, the participants could take part of practical sessions playing various configurations of tangible scores. I allowed them to have ample time to practice, with dedicated sessions of up to one hour for each of the configurations of the instruments.The embodied interactions with the instruments were also filmed.

This is how the instruments were presented:

1. As an installation: repeating the setup of the TEI Conference (five scores).
2. As a performance: repeating the setup of the ICMC Conference (two scores).
3. As an evolving tangible score: one smaller wooden score (one of the first prototypes) in which its configuration of presets changes automatically every thirty seconds. The objective was testing if this change influenced a compositional or an instrumental intention.
4. As a decomposed instrument: I created a tangible score made of fifteen small other tangible scores (square pieces of five centimeters), of various materials (wood, plastic, paper, foam). The participants were asked to take five and combine them. The participants had to choose the sound material for each of those pieces.

After experimenting with the instruments in this configurations we had a long session of reflection. Here I summarize it:

1. For Volkmar Klien, the instrument lacks sound evolution in relation to gesture. He expected more possibilities of transformation as one makes a gesture. This suggested the possibility of implementing some type of temporal enveloping of the synthesized signal.
2. For Dorninger, Klien and Gorbach, the granular nature of the synthesis is very evident. It makes the sound sometimes to be perceived as if it was low-fi. This was especially clear when the synthesizer used very small sizes of grains. This suggests the exploration of other synthesis which could afford similar control of sound but with better quality.
3. For all, the use of less rigid materials was a specific request. If the instrument was especially created for touching and scratching, other materials would suggest easier ways of activating it. That would also improve the sensitivity of the instrument.
4. For Dorninger, it was interesting to explore materials allowing control with pressure and velocity.
5. For all, the variation of timbre along the boards was not totally solved. They suggested the incorporation of other sensor technologies to solve it.
6. Kurz suggested the addition of some other controller, like a pedal, for controlling the variation of timbre.
7. For Gorbarch, Klien and Dorninger, the use of temporal change of parameters suggested a compositional structure. For Gorbach, that inspired him to the sensation of score. That gave him the sensation of working with a score.

8. Klien suggested extending the physical part of the instrument to a larger scale. This suggested the possibility of creating bigger surfaces or modular pieces.
9. For all it was important to count with a toolkit to create tangible scores. They all showed interest in working with tangible scores in the future at another workshop.
10. They suggested the incorporation of an graphic time sequencer for changing the presets of the instruments.
11. Gorbach suggested the spatialization of the synthesized sound among a number of speakers.

Finally, I wanted to evaluate Tangible Scores in a more quantitative way. I proposed evaluating the project using Birnbaum´s (2005) analysis space. It is a visual representation qualifying seven dimensions of musical interfaces, namely: required expertise, musical control, feedback modalities, degrees of freedom, interactors, role of sound and distribution in space. The form given to the workshop participants and the range of values used to evaluate Tangible Scores can be observed in figure 6.15

Name:

Birnbaum Dimensional Space Analysis	*Write in this column*
REQUIRED EXPERTISE (level of practice needed to play: 10 extensive - 0 none)	
MUSICAL CONTROL (level of control the user exerts). Select only among these categories: 1. timbral level 2. note level 3. musical process	
FEEDBACK MODALITIES (degree of real-time feedback, e.g visual, auditory, tactile, kinaesthetic: 10 multimodal – 0 low output)	
DEGREES OF FREEDOM (number of input controls available: 10 many – 0 few)	
INTERACTORS (number of people involved: 10 many – 0 one)	
ROLE OF SOUND (10 artistic/expressive — 5 environmental — 0 informational)	

Figure 6.15: Birnbaum´s dimensional space form

I collected the information and calculated the median of their evaluations. The results are (see figure 6.17):

– Required expertise: 1.6
– Musical Control: 1.8
– Feedback Modalities: 6
– Degrees of Freedom: 5.6
– Interactors: 3.2
– Role of Sound: 8.2

I interpret these results as follows. Tangible Scores are perceived as an instrument not requiring any expertise and our capabilities of control deal mostly about playing with timbre, not with notes or musical processes. Tangible Scores give a medium multi-modal feedback. Participants remarked that it was mostly tactile. Their degrees of freedom are also seen at a medium scale, the instrument would not afford varying many parameters of sound. Tangible Scores are seen as an instrument for a reduced

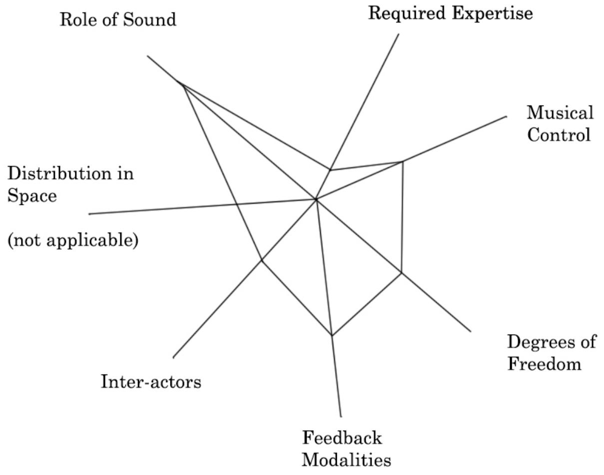


Figure 6.17: Birnbaum's diagram for Tangible Scores obtained from the workshop

number of players, although not only for one. Finally, the role of sound is perceived between environmental and artistic, the sound Tangible Scores produces affords artistic uses.

In order to compare these results with Birnbaum´s, the next two captions show how the Hands and the Theremin were analyzed at the original paper.

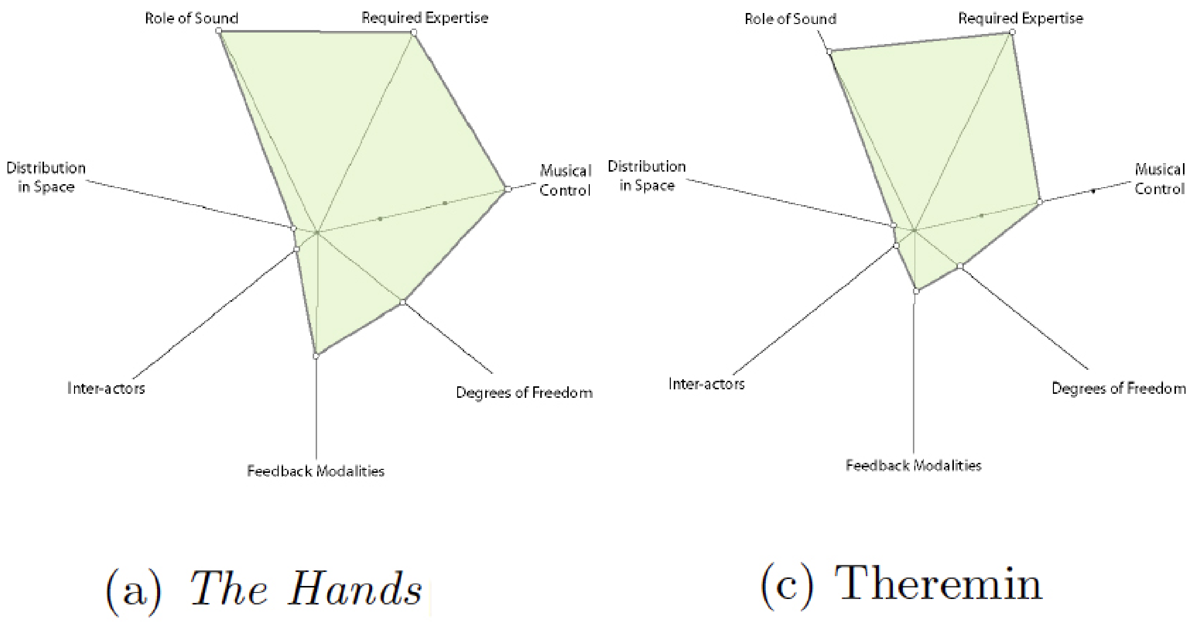


Figure 6.16: Birnbaum's diagram for The Hands and the Theremin

After this workshop I prepared a list of new features to explore and program:

1. The possibilities of sound evolution along gesture were explored using machine learning. I used the software *Wekinator* to see if I could train a neural network and recognize the evolution of parameters of particular gestures. Then, I would be able to envelope the sound correctly. However, this was not an easy task as I couldn't find a suitable way to detect the beginning and end of a

gesture. I also needed an algorithm for prediction. Therefore, I left this single feature for future work.

2. I decided to more actively explore paper as a material, after this workshop.It affords a different haptic relationship, it is not rigid and it is warm. Then, I started casting and embossing paper to create profiles of paper or tangible-scores made of paper. These scores are described at section 5.9.3 of this thesis.
3. I incorporated a layer of capacitive sensing to the new paper Tangible Scores. That would allow me to detect the locus of interaction. This is explained in section 5.15.2
4. I released a first beta of the Toolkit for creating tangible scores. This is an user-friendly application which could be tested by other developers and musicians. The requested graphic sequencer was also incorporated to this Toolkit.

- **A Tangible Scores concert played by other performers, IEM Graz, May 2017 [EVALUATION STUDY]**

  In 2017, my intention was evaluating *Tangible Scores* through the musical practice of other performers. As it happens, the perfect opportunity appeared without searching for it. Visda Goudarzi, researcher at IEM Graz, challenged me to prepare a version of *Tangible Scores* to be played by the *intra-sonic* duo (of which she is a member) in the IEM CUBE of Graz (figure 6.19). This challenge was received at the end of March of the same year. I accepted and prepared four interfaces, two made of casted paper and two made of wood.

  As the *intra-sonic* duo had to prepare the concert alone, I created a *plug & play* version using embedded electronics. Performers, in theory, only had to switch on the system and play. As it is explained in section 5.10.2, I used two Odroid XU4 mini computers.

  I understood this challenge as the perfect opportunity to evaluate my instruments-scores after musical practice done by others.

  For this challenge I decided to provide the performers with the minimum information about my project's theoretical background. My objective was to allow personal evaluation and let the instrument scores communicate my ideas.

  However, it was necessary to explain the technical aspects, so I agreed to give an introductory session of two hours to dealing with practical training.

  I learned that we could only meet two weeks before the concert in order to give an introductory session. That was not good news as I was sure the process of learning the instrument would take a much longer time. There was no other alternative and we went ahead with the plan.

  At my studio, I programmed the system for three weeks and I tested its final configuration for one week. After many technical tests, the system was ready for the performance. However, as it happened, performers found technical problems, even at our introductory session. Apparently, the system was not starting consistently always.The issue is that I did not incorporate any display for letting them know if the system was ready. Or even to debug it.

  This was a primary lesson to me: embedded systems have to be also robust for the rehearsal phase. During their rehearsals, the duo tested almost every combination of parameters in intricate ways I did not expect. Then, they found bugs I was not aware of. This led them to an impression that the system was unstable. It was not that the programming was incorrect but they felt that the Odroid computers were unstable. For that reason we had to re-implement (through Internet video conference) all the systems to run on Mac computers, one day before the concert.

  These technical complications resulted into a lack of rehearsal time for the duo. Fortunately, the last rehearsal was productive, without technical complications. The intra-sonic duo made such a great effort to play *Tangible Scores* (figure 6.18). Unfortunately, during the concert I perceived how they were still trying to understand many aspects of the work which were not clear. From a creative perspective, the concert did not succeed. However I got many conclusions and reflections:

  – the decision giving them the instrument two weeks before the concert was too risky. I needed further technical tests and rehearsals. That was a mistake I made which complicated the development of rehearsals and of the concert.

Figure 6.18: Setup for Tangible Scores concert at IEM Graz

Figure 6.19: Intra-Sonic duo Playing at IEM Graz

- implementing a closed embedded system which performers could not debug was also a wrong decision. Technical components fail and performers even can not communicate where the error was. They could only communicate that it simply did not work.
- a prior communication with performers about the basic aspects of the work has to be performed. Without that, real life constraints (time, agenda, etc) inhibit intimate and more profound exploration with the instrument.
- since then, I found it necessary to give a workshop on Tangible Scores to other performers. One issue I found is that they understood the instrument but were not prepared to manipulate it. They did not know how articulate their fingers or arms on the instrument. Obviously, they had to learn technique as with any other instrument. The idea that one can acquire the skills to play digital instruments in a few days is false.

In conclusion, this evaluation process was extraordinary valuable. It made the instrument be much better than it had been. It also made me understand many of the real life constraints pure designers have. Many software and hardware parts have been re-built but I am still trying to find an adequate way to inform performers about the status of the machine. And fortunately, new performances with the *intra-sonic* duo have been planned.

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

- Learnability. The design of the interfaces was rather straightforward, allowing for a high degree of learnability. While mastering the instruments might take some time, interaction with them is intuitive and effortless already in the first sessions.
- Explorability. Due to the combination of tactile interaction with a variety of engraved graphical designs, the interfaces also demonstrated a high degree of explorability. Each interface showcased a different graphical design, consisting of several engraved areas that enabled a plethora of gestural and sonic interactions.
- Feature controllability. In contrast to learnability and explorability, the degree of feature controllability – or at least perceived controllability – was evaluated as rather low. The intention of imitating the input signal through the use of Corpus Based Concatenative Synthesis (CBCS) (Tomás and Kaltenbrunner 2014) was not directly observable from a performer's perspective. This may be attributed to the fact that the composition in hand was based on a fixed time structure, each section of which used different sound samples as an input to the synthesis engine. As a result, no direct relationship could be established between the performative gestures and the sound samples chosen by the algorithm. The sound synthesis parameter with the highest degree of observable controllability was that of amplitude, which was in a direct – yet non-linear – relation to the amplitude of the input signal.
- Timing controllability. Due to the absence of a score that requires strict timing this parameter was omitted from our evaluation.
- Communication of compositional instructions. It is important to note that the performance that this evaluation is based on was the first performance of Tangible Scores by someone other than the composer himself. Because of this, and due to the lack of a score, the first rehearsals were both challenging and engaging. After a short demonstration of the instruments by the composer and a discussion on technical and design aspects, the performers participated in a "naïve rehearsal" (Hsu and Sosnick 2009), without receiving any prior information on either the sounds or the mapping strategies employed in the piece. This had the purpose of allowing the performers to explore and experiment with the instruments without feeling restricted by compositional instructions. However, after several "naïve rehearsals" it became clear that a performance/demonstration by the composer would be necessary, in order for the performers to gain a better understanding of the expressive capacities of the instruments. During this demonstration, the performers were able to identify a "vocabulary" of gestures, developed by the composer over his long-term engagement

with the instruments, and subsequently integrate these gestures in their own performance. While this form of communication proved to be quite efficient, the existence of some form of documentation – verbal, graphical or otherwise – of these gestures could have made the composition more accessible to the performers, while providing an alternative for the composer's physical presence at the rehearsals.

- **Tangible Scores Evaluated Through A Collaborative Design Workshop (JUne 2017) [USER-CENTERED EVALUATION]**

  The same concert given by the intra-sonic duo in Graz was evaluated using a different method. The duo decided to organize a collaborative design workshop where participants could evaluate and re-design Tangible Scores. This section is written from the perspective of the intra-sonic duo.

  In particular, we adopted a User-Centered Design (UCD) approach consisting of two steps. We first asked the volunteers to participate at the concert, listen and observe. We then conducted a one day workshop for brainstorming, creating imaginary scenarios, and sketching possible future tools for performance inspired by Tangible Scores. This study follows a UCD approach. UCD is "a broad term to describe design processes in which end-users influence how a design takes shape" (Abras, Maloney-krichmar, and Preece 2004). In this case, the end-users are electronic and computer music composers and performers. We adopted a UCD approach to better understand current practices of the composers/performers and to conceptualize a tool that addresses their needs.

  Collaborative workshops are defined as "collaborative design events providing a participatory and equal arena for sharing perspectives, forming visions and creating new solutions" (Soini and Pirinen 2005). Due to the collaborative and participatory nature of workshops, they were chosen as a key element of the adopted methodology. A one-day, 6-hour workshop was conducted, aiming to produce sketches of novel ideas for Tangible Scores. The first part of the workshop focused on the analysis and brainstorming about the Tangible Score interface and performance at the concert. The second half of the workshop was focused on creative ideation and generating new interaction ideas for Tangible Scores. During the workshop, participants went through a cycle of design process: analysis, prototypes development and evaluating. Tangible Scores were analyzed in terms of: ergonomics, interaction, expressiveness, mapping, and aesthetics.

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

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

  First they talked in speed dating format. Two by two and then switching discussion partners as soon as the timer rang. Then they were given some quiet time to think and write down their answers and sketch their ideas.

  Furthermore, we used "bodystorming" (Oulasvirta, 2003), i.e. play active situations with objects to test scenarios, or "sound drama" (Hug, 2010), i.e. the scenarios are staged with objects using audio post production. During bodystorming, one in each pair acted and the other observed and took notes. The notes and sketches were later shared during a short discussion by all the workshop participants. These exercises were complemented by sonic prototyping using sound processing in SuperCollider. They created sound textures using granular synthesis to emulate the sounds created by the composer but having their own control structures over the modulations in the synthesis.

  The intention of this workshop was getting into more details of composition and sound, therefore, we decided to gather an expert group of participants. This option was preferable than creating a random group of volunteers. Six composers/music technologists were asked to participate in the concert and the follow up workshop.

Figure 6.20: Collaborative creativity workshop session: a group came up with moving tangible interface.

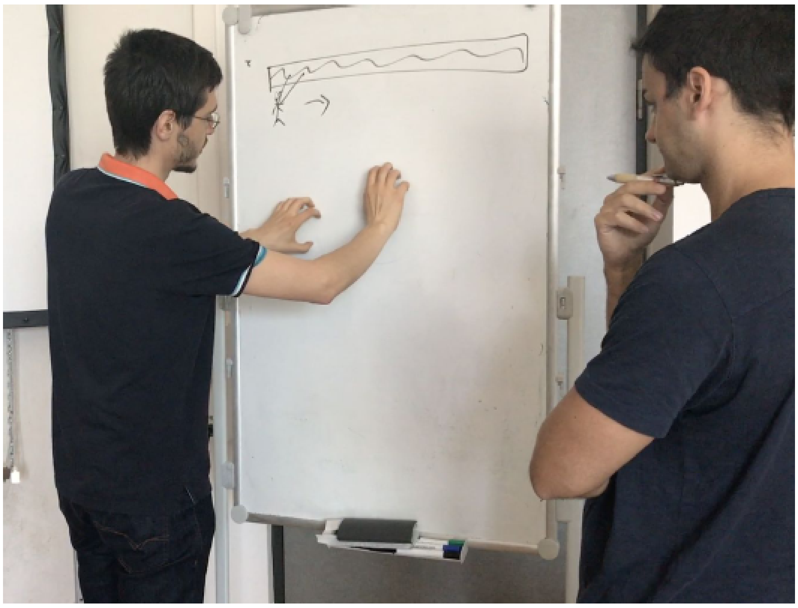


Figure 6.21: Collaborative creativity workshop session: Another group suggested a transparent and standing tangible interface to make it more visible for the audience

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

– Interaction: The participants found the interface physically very appealing and easy to use and interact with. The hand movement on scores seemed very intuitive and scratching the scores very organic. Additionally they suggested to use hands in more ways than just scratching. E.g. by using the whole surface of flat hands, or by using the bones of the hand's fist. Another suggestion by multiple groups was to use other objects to trigger the surface and not only hands to add a variety of frictions between the surface of the scores and different objects. Furthermore, one group suggested to have destructive objects to reshape the score during the performance.

– Visibility: All participants had difficulty to see the performance during the concert. After the concert they all came closer to the tangible interfaces to thoroughly observe and inspect. They suggested variations of the interface that is more visible and engaging for the audience. E.g. one group suggested an interface made of glass that is vertically on the wall so that the performer faces the audience while the score is visible to the audience. Another group suggested the performers to be on a stage located lower than the audience, or a video projection of the interface that the audience manage to observe the score and the interactions with it. The third suggestion was a tangible interface that is moving instead of the hand of the performer moving. This allows the interaction of an object with a hanging tangible score that is visible to the audience and very engaging (figures 6.20 and 6.21).

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

Through this workshop we explored the design of Tangible Scores in a collaborative creativity process. Musical interface design is a highly idiosyncratic task. Designers always have their favorite understanding about musical interaction and composition. Collaborative and participative approaches can help designers to test the validity of many aesthetic and conceptual assumptions which usually cannot be evaluated through other methods (e.g., a usability test). A collaboration with performers other than the designer/composer themselves can also be beneficial for the design and creative process. The composer-designer-performer paradigm has established a bidirectional and dynamic relationship between the traditionally separated tasks of instrument-building, composing and performing. However, the lack of a thorough documentation of technical and aesthetic components of compositions/performances created through this process often limits their reproducibility. Working in collaboration with other performers could help assess design practices and communicate musical ideas, enabling their reproducibility.

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

- **A Moment of Transition, CTM Berlin (February 2017), Blaues Rauschen Festival Herne, MEQ Festival Montpellier (October 2017), Alte Schmiede Wien (November 2017) [REFLECTION IN ACTION]**

  Once Tangible Scores had been performed by other musicians and after having visualized a possible date for the end of this thesis, I decided to create a new series of instruments. Fortunately, I could count on the support of the ENCAC Network who sponsored me to stay in Berlin in the context of the CTM festival allowing me to start producing this work. The plan was exploring materiality and creating a new work with other aspects I had not explored. In particular I wanted to create a setup which would be easier to transport. I also wanted to work with light as a part of the score. This light could be dynamic and create or modify the tactile score of the artifact. In such a way I wanted to explore the possibility of creating dynamic tangible scores.

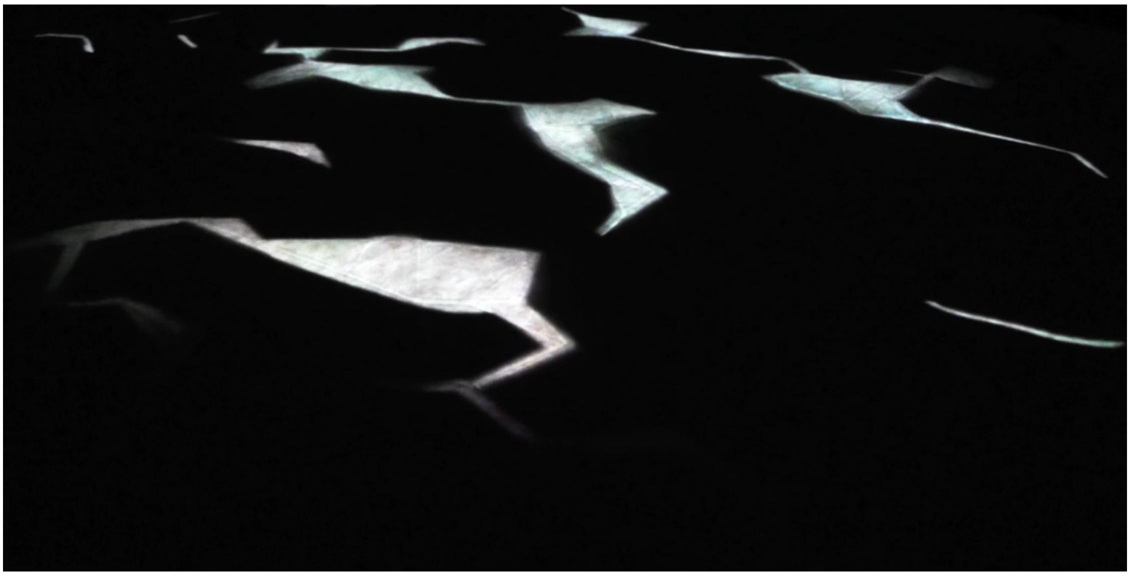


Figure 6.22: Capture of the performance A Moment of Transition with Tangible Scores made of paper and illuminated.

During this stay in Berlin I experimented with different types of materials. For example with rubber, silicones, paper, metal, Plexiglas, plastics, concrete, foams, etc. I created casts for those materials and I did various experiments. The other aspect to incorporate, the light, was solved using RGB LED stripes. In these stripes, it is possible to control both the color and illumination of each of the LEDs independently. Therefore, I needed some translucent material which could let the light flow through it.

After coming back to Linz, I started to work with the CNC machine for embossing paper in complex ways. And I discovered that the combination of thick papers with the warm colors of LEDs could be quite interesting for my objectives. The paper modulated the color and the internal structure of threads of paper could also be seen. Therefore, the effect was quite interesting.

Finally I created three profiles on three 'aquarelle' paper which can be observed in figure 6.22. Under these sheets of paper the LEDs were distributed for illuminating the area of some graphic motifs. Between the LEDs and the paper I incorporated a black paper acting as a mask. It only lets the light pass through the motifs I want to illuminate. Two microphones were installed at each sheet of paper and a polyphonic concatenative synthesizer produced sound.

Once the structure of the instrument was fixed, I started preparing for a performance in October. This twenty five minute long piece would be structure in five parts. At each of these parts the synthesizer would have different parameters and sound materials. At each of these sections of the work, the LEDs would animate the panels telling different stories.

I had the possibility of playing *A Moment of Transition* four times within a month in Germany, France and Austria. My personal impression is that it is an appealing and attractive musical piece to play. I had a lot of freedom in my improvisation but also other structures of the piece give a form to the whole work.

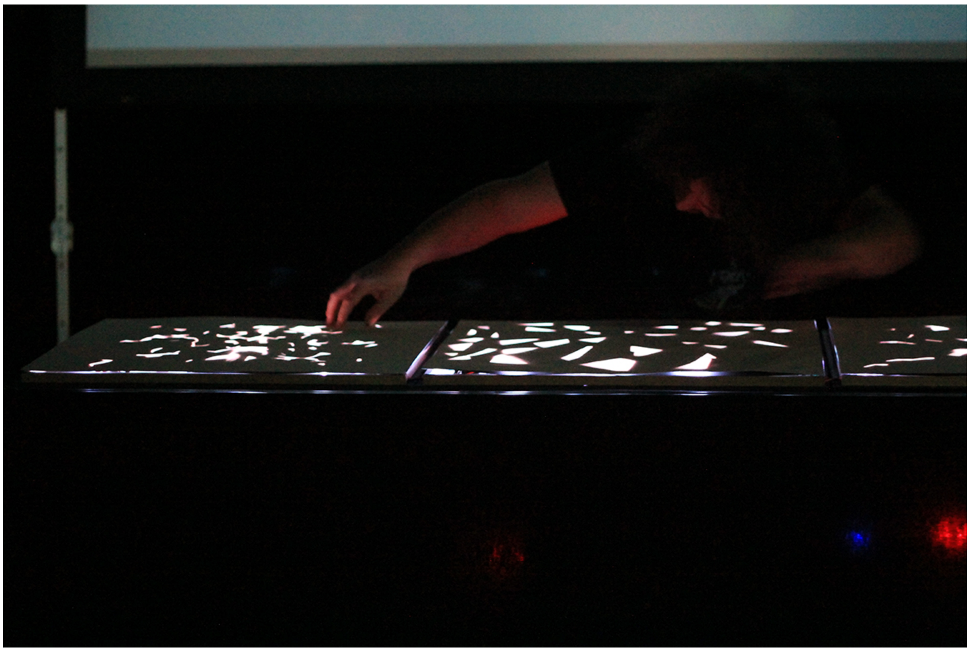


Figure 6.23: Capture of the performance A Moment of Transition at festival Blaues Rauschen.

The audience gave me very positive feedback. Many could not understand from where the light was projected and I had to open the interface to show it (figure 6.23). Others were interested in knowing more about the form of the graphic motifs. Many people remarked on the expression of the work. Some pointed out how the light helped to accompany abstract parts in the audio. For some, the presence of light was not necessary during all the performance.

A few people commented to me that at the beginning of the piece they were interested in following the lights but later they preferred not looking at them. A few remarked that the mixture of digital graphic designs with traditional techniques was very attractive.

In conclusion, the incorporation of paper and light was well evaluated. Future developments of this work suggest the creation of an installation.

- **Other Lectures and Presentations**

  The dissemination of this thesis has been not strictly through artistic practice but also in giving lectures and conferences at various universities and institutions. Defending my argument has helped me to develop rhetorical strategies. Increasingly, I understood the importance of illustrating my theories with examples and with the artifacts supporting my research.

  In figures 6.25a to 6.26b pictures of my presentations given at IRCAM Paris, University of Sussex (Digital Humanities Lab) and CTM Festival can be observed.

6.3. A Critique on Tangible Scores

The last sections of this thesis are dedicated to the critique of the project Tangible Scores. This critique is mandatory. Along this thesis I have often put the focus of my critique on third-party projects (e.g. the reacTable) as well as on particular fields of study (e.g. HCI). It is now the moment to center my analysis on Tangible Scores.

In the first subsection I am presenting Tangible Scores as a critical interface. In the following subsections I will present what is 'critical' about my critical interface.

Figure 6.24: Presentation at TEI Conference Eindhoven 2016 (TU/e)

(a) Presenting at IRCAM

(b) Workshop at IRCAM

(a) Talk at the Digital Humanities Lab of the Sussex University

(b) Peter Kirn introducing my talk at CTM Festival (Music Hacklab) in Berlin

6.3.1. Tangible Scores as a Critical Interface: Media and Illusionistic Realism

In chapter two (section 2.3), I analyzed and discussed a few artworks in regard to Pold's *Interface Aesthetics*. Briefly explained here, an interface is considered 'critical' if it serves to evaluate the assumptions of its own field of study (e.g. HCI, NIME, a philosophical trend, etc).

After having already developed *Tangible Scores*, the central artifact driving the practical part of this thesis, it is now convenient contextualizing it under the same theoretical framework (see sections 2.3.2 *Critical Interfaces* and 2.5 *Examples of Critical Interfaces*).

The critical aspects of Tangible Scores are:

1. **Non-Linguistic Communication**: At a tangible score there are no explicit digital symbols (*extrinsic symbols* see 4.6.7) represented on the interface which can be explored by the users. There is only a continuum of materiality. Users are confronted with a total absence of information about how they can manipulate the different parameters controlling the sonic engine. The interface makes us aware of the hyper-abundance of symbols utilized in interaction design, making us reflect on the issues created by the great dependency that musical expression with NIMEs hold on linguistic communication with computers.

2. **Performative Materiality**: At a tangible score, users are forced to 'think the materiality' they find in front. In fact, the project *Tangible Scores* was inspired by the recent theories of *New Materialism* which investigate 'the incessant materialization of the world' (Blanc, 2017). Under this theory, matter is not a stable substance. The agency of materials cannot be described until they are performed . In this context, *Tangible Scores* aims us at discovering the performative properties which every material features, our interfaces too, taking note ofthe importance of the physical materiality of our interfaces.

Tangible Scores presents us with the issue of the hyper-abundance of symbols we need to learn and employ when playing musical interfaces. My interface visualizes an alternative to the hyper parametrization of electronic music. Playing Tangible Scores puts us immersed into the materiality of the interface and the sonic response. For this reason it can be an example of critical interface dealing with 'media realism' (Pold, 2005). For Pold, an artwork dealing with media realism goes beyond the visual surface of the interface towards the imperceptible and unreadable code. These artworks reveal the normally hidden flow of codes that the user interaction causes. In our case, the traditional assumption in HCI that musical interfaces have to be controlled using symbols and parameters. Tangible Scores also explores new types of embodiment with the interface, trying ideally to make the instrument disappear when performers are well trained to play it. Performers would be immersed in media, in this case immersed in sound. This is typical of 'illusionistic realism' (Pold, 2005), artworks beyond pure representation, interfaces maximizing reality towards immersive simulation. These artworks make the user forget about the interface and become immersed in the illusionistic world it presents.

As I did with other examples of critical interfaces at chapter two (section 2.5) I will describe Tangible Scores using a threefold framework: problematization, methodological conceptualization and artistic inquiry. As I formulated in chapter two, my impression is that every artistic research project can be described using these three dimensions.

In terms of *problematization* of the project, the spark for creating *Tangible Scores* comes from a research question: is there a possibility to create musical interfaces incorporating the idea of 'musical score' at its configuration? What are the philosophical and practical consequences of understanding musical interfaces as musical scores? This question arose after the observation that many electronic music instruments containboth the characteristics of instruments and compositions (Tomás and Kaltenbrunner, 2014). The answers to this questions are found in the following subsection.

The project was developed following a specific *methodological conceptualization*. At Tangible Scores I followed practice-based methods and other taken from user-centered design and collaborative design. My practice (concerts, compositions, etc.) with the interface is the basis of the contribution to knowledge. Whilst the significance and context of the claims of research could be described in in writing, a full understanding can only be obtained through a direct experience with the artifact produced. As in *Tangible Scores*, many aspects of its contributions to research come after the direct observation of the artifact. Through this methodology, the artifact informs the author of important concepts which were in fact not formulated at the moment of conceptualization. They can only be perceived at the moment of experiencing it, at the moment of practice.

My artistic inquiry with *Tangible Scores* follows an aesthetic strategy inspired first by the aesthetics of graphic scores and second by musical performance. Tangible Scores release their original nature as inscriptions on paper: they extend themselves towards materiality and performativity, transforming the nuances of the materials employed into changes of the parameters used at interaction. It will not produce the same sonic outcome, for example, when creatingthe scores out of wood, rubber or metal,as the algorithm depends on the acoustic properties of the sounds created within the objects. At the same time, having a graphic score look helps musicians in finding ways to navigate the 'interface'. As many performers have experience with performing graphic scores, they have already developed methods and skills for exploring the graphic ideas drawn by contemporary composers. For instance, non-linear reading and random navigation are implicit characteristics assumed by performers and do not need to be explained.

6.3.2. Critique to Tangible Scores

Once the project Tangible Scores has been exhaustively described it is the good moment to resume some criticism about the project. This subsection resumes many aspects of the previous sections. Certainly, a project has been developed during the last five years of research has been able to explore and adopt only a limited amount configurations and possibilities. This subsection resumes some of the critiques the project has received. It also aims at imagining other futures for Tangible Scores.

1. **Implementation of the tangible score paradigm**. The instrument I have developed has explored the notion of a 'tangible score' as an acoustic interface. This implementation has allowed me exploring the materiality of interfaces as the active agent in synthesis control. The first results of combining an acoustic interface with concatenative synthesis were brilliant. I could touch the score and that was also a performative act. I played physically the score, the representation of a musical idea! In fact, fixing the technical setup allowed me early in this PhD exploring creativity in depth.

   But, is this implementation the best of the many possible? This question was often formulated. Would it have been better to compare various types of implementations. Section 5.13 shows the alternative implementation of the tangible score idea by other authors after my NIME paper in 2014. They include computer vision and gesture recognition. Therefore, my critique is directed to the fact of not having explored other technical systems towards the same intentions. This lack of technical exploration may reinforce others in the idea that the tangible score paradigm must be implemented only with acoustic interfaces. And this is radically false. The tangible score paradigm is independent of the technical apparatus used.

2. **Non-Linguistic Communication**: my declarative presentation of the project. This thesis studies the representational dimension of musical interfaces. It contributes towards a non-linguistic and non-representational vision of performing with musical interfaces. My performances with Tangible Scores have shown my personal approach. However, a great part of the time invested in this PhD was dedicated at preparing papers for academic conferences at speeches. Like public talks and workshops. But these formats are highly declarative. That means speaking and projecting slides containing texts and data results. These are setups radically opposed to my non-representational intentions.

   When after a conference at CTM Festival some of my talks where linked by the Creative Digital Music blog[2] a few reactions at the comments section were quite direct:

   > *I was surprised to see him talk through a PowerPoint presentation about... not using linguistic representation. If he danced while playing his instruments, that would really be something! (Michael L)*

   After these reactions I took decisions. I decided that at every presentation I would do, I may have a big percentage of performativity. For instances, my talks should begin with a small performance with Tangible Scores. Obviously, this thesis book and many of the materials supporting it are highly representational and linguistic. There is not an easy way to escape for this concern. May I defend my PhD thesis dancing? The critique against the representational aspects of the thesis are clear. However, as I

[2] http://cdm.link/2017/02/touch-feel-score/

will defend on section 7.4 (On Representation) our culture does not easy support non-representational approaches. It is not only an issue of my PhD. Its solutions do not begin with a PhD but at the very ground and foundational pillars of our culture (e.g. educating towards a non-representational sensibility).

3. **Playability**. A recurrent critique to my project has focused on the instrument's control. How to predict the sonic content. How to repeat the same musical content. How to play scales. Certainly it has been a central issue. Interestingly it has never been a problem for me. I always understood that the music produced by Tangible Scores was mostly textural and timbrical, highly affected by the random character of the concatenative engine (which can be limited). The aesthetic of the music I produced before this thesis was fairly quite similar. I also liked the particularity of the system which does not allow me repeating fragments of sound. I can only repeat the gesture. That made me evolve my musical intentions during the performance and focus on gestures, on dynamism not on contents. I never felt that I had to program the apparatus of Tangible Scores with this feature. However I have to admit that this is a very personal interpretation of the project. A critique to my decision can be that I was not interested in opening the instrument to others. That I did not dedicate enough time to force it to be more predictable. Or at least controlling it until some level. We can call it my idiosyncrasy or my aesthetic, but certainly it can be criticized and analyzed.

4. **Materials and Dimensional Form**. I also assume the critique regarding the limited amount of materials used and the low dimensionality of my project. Why have I used so much wood and paper? Clearly they are malleable materials, easy to modify and sculpt. Embossed paper also reminds to graphic scores and it creates great relationships when one sees someone touching a paper score as a musical instrument. The result of the extensive use of these materials is loosing one dimension. I could have created more three-dimensional tangible scores too. Objects working with the same principle, incorporating a tangible score. In my defense I argue that I produced experiments in this direction (section 5.9.7). I presented a three dimensional tangible score to experts at workshop celebrated in 2016 (section 6.2, page 125). Their feedback showed that three-dimensional objects created different affordances and expectations about interaction. For instance, one expects sonic response when one squeezes the surface or rotates the object. These aspects are limited in my two dimensional scores. Why should one have a three dimensional object to play only with its surface? I assume this critique and I defend myself only saying that this work had be left for the future work. The production and evaluation of tangible-object scores would have required a few years more of work. Also it would have extremely changed the impression of what the aspect of Tangible Scores can be.

6.4. Conclusions

This chapter has summarized the lessons I learned about about my instrument's design. For each of the events I have taken part in, I have described their context and objectives. Detailed why these objectives were or were not fulfilled. Looked at ways to improve some of the issues.

This chapter has allowed me to study systematically my practice during these years. I can compare my own practice from various perspectives and evaluate it internally as an artist. It was also necessary to formulate a critical resume of the expectations created by Tangible Scores. Obviously, many aspects of the projects will have to be left for future developments.

7

Embodiment
Further Contributions After Practice

One sees the environment not just with the eyes,
but with the eyes in the head on the shoulders of a body that gets about.

Gibson (1979:222)

The purpose of this chapter is presenting and discussing other contributions of the project *Tangible Scores* which appeared after reflection about my own artistic practice. During this short history of five years of design and performance I have developed a personal voice in regard to the material account of musical interfaces and our embodiment with digital instruments. The original research questions of this thesis extended themselves towards investigating other notions like interface materiality, the limits of our linguistic communication with interactive systems and the difficulties of conceptualizing and materializing musical intentions.

7.1. Structure of Contents Examined in this Chapter

In the following sections, I will discuss a number of aspects involved in digital musical instruments: materiality, touching, intention and representation.

- First introducing its theoretical background with examples
- Then, discussing those theories from the experience of performing and designing *Tangible Scores*.

This chapter is structured along the following topics:

1. Interface Materiality: performative value of physical materiality
2. On Touching: a new sensibility for tactile interfaces
3. Representation: the representational dimension of musical interfaces
4. Musical Intentions: intention as design framework

7.2. Interface Materiality

The possibility of dedicating a whole section of this thesis to materialism, one of the branches of philosophy engaging thinkers since immemorial times [1], turned into mandatory for describing many of the subtle concepts behind *Tangible Scores*.

[1] Only in ancient Greek Thales, Parmenides, Anaxagoras, Democritus, and then, later, Epicurus are considered the first materialist philosophers

Materialism can help us to better understand what an embodied experience is. Novel approaches to materiality always carry new conceptions about the relationships ruling our interactions with the world. For Stack (1998) materialism is an understanding of the world asserting that "*all entities and processes, including human beings, are composed of -or reductible to- matter, material forces or physical forces*". Interestingly, materialism has been specifically applied to the mind-body problem in the so called 'Philosophy of Mind', a branch of philosophy concerned with the nature of mental phenomena and the nature of thought, feeling, perception, consciousness, and sensory experience. Therefore, the intention of this section is discussing recent approaches to materialism which have inspired this thesis.

We can say that materialism serves to explain what the nature of things is. During the long reign of Christianity, the denial of spirit as the basis of human nature was condemned by the Church. It was not until the 17th Century that the interest in materialism was revived by the scientist Pierre Gassendi and the political philosopher Thomas Hobbes. Until that moment, materialism was mostly about the Cartesian Dualism. It survived due to its compatibility with Christianity.

Interestingly, materialism is nowadays understood as a multiplicity of visions about the nature of things. Materialism acknowledges that things can have multiple natures and theories explaining their natures. Indeed, as long as science and technology develop new materials, new conceptions about materialism are created too. Materialism is open to the incorporation of new visions about the nature of things.

In the scope of this section, I want to discuss which is the multiple nature of digital musical interfaces. An answer can be formulated through the study of all those of the various physical and virtual parts which can be found at musical interfaces. In conclusion, the objective in this section is presenting some recent understandings of materialism as a vehicle to describe the nature of *Tangible Scores*.

7.2.1. Criticism to the immateriality of digital media

One of the popular myths created by technological complexity has been the perception of electronic and digital media as immaterial. It is still quite common to find projects attributing immaterial and dematerialized properties to digital artworks. For instance, during the last Ars Electronica Festival 2017 we could see the exhibition *De/materialize* of the Fashion and Technology department in the University of Arts of Linz. The curators explained that when digital technologies meet textile art, textile becomes dematerialized (figure 7.1).

This myth has its origins in post-modernity. The use of conceptual means as as the central material was often associated with the attempt to 'dematerialize' the artistic work. In this period, the artistic object itself became obsolete. The book *The dematerialization of the art object* by John Chandler and Lucy Lippard (1968) explains that:

> *The visual arts at the moment seem to hover at a crossroad that may well turn out to be two roads to one place, though they appear to have come from two sources: art as idea and art as action. In the first case, matter is denied, as sensation has been converted into concept; in the second case, matter has been transformed into energy and time-motion.*

Certainly, if the artistic object becomes obsolete and changes its form, it can be perceived as made of another nature. But this does not mean that, for instance, conceptual arts would have become dematerialized. Only its recipient has shifted its materialization. For this reason Lippard, in the same essay, draws a vision of artists escaping from the constraints of matter, but not an art 'emptied' of matter.

In 1985, the exhibition *Les Immatériaux* curated by Jean-François Lyotard at the Centre Pompidou in Paris, had the motto 'the immaterial is matter'. For Lyotard, immaterial matter is matter subject to interaction with other conceptual processes (figure 7.2).

In the mid-2000s, Matt Kirschenbaum (2008) questioned many of the discussions about digital media, pointing out the popular misconception of electronic technology as immaterial. Some scholars, influenced by deconstructive philosophy, simply described fungible, fluid, rapidly re-inscribable digital code as an immaterial medium. While poststructuralism builds on the insights of structuralism, it holds all meaning to be fluid, rather than universal and predictable. Therefore, this new type of inscription, the electronic, would perfectly account for being fluid and immaterial too. Reacting to that, Kirschenbaum nicely termed distinctions of forensic and formal materiality in the book *Mechanisms: New Media and the Forensic Imagination* (2008). Forensic materiality refers to evidence, while formal materiality refers to the codes and structures of human expression. For instance, the forensic elements of a printed book are its ink, paper, stains and any other physical components. The formal elements would be its layout, its design, the style, etc. This distinction, although does not exhaustively list all the possible types of materialities in electronic media, is useful as far as it reminds us that digital media have these basic dimensions. For Johanna Druker (2013) the intervention of Kirschenbaum came at a crucial moment for reorienting the debate in digital humanities towards the study of the multiple materialities of electronic media.

In the same direction, the book *Burdens of Proof* of Jean-François Blanchette (2012) argues against the immaterial perception of digital media. Blanchette was trained in informatics, encryption, and the theoretical study of digital code from a technical and legal perspective. And he is responsible for adding 'distributed materiality' to the inventory of materialities about technologies. The notion of 'distributed materiality' provides language to describe the co-dependent, layered contingencies on which the functions of drive, storage, software, hardware, systems, and networks depend. Certainly, all of these elements are material, but importantly, they are locked into relations with each other governed by their material design and constraints in relation to the system where they perform. Distributed materiality, though still focused on entities (the devices constituting and electronic system) and their relations, suggests the structure of event-based models[2] for understanding the nature of digital technologies. With its roots in other complex systems theories (e.g. Bruno Latour Actor-Networks) it creates suggestive connections to the field of new materialism which is described in the following section.

Summing up, as Kirschenbaum did first decades ago, we can conclude this subsection repeating Edmond Locard's uber-quoted basic principle of forensic science: "every contact leaves a trace". Also in digital media.

7.2.2. Media Archeology and Kittler's Materiality of Communication

Media archeology is a field that attempts to understand new and emerging media through close examination of the past. Especially through critical scrutiny of so-called dead media, those material and techniques of communication that had been lost, neglected, or obscured (Parikka, 2010). One of the interesting aspects of media archeology is its insistence on the materiality and material ecologies of media objects, systems and processes, informational technologies and processes in disembodied and immaterial terms. This is distinct from phenomenological approaches which are centered on human body and experience (Hansen, 2006).

Friedrich Kittler's 'materiality of communication' is one of the foundational stones of media archeology. Kittler is considered one of the pioneers of what might be called 'media materialism', the analysis of the material structures of technology over the meanings of these structures and the messages they circulate (Gane 2005). Kittler's original work are influenced, above all by Shannon's 'The Mathematical Theory of Communication' (1948). Shannon's theory separates the meaning of communication from the mathematical problem of how communication takes place. Shannon's solution conceive of information in terms of choice and uncertainty and treats communication as a question of probability rather than of semantics. The technical problem of communication -how accurately can the symbols of communication be transmitted- is given primacy over semantic or effectiveness problems -how precisely do the transmitted symbols convey the desired meaning-.

For Kittler 'meaning' is little more than an 'anthropocentric illusion' and asserts that "the dominant information technologies of the day control all understanding and its illusions" (1999). Kittler' s writings do not seek to understand media but rather to document their effects and emergence, making visible the structures of communication that technology introduces. His interest lays on the basic material structures of the technologies themselves and the changes they introduce into culture. His method is consequently distinctly a radical 'post-human' reading of the historical development of media. Kittler builds on McLuhan's theory of remediation[3] (1964, p.19) to declare that all current technologies are built on previous technologies. However, Kittler breaks with the traditional distinction between form and content in media. The world of digital media reduces all cultural forms to binary code, which for Kittler is both form and content. For Gane and Hansen-Magnusson (2002) this move shifts "the history of media away from traditional sociological discourses that focus on social production or human invention to look instead at the powers of technologies in themselves".

7.2.3. Material Thinking: New Materialism

New or neo-materialism appeared as a theory with the urgency to implement solutions within a world full of ethical, ecological and political threats (e.g. gender identification, global capitalism, extensive use of energy, etc). For Barbara Bolt (2013), neo-materialism is the acknowledgment of agential matter and the questioning of the anthropocentric view of us, humans, as makers in a world which serves as a mere resource for our

[2] A system model based whose basic element is the temporal event, discretized in a progression as a series or sequence of events.
[3] MacLuhan describes the content of new media in terms of the structure of previous media forms (McLuhan, 1964, p.19)

Figure 7.1: De/Materialize exhibition of Textiles and Technologies at Ars Electronica Festival 2017

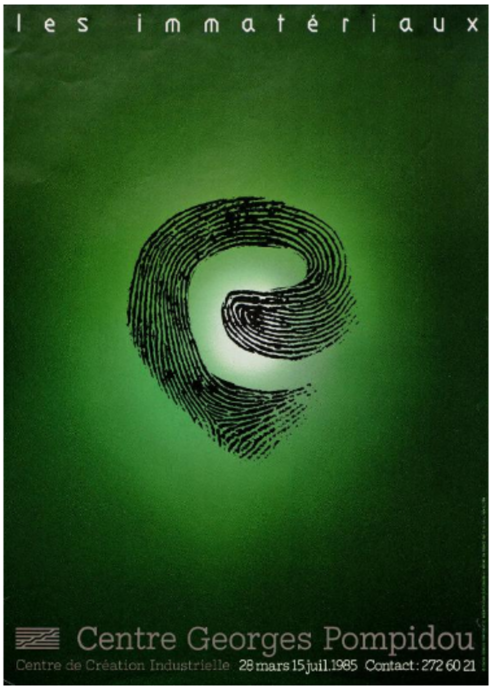


Figure 7.2: Les Immatériaux exhibition at the Centre Georges Pompidou Paris in 1985

endeavors. For Haraway (1991) the "I" in new materialism encompasses the human and the non-human, the social and physical, and the material and the non-material. In this vital materiality, for Bennet (2010), not only humans 'do things'.

It is a consensus that neo-materialism appeared as a reaction to the 'cultural turn' which dominated the late years of the twentieth century. For Rosi Braidotti[4], in 1980 Althusser's *Pour un materialisme aléatoire* inagurates and establishes a consensus about materialism across the whole spectrum of his students (such as Foucault, Deleuze and Balibar). At that moment, it was necessary to redefine contemporary materialism in the light of recent scientific investigations but also in terms of the new mutations of capitalism and psychoanalysis.

Post-structuralism adopted 'materialism' as a necessity too and leaders of the linguistic turn like Lacan and Barthes wrote frequently about 'the materiality of the sign'. In contrast, Althusser's 'aleatory materialism' refers to a 'materialism of the encounter' and find its roots in Spinoza, Marx and Wittgenstein. It is characterized for ignoring the origins or ends of materiality. Instead, it emphasizes emptiness, contingency, and chance. Althusser enables 'materialism' as no more than a temporary label to engender a certain sensitivity.

After the mid 1990's the post-structuralist project loses certain hegemonic position. For Rosi Braidotti (2002) "*neo-materialism emerges as a method, a conceptual frame and a political stand, which refuses the linguistic paradigm, stressing instead the concrete yet complex materiality of bodies immersed in social relations of power*". During the beginning of that decade, Gilles Deleuze guided those involved in defining what is exactly the 'matter' in neo-materialism. In parallel, the branch of feminist philosophy builds on the embodied and embedded brand of materialism that was pioneered in the last century by Simone de Beauvoir. But this feminism also combines in a manner the phenomenological theory of embodiment with Marxism and a re-elaboration of the complex intersections between bodies and power. The consequence is a philosophy rejecting dualistic partitions of minds from bodies. Or nature from culture. For Rosi Braidotti, feminist philosophers introduced a new brand of materialism, of the embodied and embedded kind. Closing the loop, Deleuze's emphasis on the 'becoming woman' of philosophy (Deleuze and Guattari, 1987) inaugurates a new kind of masculine style in philosophy. For Braidotti (2002), in Deleuze *"the 'other' is not the emblematic and invariably vampirized mark of alterity, as in classical philosophy. Nor is it a fetishized and necessarily othered 'other', as in deconstruction. It is a moving horizon of exchanges and becoming, towards which the non-unitary subjects of postmodernity move, are by which they are moved in return"*.

At the beginning of *Matter comes to Matter* Karen Barad (2003) summarizes many of positions against a linguistic framing of the world:

> *What compels the belief that we have a direct access to cultural representations and their content that we lack toward the things represented? How did language come to be more trustworthy than matter? Why are language and culture granted their own agency and historicity while matter is figured as passive and immutable, or at best inherits a potential for change derivatively from language and culture? How does one even go about inquiring after the material conditions that have led us to such a brute reversal of naturalist beliefs when materiality itself is always already figured within a linguistic domain as its condition of possibility?*

In short, new materialism is a category of theories in response to the linguistic turn. Infused with a history linked to feminisms, new materialism attempts to offer a different perspective to signification, materiality, and methodologies of crafting knowledge. Classical theories attached to enlightenment, ontology (what is in the world) and epistemology (what we know about what is in the world) were considered to be separate and not affecting one another. What new materialists point out is that what is in the world and what we know about things in the world cannot be considered as different things. What is in the world and what we know about things in the world are constantly shaping one another.

7.2.4. Art and New Materialism

During the rise of cultural studies (the 'cultural turn'), contextualized by postmodernity and post-structuralism, Art is framed primarily as social and ideological in nature. Is this moment when Art is defined as 'cultural production'. Only from this moment Art is not understood as a given thing, but a socially constructed activity produced through discursive practices. It is this moment when Foucault in 'The Archaeology of Knowledge' (1972) coins the term '*discursive formations* to describe the categorical enunciative structure put on many

[4] https://quod.lib.umich.edu/o/ohp/11515701.0001.001/1:4.1/–new-materialism-interviews-cartographies?rgn=div2;view=fulltext last accessed 20/11/2017

disciplines in order to comprehend them. In other words, discourses elaborate what can be thought and what can be represented in Art. This notion of discourse, the structure or grid put on top of the Arts, reaffirmed the idea that all Arts are socially and culturally constructed and mediated.

New materialism expresses its criticisms against these discursive notions about the Arts elaborated in the 'cultural turn', pointing out how the Arts very materially dissapears into the textual and the discourse. Art is understood as constructed through the vehicle of language.

This neo-materialist turn has gained interest within contemporary art. For instance, between 2016 and 2017, the Leopold Museum of Vienna presented the exhibition "The Poetics of Material" oriented towards exhibiting artists embedded in new materialist sensibilities. For its curator, Stephanie Damianitsch (Wipplinger, 2016):

> *"For theorists of the so-called 'new materialism' material is no longer something passive that waits for the intellect or spirit to provide an additional formative force or animating spark. Rather, materials and things are perceived as 'co-actors' in historic processes and as the products of these processes. They thus function – comparable to language – as a vehicle of the discursive constitution of reality."*

Interestingly, many of the neo-materialism theories about the Arts inherit directly from Heidegger's philosophy of the Arts and Technology. Heidegger (1977b) gives emphasis to matter as "*the substrate and field for the artist's formative action*". Heidegger coins the concept of 'form-matter synthesis' for describing how physical artifacts are produced. What is constant in the form-matter synthesis, says Heidegger, is the fact that matter stands together with a form. For Heidegger, the thing is formed matter. However, the philosopher adverts of the danger of this synthesis (1977b: 153):

> "*If form is correlated with the rational and matter with the irrational, if the rational is taken to be the logical and the irrational the alogical; if in addition the subject-object relation is coupled with the conceptual pair form-matter; then representation has at its command a conceptual machinery that nothing is capable of withstanding*"

We can interpret the form-matter synthesis danger as the possibility to transform matter into a 'mute and irrational matter' if language is the vehicle modulating it. Matter would become the dumb irrational substrate where humans create. Barbara Bolt (2013) discusses Heidegger from the perspective of new materialism when she cites the famous example of the fabrication of a silver chalice (Heidegger, 1977b: 155):

> "*for Heidegger both the artist, together with a notion of 'aspect' and the matter of silver are co-responsible from bringing silver into the appearance of a chalice. The artist does not create the silver chalice nor is the chalice formed matter. The silversmith is co-responsible for and indebted to other collaborators for the emergence of the 'thing' as a silver chalice*".

This redistribution of the power of creation and production has a lot in common with neo-materialism. For Barbara Bolt, Heidegger's reinterpretation of causality as co-responsibility shifts the debate:

> *"from the notion of form-matter synthesis to a notion of care and indebtedness between co-responsible elements. Art is co-collaboration and matter as much as the human has responsibility for the emergence of art. In other words, matter as agency."*

7.2.5. Performative Materiality and Realizational Interfaces

The theory of performative materiality has been proposed by Johanna Drucker (2013) who suggests that the materiality of a system "only occurs when we action it, and only and at that moment we perceive and discover it, always distinct in each instance". This viewpoint inherits clearly from a post-phenomenological approach. Postphenomenology (like Don Ihde's) generally argues that technological artifacts have a mediating role in the relation between human beings and the world. Moreover, it claims that the subject and the world are not given a priori, but they constitute themselves at the precise moment of the relation (Romele, 2016).

For Drucker, "material conditions provide an inscriptional base, a score, a point of departure, a provocation, from which a work is produced as an event". From the perspective of performative materiality, the identity of something is 'what it does' and not 'what it is'. Therefore, in order to know what something is, we cannot only rely on the analysis of material conditions and structures (or on the forensic and formal which proposed Kirschenbaum). The materiality of the system, no matter how stable, "bears only a probabilistic relation to the event of production, which always occurs only in real time and is distinct in each instance". Drucker connects her theory with the distributed materiality of Blanchette (section 7.2.1), although the sequences of events in performative materiality are less related to other entities of the systems and more related to our bodies, as we have to 'action' the system to perform it and uncover its nature.

Performative materiality, heavily influenced by post-structuralism, emphasizes the production of a work as an interpretative event. Every person would then perform differently with the same matter: both the matter and the person wouldn't perform in the exact way at two different moments. At the encounter between person and matter, these events are for Drucker "acts of reading or other embodied individual experiences". However, the notion of performative materiality, explains Drucker, escapes from the intention of becoming a language for matter. Drucker understands it in a way in which "objects don't represent, they perform" in a clear connection to the posthumanist arguments of Haraway (1991) against gender representation or Barad's concept of performativity and intra-action (2013). For Drucker, objects need to be performed not with the intention to discover what they represent but what they are. Performing matter obligates us to see how things work first.

Drucker also inscribes her discourse within new materialism. For Drucker matter is not inert, they are part of a flux where things are events: "the concept of flux and change, of fundamental instability in all material systems, offers the possibility of transformation and modification in codependent or emergent materialities". Drucker also criticizes some aspects of Media Archeology[5] because "the archaeology of the approach stresses analysis of quantifiable characteristics rather than interpretative cycles of production, eschewing narratives of history in favor of descriptions of sites and artifacts".

> *Some of the media archaeology approaches to studying in an archaeographology, to use Wolfgang Ernst's term, reinscribe digital media in an entity-driven approach that is both literal (code as inscription) and virtual (code as model) (Parikka, 2011). These counteract the model of immateriality, though they do not replace it with a concept of digital flux, or of material as an illusion of stability constituted across instabilities...*

For Gary Hall (2016), Drucker points a clear critique to those discourses in digital humanities who often study materiality without having matter in consideration. For Hall, Performative Materiality would make a very similar move to the one of Tim Ingold's *Materials against Materiality* (2007) when he distinguishes between the objects of the material world of material culture theorists, on the one hand, and the properties of materials that are processual and relational and regarded as constituents of an environment on the other. Things are active not because they are imbued with agency but because of ways in which they are caught up in these currents of lifeworld. The properties of materials, then are not fixed attributes of matter but are processual and relational.

To describe these properties means telling their stories. In short, it is a world of materials. And as the environment unfolds , the materials of which it is comprised do not exist but occur. Thus the properties of materials, regarded as constituents of an environment, cannot be identified as fixed, essential attributes of things, but are rather processual and relational. The properties of materials are not attributes but histories.

Interestingly, Johanna Drucker applies her theory to the field of interfaces at the essay *Performative Materiality and Theoretical Approaches to Interface* (2013):

> *The interface is not an object. Interface is a space of affordances and possibilities structured into organization for use. An interface is a set of conditions, structured relations, that allow certain behaviors, actions, readings, events to occur. This generalized theory of interface applies to any technological device created with certain assumptions about the body, hand, eye, coordination, and other capabilities.*

In elaborating a performative vision of interfaces, Drucker emphasizes two aspects of interaction:

- Interfaces should not be entities returning selected results from a data set. Performing means being instable and open to create unexpected results.

[5] The field that attempts to understand new and emerging media through close examination of the past, and especially through critical scrutiny of dominant progressivist narratives of popular commercial media such as film and television.

- Interacting with interfaces is an act of interpretation, not the functional and mute task of interacting some a machine. Interfaces can be places for expression.

In this regard, Andrew Feenberg in *Questioning Technology* (1991) makes a distinction between functional and realizational interfaces. In the thesis *Enactive Interfaces*, Armstrong (2006) defines both as:

> *Functional interfaces are those 'which serve a predetermined function; they are structured around a finite set of interactions which are known in advance of the task's execution. The well-designed functional interface conceals the specific mechanics of the task, and presents the user with possibilities for action that draw on familiar and often rehearsed patterns of experience and use. The realizational interface brings the possibility of continuously realizing new encounters and uses, and, in the process of redetermining the relationship between technical objects and their human subjects. In short, it is a form of play"*

In his thesis, Armstrong describes how functionalism has become a standard metric in the evaluation of the successes and shortcomings of computer interfaces. The realizational interface, quite connected with Drucker's ideas, is a non-deterministic agent, it brings a continuing potential for new encounters and uses, and human knowledge continues to expand over a history of interactions. For both Drucker and Armstrong, realizational interfaces create a space for inquiry and research, where investigations are based on creative encounters with the materiality of the interface. Redressing the humanist commitment to interpretation, Drucker aims at embracing ambiguity and uncertainly, contradictions, etc.

7.2.6. A Neo-materialist Account for Tangible Scores

Tangible Scores combine both a notational and an instrumental nature. Their hybrid nature also combines physical and virtual components and therefore they incorporate digital materiality, physical materiality, performative materiality, etc. As the neo-materialist sensibility explains, things are not given with specific agencies as if they were physical attributes. A tangible score is not a musical work per se. Instead, it is a score because of the way in which we engage its materiality at a musical context. The notational nature of tangible scores is processual and relational. For this reason, in *Tangible Scores*, the inherent score does not exist but occurs. Inherent scores, as tangible scores, only exist by virtue of a performer's commitment to interpreting some type of materiality as a score.

Tangible scores expand the symbolic substrate of traditional musical notation and graphic scores towards matter. Physical materiality is, in *Tangible Scores*, as a place for the musical encounter and not as a static-given-form entity dedicated only to representation. Matter is the place to perform.

Matter, in *Tangible Scores*, is culturally formed not as a rational structure of things conveying a logical or functional message. Matter is organized in the artistic way, without converting it into a *standing-reserve*[6]. While we touch a tangible score we find ourselves performing music without having prepared any musical piece. We do not follow any represented musical plan. The score, the choreography of a tangible score is enacted after a process of tacit, non-linguistic engagement with matter.

In a tangible score both designer and matter are responsible for its final form. The original plan of engraving, casting or embossing graphic marks always gets reconfigured by unplanned encounters with matter. Matter always suggests different ways of approximating ideas. Touching the matter, feeling it, is necessary to fabricate a sculpture. We could not understand the opposite. Why have we put matter so far from musical interface design? Why have we naturally accepted that the symbolic realm can easily dominate matter?

Tangible Scores addresses these issues and forces a materialist encounter with the interface. My instruments force us to think materiality, force us to re-discover that interfaces have agency to inspire performances and that our body knows well how to decode that information. However, these encounters with *Tangible Scores* need of some commitment as they are not always specially deterministic. Tangible Scores are aleatory not because they contain a random program, but because both materiality and interaction with matter are necessarily aleatory.

But, what type of encounter is an encounter with *Tangible Scores*? It is a tacit interpretative act. It is not only an act of performance towards a functional objective. *Tangible scores* are designed in order to disable a certain degree of determinism or the expectation of a stable and predictive conversation. *Tangible scores* are a place for different types of events to happen, expected and unexpected. As a realizational interface,

[6] That Heideggerian reserve that I explained in chapter 2.4.1

it provokes new relationships with its materiality at every encounter. It serves then well as a medium for crafting research. A research process which is not instrumentalized towards proving knowledge, *Tangible Scores* becomes a research tool.

7.3. On Touching

Tangible Scores are instrument-scores forcing us to develop particular haptic abilities. They also make us reflect about the meaning of touching in human computer interaction. This section explores 'touching' in the context of digital musical instruments and *Tangible Scores*.

7.3.1. Touching and the action of the hand: Riegl and Deleuze

The sense of touch has been center of constant study in philosophy. According to Derrida (2005), the sense of touch has not designated a single sense traditionally. It was seen rather as a metonymy for the entire human sensorium system. In philosophy, from Aristotle to Husserl and Merleau-Ponty, touch has been positioned in a privileged situation in comparison to other senses as it offers 'the grasped object' in immediate and full intuition. For this reason Derrida asserts that philosophy has been 'haptocentric'.

An interesting characteristic of touching is that we usually do not perceive the medium for sensing. If with hearing and sensing we usually perceive how sensing depends on the medium, it seems that we touch at a glance. For Aristotle in *De Anima* (1994), the elusive medium is the flesh, which "is the medium of touch, the real organ being situated farther inward". This medium for Aristotle is different:

> *there remains this difference between what can be touched and what can be seen or can sound; in the latter two cases we perceive because the medium produces a certain effect upon us, whereas in the perception of objects of touch we are affected not by but along with the medium.*

The first references to the 'haptic' in art theory come with Aloïs Riegl, the art historicist born in Linz in 1858. Riegl is recognized as a seminal member of the so-called 'First Vienna School' of art history. Riegl denounced the influence of a simplistic vision of art conception in his society. In particular Riegl lived in a Vienna increasingly renovated with monumental buildings designed by Gottfried Semper, an architect and critic who asserted that artistic style was a mainly a consequence of a conjunction of certain materials and techniques. In contrast, Riegl countered that the 'will' to make art in a particular style transcends any necessities imposed by practical utility.

Through the notion coined as *Kunstwollen*, Riegl argued against the simplistic materialist view that imitation of nature had much to do with the appearance of new motifs and styles. He showed how many historical motifs, like the omnipresent leaf of acanthus was in fact an evolution of a lotus motif along many generations and iterations of designers. In the words of William Sieger (2007), Riegl shows how "*simplistic approaches to style have afforded casual explanations, rather than an interpretation in terms of peoples' most fundamental attitudes*".

Riegl's great contribution to the history of ancient art is the distinction between two modes of representation: 'haptic' (or tactile) and 'optical'. After systematically having studied the Late Roman Art production, Riegl (1985) suggests that many of the works produced during this period should be understood from the perspective of the 'haptic' (*taktisch* was the German word he used). Thus, the notion of 'haptic' for Riegl is linked to a close-up vision of the artwork.

Riegl proposes an understanding of ancient art in relation to the distances created between eye and work, suggesting three phases. First, most of old Egyptian bas-reliefs would be produced for "*Nahsicht*" (close-range vision). For Riegl, this type of seeing close to the artwork is similar to touching. In other words, the idea of a three dimensional perception is refused at the moment of creation(e.g. shadow or depth (obviously not perspective)). Second, the type of seeing "*Normalsicht*" (normal vision) would be typical of classical Greek art. In this case depth is created by appearance of shadow. Viewers need to stand at a further distance from objects to perceive deepness than in the close-range vision. However the viewer does not stand so distant from the object that the connection of each part of the object becomes indistinguishable. The third type is "*Fernsicht*" (seeing from a distance) which Riegl characterizes as the art of late Roman Empire. Here the viewer necessarily must keep some distance from the artistic elements. This mode of vision is called "*optisch*" (optic).

Riegl's classification brings at least two consequences:

- The history of Arts is drawn as a linear evolution of physical separation to artworks.

- For Riegl, thinking implies a transition from the sense of touch to the sense of vision in the mode of representation and appreciation of the work.

Interestingly, Deleuze discovers Riegl (who was only recognized in the Austrian-German world before his work was translated in 1985) and reveals Riegl's influence on some of his works. For example in *Francis Bacon: The Logic of Sensation* (2005), the work of Bacon is often explained in terms of Riegl's tactility. However, Deleuze does not accept Riegl's linearity of distance to vision. Deleuze rejects this linear mode in favor of one that discusses 'the action of the hand' and the non-linear modes of the vision. Deleuze does not read Riegl's concept of '*haptisch*' as the external relation between the eye and the hand but as one of possibilities of seeing.

Deleuze's classification of the 'actions of the hand' in relation to the eye is twofold:

1. The "manual" means that the hand is liberated from the eye. For instance, at many of Jackson Pollock's paintings (figure 7.3) we discover how the artist leaves the hand having accidents, surprising the eye and making decisions.

2. The "digital" means that the hand is completely subjected to the eye. For instance, Mondrian's paintings (figure 7.4) would be digital as there is no possibility for the hand to modulate what the eye has already planned.

In the opposite direction, the action of the eye in relation to the hand, Deleuze (2005), re-elaborates Riegl's discourse describing how bass-relief would constitute the most rigid link between the eye and the hand. The reason is because the main element of bass-relief is the flat surface, which allows the eye to function like the sense of touch. Bas-relief confers and imposes upon the eye a tactile or rather haptic function. For Deleuze "*it is a frontal and close view that assumes this haptic function, since the form and the ground lie on the same plane of the surface, equally close to each other and to ourselves*".

The idea that vision also has to be with other senses has been studied in neuro-science and in the Philosophy of Mind. The philosopher Alva Noë points out in the book *Action in Perception* (2006) that our vision is a process that depends on interactions between the perceiver and the environment and involves contributions from sensory systems other than the eye. For showing that vision is not passive, Noë makes use of the analogy of touch: touch involves skillful probing and movement, and so does vision.

Finally, a relevant contribution to understanding the sense of touch in art history is Ota Yoshitaka's *What is the Haptic?* (2013) where Deleuze's 'action of the hand' is emphasized as a notion linking the haptic and the concept of chance within arts. For Yoshitaka, a hand makes "*countless interplay with the eye*" and the haptic is the sense which better captures a moment of transition between hand and eye. In other words, the haptic is the sense which better grasps accidents and chance. As Yoshitaka asserts, *"it is not the 'mechanical hand' which works according to a plan and produces standardized products, but the 'action of the hand' itself, which leaves itself to a critical impetus of chance*". For Yoshitaka, Deleuze's type of tactility is responsible of both creation and destruction simultaneously: "*the haptic sensation is the one that grasps the moment when artists leave themselves to chance, or to contingency or the chance of becomings*".

7.3.2. Touched Electronics

Touching the circuitry of electronic music instruments is one of the oldest practices in electronic music. Early practitioners include David Tudor, Nicolas Collins, Michel Waisvisz or Reed Ghazala. Certainly, the most direct interaction with an electronic device is tactile interaction. While touching the electronic board we are adding our body resistance and capacitance to the circuit. As a result, we modify the functionality of the instrument. For example, touching the motherboard of an electronic keyboard one can modulate the frequency of the note pressed. But touching the circuitry is also not an easy task. It is often difficult to find the adequate points to touch. Sometimes circuits are miniaturized, isolated or they are completely digital. Often, it happens that our body resistance is too different to the expected by the circuit and our interaction does not change the sonic output very much.

Is this practice an instrumental discovery or does it also transcend to composition? Michel Waisvisz in the online publication *Crackle History*[7] (2004) sketches the origins of the crackle box instrument design:

[7] http://www.crackle.org/CrackleBox.htm

Figure 7.3: Jackson Pollock: Enchanted Forest (1947)

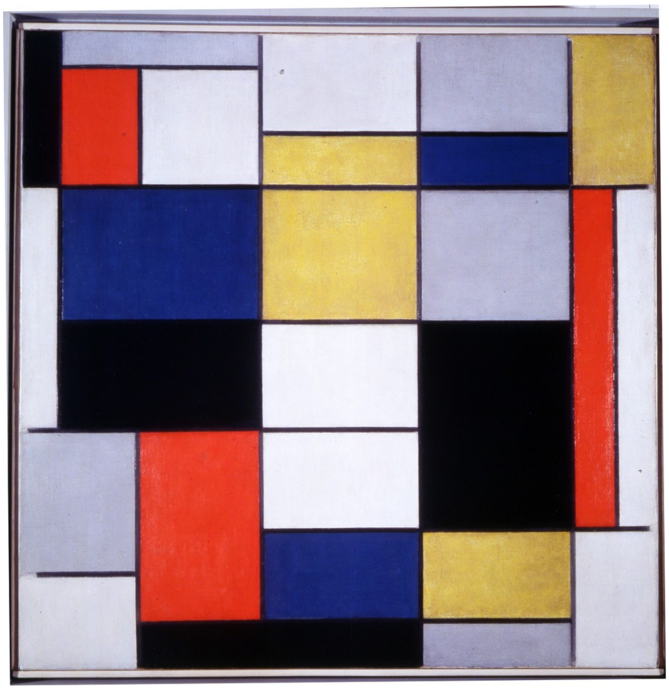


Figure 7.4: Piet Mondrian: Composition with Large Red Plane, Yellow, Black, Grey and Blue, 1921

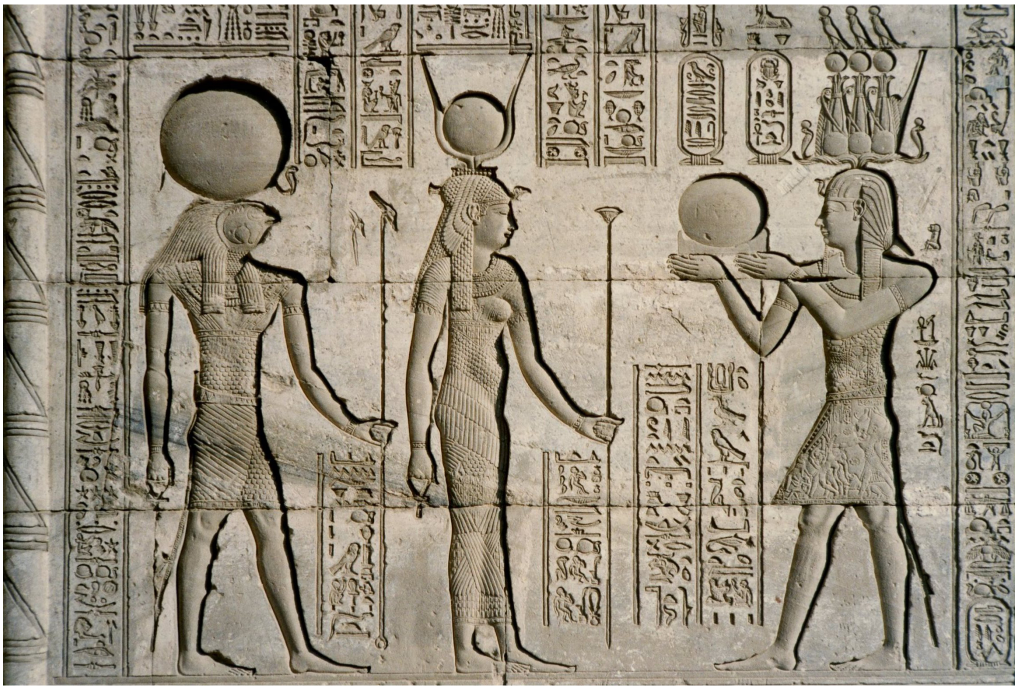


Figure 7.5: Egyptian Bass-relief at the Dendera Temple showing Traianus,Horus and Hathor

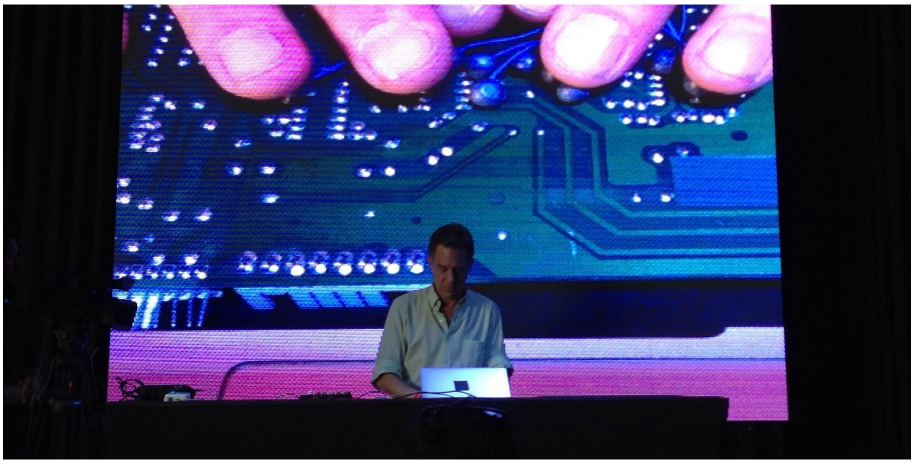


Figure 7.6: Nicolas Collins: The Royal Touch (2014)

> *I had already heard some of the early recordings of electronic music, but these often sounded so dull, so constructed, so without musical soul. Touching the inside of audio electronics was way more exciting to me. I knew this could change ideas about electronics and music. Touched electronics sounded rougher and sort of rebellious against the clean and high-tech quality of the electronic music from the fifties and early sixties. [...]*

Touching electronics means for Waisvisz a liberating strategy towards developing a new type of music. A step forward towards liberating music from the modernist vision of composing and playing music as if we were telephone operators, disembodied from the objects of music and its bodies.

In my opinion, the same idea can be found in Nicolas Collins' *The Royal Touch* (2014) (figure 7.6) a work especially composed for exploring the sonic and haptic affordances of an electronic board. Collins uses an old radio motherboard which is exposed for its tactile interaction. Nicolas Collins is a crucial figure in *touched electronics* because he has lived through the process of digitalization of music. For Collins (2010), we have developed a post-digital tactility in regard to musical instruments. Collins sees how increasingly performers develop more and more instruments and interfaces emphasizing a haptic relationship with digital music. This post-digital tactility would be necessary to overcome the lack of immediacy and tactility in digital media.

Finally, Waisvisz's rebellion is another example of the Deleuzian 'accident of the hand'. It is a performer's hand, liberated from the relationship with the eye which explores circuitry in the look for music. The hand is liberated from the eye because the eye cannot anticipate the effect of touching the circuitry. The action of the hand becomes, like in Francis Bacon, a way of working inside chance. The artist uses the hand not as a way to determine parameters or sonic outcomes. The hand is the way to access the critical impetus of chance.

7.3.3. Touching the Cracklebox

As I wanted to live this perception of touching electronics, I decided to study my own way of approaching and playing the Cracklebox (figure 4.15) or the *Kraakdoos* in its original Dutch denomination. It consists of a small box incorporating at least six metal contacts on top, a circuitry consisting of an amplifier with most of its pins open and connected to the metal contacts (thus making it quite sensitive to feedback loops), a few transistors for amplifying the output, a speaker and a battery. All components are embedded within a case so one can directly switch the circuit on and play. The instrument will sound without the need of any other external component. For playing a Cracklebox performers usually put their fingers on the metal plates, therefore adding changes to the original electrical impedance of the circuity which determines the ranges of frequencies.

Every user of Crackle boxes would agree in describing the instrument as unpredictable and unstable. For instance, it is usually impossible to anticipate the frequency of the tones produced before touching: we never touch in the same manner twice and the circuitry gets charged through different feedback loops we are not aware of.

It is possible to say that there is nothing like the formula of the Cracklebox. For that reason, usually it is necessary to modulate the sound "after touch" in order to fulfill some intention or just letting the sound be as it comes. When performing with a Cracklebox, one could almost feel that the instrument takes its own decisions. One does not know who is controlling the musical outcome in a more active way, the performer or the instrument.

What makes a Cracklebox a creative instrument?. For Michel Waisvisz (2004):

> *Human touch can shape electronic sound in a particular way: Finger pressure curves are very basic information standards. The act of applying physical effort through touch is empirically 'known' to all human beings. The listener can feel the performer's touch and recognize the effort. The handling of physical effort is part of an universal language.*
>
> ...
>
> *The great advantage was that by intuitively touching the electronics one could learn to play this new instrument without having to have schematic knowledge about the circuitry - very much like a traditional music instrument. It could be learned by playing by ear and developing experience and manual/mental skills instead of having to dive into a world of logic, functions, interaction schemes, electronic circuit theory and mathematical synthesis methods. One could play an electronic instrument in direct relation to the immediate musical pleasure of performed sound.*

In the text below, Michel Waisvisz emphasizes three aspects which are relevant for this thesis:

1. Tacit interaction: touching is universal and intuitive

2. Embodied experience: playing is not a cognitive action of the mind but of the embodied mind

3. Tacit learning: learning does not depend on manuals or formulas but on musical intentions.

7.3.4. Touching Tangible Scores

As we have seen in the previous section, playing the Cracklebox means exploring the instrument's haptic properties in relation to the sounds produced. Cracklebox performers enter into an intimate haptic relationship with the physicality of the instrument exploring the causal effects produced by the touched circuitry. A loop of tactile action and sonic perception mediated by the creative instability of the circuitry, the physical characteristics of the instrument and the performer's body. At the moment of performance, the instrument communicates many aspects of the performance. And that is again, for many performers, the instrument-score.

It is my impression that when I play *Tangible Scores* I have a similar relationship with the instrument. Performing with *Tangible Scores* means dealing with an enactive process. Touching informs me about the medium of interaction, elucidating the haptic profile, but it mainly aims me at discovering more about the artifact. As when we immerse our hands into the sand on a beach without any interest of building a castle, we touch *Tangible Scores* because its materiality provokes this action. We do not need to understand how the tactile interaction with these grains of sand happen at many scales. There is a loop of action-perception satisfying us. In the same way, touching a tangible score means discovering the artifact, not for understanding it, but for revealing the haptic and sonic subtleties, its qualities and characteristics.

Touching *Tangible Scores* means a moment of transition from the visual to the haptic, and then again towards the sonic. *Tangible Scores* enact a causal relationship from the visual to the aural through the haptic. An enactive process where the eye guides and forces the hand to produce sound. But the action of the hand is also governed by the impetus of chance. It is the hand in *Tangible Scores*, the element which introduces chance at the musical encounter. It is the generative agent making us touch again and again until we understand the patterns of the artifact. This is coherent with Piaget's (1957) three stages of learning. The first stage, the enactive, serves us to build a first model of the world when we are infants and the iconic and linguistic levels are still not formed.

Finally, in the age of post-digital tactility, *Tangible Scores* reminds us of the importance of touching in all its importance. Many modern commercial digital instruments constrain touching to the fingerprints. Biasing to this limit of our bodily interaction, these interfaces can be more robust and more efficient. However, we have to be aware of the risk of performing only with these type of devices (e.g. tablets or a smart-phones), as far as they "en-frame"[8] us in paradigms eliminating the creative possibilities of the 'action of the hand' and its chance impetus. Contrary to this, *Tangible Scores* is critical with this naturally accepted way of touching. While touching the score, the hand becomes another part of the instrument. Our body, not only our bodily interaction as we have seen in chapter five, can mediate the sonic outcome as much as the materiality of the instrument.

7.4. On Representation

Representation is another prolific topic in the history of philosophy. It is not possible to talk about 'the issue' of representation in general, as it has many bifurcations and applications in various directions: mental representation, political representation, the differences between knowledge and representation, representationalism, etc.

This section is oriented towards two branches on the issues of representation. First, the problem of how our ideas and intentions become represented within the Arts is examined. Then, questioning if our embodied actions in the world create mental representations and of what kind of strategy will be used to approach non-representational positions.

[8] Enframe or frame us in the Heideggerian way that we have explained in chapter four of this thesis.

In our world, representation has come to be understood as the structure that enables thinking. In a way, representationalism dominates our contemporary way of thinking. As a mode of thought, it prescribes all that is known, it orders the world and predetermines what can be thought. Karen Barad (2003) states that:

> *Representationalism is the belief in the ontological distinction between representations and that which they purpose to represent; in particular, that which is represented is held to be independent of all practices of representing. That is, there are assumed to be two distinct and independent kinds of entities—representations and entities to be represented.*

Representationalism affords relevant questions, like, is Science accurate in representing real phenomena? Can languages represent what we really think? Is political representation accurate to what the represented think? Representationalism also implies the incorporation of a third party, apart from representation and represented: the one in charge of building representations.

The representational responsibility is nowadays given to both humans and non-humans. Lawyers can represent us for dealing with legal issues while computers represent our information to other agents at daily tasks. Representation has become a business in our modern and technologically complex life. For Latour (1988):

> *"The most humble of us lives surrounded by a princely retinue of delegates and representatives. Every night, on television, our representatives in Parliament talk on our behalf. We have delegated to hundreds of non-human lieutenants the task of disciplining, making, and moving other humans or non-humans lifts, cars, trains, machines. Hundreds of scientific disciplines and instruments constantly bring far away places, objects and time to us which are thus represented that is presented again for our inspection. In dozens of books, movies, plays and paintings, human and non-human characters represent us with our violence and our fears, populating our world with crowds of friends and enemies." (Latour 1988a:15-16)*

Karen Barad (2003) explains that representation has a history. In the treatise *Art Beyond Representation* (2004), Barbara Bolt asserts that the pre-Socratic Greek world was not predicated on a concept of representation and the ancient Greeks did not think representationally. Due to Ian Hacking's anthropological philosophy (*Representing and Intervening* (1983)), representations were unproblematic prior to Democritus: “the word real first meant just unqualified likeness". As Barad (2003) explains, "with Democritus's atomic theory emerges the possibility of a gap between representations and represented". For the early Greeks, noted Derrida (Derrida 1982:306), "the being of what-is never consists in an object brought before man, fixed, stopped, available for the human subject who would possess a representation of it". Finally, for Heidegger (1977), Plato's separation between Ideas and Form (the world) is the foundational stone of representation.

After Plato, explains Barbara Bolt (2004), from Descartes up to Kant, representation was simply identified with thought. Therefore, thinking meant employing ideas to represent the object of thought. The great 'turn' in philosophy comes with the Kantian questioning about representation. From this moment, words are disembodied of their function as carriers of knowledge. It is now possible to think that knowledge might be something other than representation.

Heidegger's critique of Cartesian representation lays on the reduction of thinking to a schema, to a model, objectifying the inherent complexity of Being. The loss of Cartesian representation is exemplified comparing Greek's apprehension of the world as 'presencing', against the modern representation of the world as 'subiectum' (object). Heidegger remarks, that through the ability to represent or model the world, we secure the world for our own use. But with this newly acquired power, Heidegger warns, a terrible loss is incurred. Because man no longer lays himself open to the world, we can no longer experience what-is as Being. In conclusion, for Heidegger, we should pay attention to the presuppositions of modern representationalism and call into question its goals (Bolt, 2004, my emphasis).

Humans we are symbolic cognisers. This is clear looking at our cultural and intellectual production: how our knowledge has been supported by symbolic language: mathematics, language, music, games, etc. Yet, as it has been explained, a certain turn in the perception of representation was produced with post-modernism affecting not only philosophy of language but Science too. Impulsed from the philosophy of language of John Langshaw Austin and Jacques Derrida, a new interpretative vision of representation was built: utterances (philosophical or general) cannot have fixed meaning because context is always subjective. Although the notion of "intention" is still existing as a will, it becomes an irrelevant character. The idea that a biological organism would not feature an intention ’per-se’ triggered new social and political disputes. For example, gender would not be communicated by the physical attributes of a body (its sexual gender). Through the work of Judith Butler we learned how the idea of representation blurs the personal activities of self-identification. Only performative acts define signification.

Roughly, the crisis of representation can be summarized as:

- An epistemological crisis which questions the relationship between our representations and reality. The problem is how our ideas, words or other signs are able to correspond to real objects when they seem to be very different kinds of things. The linguistic turn of the last century externalized the sphere of representation, yet the problem of representation stayed much the same.
- An ontological crisis which takes for granted that the crisis has been brought about by the expansion of mass communication, which has made our modern life world increasingly packed with representations and virtual artifacts of all sorts. It is supposed that rather than being in contact with reality, we are thus increasingly dealing with representations of it.

The contradiction occurs then with unique human or cultural affairs like books, photographs, Phd thesis like this... where we still need to use symbolic representations. For this reason, the artistic artifact becomes a key to understand non-representationalism. What cannot and should not be represented, can be communicated through the action with the artifact. Artists have been the greatest specialists in expressing what cannot be represented. More than a ’representation without words’ which could without efforts be applied to what an image is, we look out for a poem disengaged from representation. Like when Mallarmé dreamed of a dance as a "poem unburdened of scribal accessories" (see chapter 4 section 4.4.1) where nothing but a pure whiteness without contents is inscribed (Louppe, 1994).

7.4.1. Representation in Arts and Music

One of the basic questions of visual arts, or aesthetics if we prefer, is the nature of the representations artists make use. It is assumed that the Arts are representational practices. Art would produce representations and when audiences engage with paintings, photography, videos, sculptures, etc they are dealing with representations. Obviously, this would apply to certain traditional art but not to many contemporary artifacts. For instance, painting has been often classified in terms of its representalism as representational (figurative e.g. Velázquez), abstract (if it departures from reality e.g. Picasso) or as non-representational (when it does not relate to any real or imaginary object e.g. a Mondrian). In the case of conceptual art or sound art, for example, the attempt to analyze their degree of representationalism would be no more than a mere academic exercise.

Is music representational? In music two different understandings of representation are used (at least):

- Representation through music: like in the case of Art, if music, as a physical phenomenon, serves as a representation of other represented object.
- Musical representation: the strategies to represent a musical intention. It is usually called notation.

The idea that music is representational is not that easy to apprehend. For Plato (in *Ion* and *The Republic* books II, III, and X), music is mimetic, just like in the case of poetry and other arts. Therefore, Plato saw in mimesis the representation of nature. Contemporary philosophers of music, like Hanslick or Kivy assert that music is not representational but ’pure sonic design’. Certainly, music can have a programmatic intention (e.g. Vivaldi’s Four Seasons) but we cannot say that any of Bach’s cello Suites represent more than its author expressive intention. For this reason, we usually think of music as quite a different type of art than for example, painting or photography. But also, music often accompanies other arts. Like int the case of opera or film. In this case the line dividing representational practices from others start to blur. It is quite common in films using music to suggest a character’s personality or the particular emotion of a situation. Indeed, many authors insist in rendering representational attributes to musical pieces using eloquent titles like "Imaginary Landscape", "Nocturne", "La Mer", etc. In this case, composers seem to have a representational idea, perhaps not programmatic but inspirational, which they need to make public for the fully comprehension of the representational value of their pieces.

The case of representation as notation has been extensively covered in chapter four of this thesis. However, a relevant aspect needs to be studied at this section: what is represented in musical notation?

Wiggins (et al) (1993) remarks "the importance of assessing notation in the context of a whole representational system i.e not just the notation but also the processes that act on it". I understand Wiggins in the sense that creating a notational system always creates a certain bias. It is always a process of filtering possibilities.

Music language has shown its efficiency in classical music. But interestingly, other systems have also appeared: graphic scores, performative scores, etc. Which other system is it possible to create?

We humans are specialists in inscribing representations everywhere. But we are also specialists in interpreting materials and activities (performances) as representations. As Sally Jane Norman poetically explained at the *New Notations symposium*[9] (2016) in her *Object of Notation*[10]:

> *Unfolding from within and around these beings we call*
> *our selves, we learn to read the substance of the world:*
> *to make markings stand as notation, we discern and give*
> *symbolic structure to the strands and knots of tangled*
> *temporalities that shape materials, including those*
> *that are evidence of our own corporeal existence [...]*

Many types of notational systems (not in the Goodman sense as I have explained in chapter 4) do not use a pure linguistic strategy for notating music. For example graphic scores, sculpture scores or choreographic objects would be the case. In these types of representations, in words of Panos Vlagopoulos (2012) we cannot dissociate the pictorial from the musical aspects of the mentioned works because the pictorial representation "enlarges the conception of music by combining the allographic-notational with the autographic element". Indeed, "the pictorial (autographic) element is bent towards the allographic pole, by being used as a score". In the same direction, Earle Brown has often commented that his scores are merely improvisational scores, serving as a basis to a way of performing, not a performance itself. For Vlagopoulos (2012) "a graphic score is not subsitutable by a normal score (...) a graphic score is unique in the sense it can guarantee a unique way of performing as opposed to a unique , compliant performance which would succesfully passs what Goodman calls the retrievability test".

The pertinent question now is, could all these notions be extended towards musical instruments?

That musical instruments can be used to represent is not new. The timbre of a musical instrument can represent, through mimesis, various characters. For example, in Serge Prokofiev's *Peter and the Wolf* the 'wolf' is a French Horn.

However we are not interested here in the Platonic mimesis. We are interested in the notational aspect of representation. In seeing instruments as notational systems. We can describe three different types of musical representations as they can be observed in figure 7.7. First, a traditional Western musical score (Mary had a little lamp), a graphic score (Brown's November 1952) and third Nicolas Collins' *The Royal Touch.* We may all agree that these three works are represented by those artifacts we see in the figure. We see how, conceptually and regarding their materiality, they are very different, but all represent music. For many, there will be no discussion about the first and second types of representations. As we have seen at chapter 4 they are used by composers and practitioners, so they are musical representations. But, what about the third? The only difference between them is the level of interaction. A musical score represents at a symbolic level, graphical score represents at an iconic or image-based level and the circuitry at the enactive level.

Can we talk about an enactive sort of representation? Does the body represent anything when we touch? For answering these questions we first need to include some concepts imported from embodied music cognition.

7.4.2. The enactive and embodied cognition view

Jerome Bruner (1966), following Piaget (1957), theorized that learning occurs by going through three stages of representation. Each stage is a "way in which information or knowledge are stored and encoded in memory" (Mcleod, 2008). Bruner was a psychologist who focused much of his research on the cognitive development of children and how it relates to education. Each of Bruner's stages of representation builds off of the knowledge

[9] Organized by Thor Magnusson `http://www.sonicwriting.org/ircam.html`

[10] published in Norman's website `https://www.sallyjanenorman.net/sallyjanenorman.net/Object_of_Notation.html` las access 1/12/2017

and information learned in the previous stage, or in other words, the stage before acts as scaffolding for the next stage. The three stages are:

- Enactive (action-based)
- Iconic (image-based)
- Symbolic (language-based)

The enactive level involves encoding action-based information and storing it in our memory. For example, in the form of movement as a muscle memory, a baby might remember the action of shaking a rattle. In the same way, violinists remember the optimal physical trajectory for sliding their bows on the instrument. Enactive cognition allows us perform a variety of motor tasks e.g. bicycling or playing instruments that we would find difficult to describe in iconic (pictures) or symbolic (words) forms.

The embodied approach to cognition is an experiential approach that is grounded in sensorimotor interactions of an organism with its environment. The enactive approach defines knowledge as the result of an ongoing 'interpretation' emerging from our capacities of understanding our environment. These understanding capacities are rooted in the structures of our biological embodiment but are lived and experienced within a domain of consensual action and cultural history (Varela, Thompson and Rosch, 1991, p. 15). It is important to remark first, that seeing knowledge as an act of interpretation allows for personal identifications with the world. And second, interpreting the world means performing it, engaging with its materiality.

For Reybrouck (2017) embodied cognition is an orientation that views cognition as 'enaction' and that is consonant with the 'experientialist approach' to cognition, which is "a cognitive semantics that does not take the world naively (naive realism) but that accounts for what meaning is to human beings (cognitive realism)". This, in the case of music, may result in the construction of an internal model for sonic perception, which allows the listener to go beyond the constraints of perceptual bonding and to carry out mental operations on symbolic representations of the sounds. This entails a transition from the traditional view from sensori-motor loop action as coordination, to a view of simulation, modeling, and symbolic play. For Reybrouck (2007), the brain, engaged in this process, "no longer operates as a 'controller' that reacts to sensory stimulation but as a 'simulator' that carries out internal operations on mental replicas of the sound".

Newton Armstrong, in his thesis *An Enactive Approach to Digital Musical Instrument Design* (2006) defends that the kind of representation that serve as the access point to the medium constitute an important matter for consideration. By definition, an enactive model of performance would situate the agent's cognitive activities entirely within its environment. In contrast, an objectivitist model of representational content, which would situate the agent's cognitive activities outside of its environment, therefore throws up a not inconsiderable obstacle to arriving at embodied modes of interaction. For Armstrong, "the crucial point then is the form of representation, more specifically, the difference between those forms of representations that set out to passively encode the state of the task domain, and those that would seek to structure the agent's active involvement within the task domain". Armstrong is alluding to the types of representation which can be constructed without the direct involvement of the agent which will perceive them (e.g. a photography). Instead, a tactile pattern in a dark room would necessarily need the direct involvement of the perceiver for creating a representation. Therefore, from Armstrong's arguments we can classify two forms of representations. Those which are built without the active involvement of the agent and those which seek to organize agent's involvement in the task.

This is coherent with Alva Noë's understanding of what the author calls "organized activities" (2016). Noë remarks how our lives are characterized by several of these "organized activities", from breastfeeding to talking, from dancing to driving. Such activities shape ourselves, our way of thinking and acting. In other words, we get organized by means of them. In this direction, explains Noë, dancing is an "organized activity" but choreography is not. Choreography is not dancing: choreography puts dance on the stage. Choreography focuses and acts on showing what dancing can be and how it can be worked on and re-organized. One dances when one finds herself dancing (the organized activity), not when one plans and re-organizes the activity (through some kind of external to the agent representation, following Armstrong arguments). In this sense, if dancing is an organized activity, choreography is a re-organizational one. Indeed, according to Noë, we can think of two levels of activities. Level one is the one of organized activities (e.g. talking, moving, dancing, singing). Level two is the level on which "the nature of the organization at the lower level gets put on display and is investigated" (Noë 2016, 29). In this sense, level-two-activities re-organize the lower-level. Among such level-2-activities we can find choreography, as well as art and, interestingly, philosophy explains Noë.

In the words of Magnusson (2009) "at the enactive level is where cognition is subconscious, pre-conceptual, distributive and emergent". Enactivism explains the existence of symbolic systems, like language, asserting that "symbols are higher-level description of properties that are ultimately embedded in an underlying distributed system". In other words, as "macrolevel descriptions of operations whose governing principles reside at a subsymbolic level" (Magnusson, 2009). In fact, Magnusson uses these ideas to explain how the process of learning an acoustic instrument is primarily sub-symbolic. The incorporation to our cognition of the necessary skills to play an acoustic musical instrument is necessarily an embodied process, an organized task, which is usually not based on symbolic or theoretical relations.

It is also important to remark that, in the active engagement with artifacts, the concept of affordance, has helped to create cognitive frameworks. The notion of affordance was introduced by Gibson (1977), which stated that animals perceive their environment in terms of what it affords to the consummation of their behavior. For Reybrouck (2017) affordance can be defined as "the perceived functional significance of an object, event, or place for an individual, referring to environmental supports for an organism's intentional activities". The notion of affordance is inseparable from the existence of a perceiver which experiences objects and is able to find meaningful features. Affordances are purely subjective values and functionalities given to the environment which are necessary to support life, from social interaction to nutrition. Being eminently subjetive, they rely on objective environmental features of the world as well as on perceiver-specific qualities, which are variable and subjective to a great extent.

Summarizing all these arguments, I affirm that it is not possible to say that the active engagement of action and perception with an artifact may, or may not, involve representations. That mostly depends on the level of the activity we are involved. Re-organizing activities (level-2 in Noë's paradigm) build on organizational activities which often show an intention. Yet, these activities contribute to an incessant process of classification and creation of ontologies of objects. For example, the simplest ontology for an animal would be defining something as eatable or not. And this ontological separation creates automatically a representation. The eatable animal and the one which is not. It is possible to say that intention always leads to ontology. An ontologies are made of representations.

But we can also find level-1 activities which do not lead to representations. If we see a piece of paper as part of a level-1 activity, and we do not project any particular intention onto it, it may not create representations in our mind. That would be the case of engaging with the materiality of the paper in an enactive way without giving it any other value. That would also be the case with swimming or again, playing with our hands with the sand on a beach which we can all agree that do not produce representations. However, the same piece of paper for John Cage afforded a level-2 activity, the composition of the *Solo Suite in Space and Time*, a chance process in which the notes or tones corresponded to "imperfections" in the paper upon which the piece was written. The level-1 got reorganized and as a result it produced many representations.

In conclusion, one of the crucial results of the development of enactivism has been the consideration to non-representational scenarios. For Heras-Escribano, Jason Noble and Manuel de Pinedo (2014) enactivism has finally put forward a positive alternative to representationalism to understand mindfulness, cognition, perception and agency.

7.4.3. Non-representational Interaction Design

One of the big issues of non-representationalism is approaching pragmatic implementations. Especially when it depends on computational systems like as in our case. Computer science is built on the concept of representation. And so it is with musical interfaces usually too. In fact, many of the guiding metaphors of HCI are at odds with the embodied and enactive approach.

Alternative discourses to representational computer science have been progressively produced. Winograd and Flores in *Understanding Computers and Cognition* (1986) is probably the most complete effort towards another form of computer science. For Winograd and Flores computers operate in a domain of language. The computer is a device for creating, manipulating, and transmitting symbolic (hence linguistic) objects. Only what can be represented exists for the computer, and therefore creates a bias against other non-representational entities and relationships.

Bill Verplank explained in his Sketchbook[11] (2009) that when interacting with computers different types of representations can be afforded. Briefly, Verplanck suggests that our modern computing has had three

[11] Never published, only released as a PDF in `https://hci.rwth-aachen.de/tiki-download_wiki_attachment.php?attId=797`

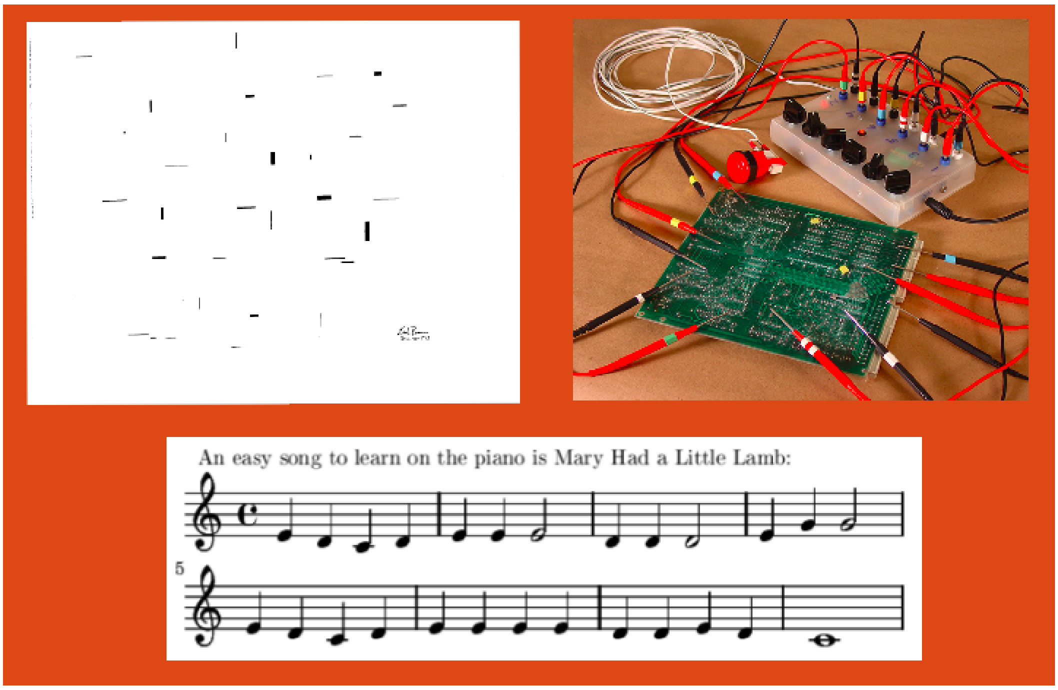


Figure 7.7: Notations and Instruments at discussion

Figure 7.8: Leap Motion promotion in 2013.

eras as far as representation is concerned: first the textual, second the graphical and finally the tangible. Textual interaction is typical from command-line interfaces through consoles and terminals. This type of interaction with computers is based on linguistic representations. Then, graphical interfaces make use of graphical representations and graphical metaphors for interaction (i.e. drag and drop) to improve efficiency. Finally, Verplank describes tangible interfaces as an enactive way of communicating with our machines. At this last interactive mode, users would be immersed within media. In this case, computers are not seen as tools but as media. At tangible interfaces, it would be possible to grasp and feel directly data. Thus, metaphors like sculpting or modeling information would be adequate. Enactive interaction would make users forget they are managing with variables and parameters. They would only feel the feedback from interacting with the properties of physical materials. Or in other words, data is embodied within materials. In principle, at enactive interaction intermediary representations between users and data are not needed. If these interfaces are designed to control music, the interactive experience would remind us of the one obtained from playing an acoustic instrument.

Certainly, there are a huge number of tangible interfaces out there, but how many can be considered enactive? And among the purely (or academically) enactive, how many really can be described on the immersive terms explained by Verplank?

Performing music with musical interfaces can be felt at different levels of interaction. A live coding[12] session is essentially textual and uses linguistic communication with computers. A digital DJ session with an standard graphical interface involves the navigation of graphic information. But when we observe pianists playing, we think of them as immersed into music. Performing with virtuosity sequences of notes with a gestural controller will require it. However, immersiveness does not only depend on the way we control or represent information. Other parameters like the degree of feedback obtained from the instrument and from the environment can easily destroy our impetus for immersiveness.

A recent contribution to the topic of non-representational computing is Gillies and Kleinsmith's *Non-Representational Interaction Design* (2014). Departing from the general asseveration (which I agree) that Interaction Design is a discipline saturated with representations, the authors propose different alternatives to shift to interface models favoring bodily forms of representation, which "can tap our prior skills for interacting in the world". As it is not easy to implement those strategies through traditional computational models, the authors aim at implementing interactive machine learning methods which in theory, can grab aspects of non-representational couplings which would allow users to perform with them instead of representing them.

For the authors, classical representational systems and non-representational can be compatible. Introducing the work done by Jacob et al. (2008) in virtual reality, they defend that bodily interaction with computers is successful because it leverages a different set of pre-existing skills from users. For example the skills that enable us to move in the world. Instead, GUIs obligate us to have skills in graphic and symbolic manipulations. Other interesting appreciation by Gillies and Kleinsmith is that many of the technologies present at bodily interaction work as "just extensions of a symbolic, representational interface which are just a more physically tiring version of a GUI". We can for example think of how a LEAP Motion interface is used for browsing the Internet (figure 7.8).

Following this direction, a number of technologies have allowed implementing gestural recognition (e.g. kinect, leap). The issue is that in this case, these gestures are always recognized after users have made them. For Gillies and Klensmith this is like being "closer to a textual command line interface where users must remember obscure commands with no visual prompts". Therefore, a possibility is avoiding the need of representing those 'commands' but making use of the sensory motor skills without representation. In short, gestures must not be limited to a vocabulary, to a set of pre-defined symbolic gestures. The authors propose an scenario for tangible interaction design which shifts a designer's role from designing representations to designing sensory motor couplings which users must perform without mental or external representations.

However, computation does not have access to sensory-motors action without the use of numeric representations. For this reason, Gillies and Kleinsmith reduce designing non-representational interaction to one possibility, the one of designing with the body, "defining movements by moving". The tool suggested by these authors is machine learning, where it is possible to infer recognition models from training examples. In particular, the authors propose implementing interactive machine learning routines where users provide training data and progressively they refine the classifiers they are creating. This strategy has been used by

[12]A live coding session involves a musician who programs the source code of the instruments on stage in real time and from scratch, often visualizing this source code to the audience.

Fiebrink (2011) for designing digital musical instruments. Out of this research Fiebrink has programmed the machine learning environment *Wekinator*[13], one of the systems *Tangible Scores* uses for designing interaction.

7.4.4. Representational Dimension of Musical Interfaces

In this section I will discuss different aspects of representation in regard to musical interfaces. The intention is answering the following questions:

- which are the representational features of musical interfaces? How can we compare them?
- How does representation reconfigure musical interfaces?

Although in chapter three of this thesis I have studied in detail the the apparatus of a digital instrument, the objective now is answering how much does the computational representation of this apparatus mediate the embodied and hermeneutic modalities of our relationship with the system. For Magnusson (2010), the use of digital systems for controlling sound makes it impossible to escape from the use of symbolic systems. Our musical models and intentions are communicated to the computer inscribing them at some part of an application, a memory, or in the form of written source code or information. For Magnusson, "although one could create sophisticated tangible hardware as interfaces, the interaction will always be primarily symbolic, and taking the form of representational patterns". One of the most interesting results of Magnusson's research is his understanding of digital instruments as text. Apart from the embodied dimension of every instrument (as an extension of the body), "digital instruments are external tools to the body whose information we have to interpret -thus hermeneutic-. This information can be seen as a text, something we have to read".

But, what does it mean being primarily symbolic? Can be one partially symbolic? I affirm that it is possible to analyze and study how computational representation affects the embodied versus hermeneutic relationship in the instrument. This simple and one dimensional space of analysis can help us to define the representational dimension of the instrument. A hypothesis would be that the more computational representations the instrument incorporates the less embodied it is. In particular, this study analyzes how the representations incorporated to digital musical interfaces are perceived as embodied affordances. If they are embodied, users will have the impression of being immersed within media (Verplank, 2009). In the opposite direction, if these affordances are hermeneutic, performers will have the impression of dealing with symbols and parameters. Various similar dimensional spaces for analyzing musical interfaces have been proposed in the past (Magnusson, 2010; Birnbaum, 2005). The methodology followed here is similar, but we are going to simply add another representational axis.

For developing this analysis, eight different and contemporary musical interfaces have been chosen. These instruments have been chosen because they are considered highly embodied and I have been able to test or play them at different art events or musical festivals. Each of the interfaces is evaluated with a number. Zero means representational while ten means non-representational. Therefore, a zero means being hermeneutic in the moment of performance while ten means that the performer is totally embodied into the performance.

Under this perceived representational analysis, one extreme would feature pure embodied instrumental relations and at the other pure symbolic communication without embodiment. An instrument like the Crackle Box (electronic although analog) would be at one extreme because no symbolic intermediation is needed for playing it. Live coding would be at the other side: the live coder uses textual commands, thus communicates with computers in a dialogue, and although some embodied skills are necessary (typing on keyboard for example) they are not principal or can be substituted.

Additionally, it is crucial to remark that the following analysis only relates to the performing phase, not to the phases of design and configuration. Also, this analysis has been made from a performer's view, I am only interested in analyzing the experience of performing with the instrument and not the audience's experience with the performance (which can be quite embodied independently from the instrument). The instruments chosen are the Karlax, the Tingle, the Expressive E Touché, the Linnstrument, the Qgo, the Xth Sense and Tangible Scores. These instruments can be observed at figures 7.10a to 7.12b:

[13] `http://www.wekinator.org/`

- Karlax[14] resembles the form of clarinet although it is strictly a wireless gestural device, combining ten continuous controller keys, seventeen buttons and eight velocity pistons and three axes of accelerometers and gyroscopes. One of the most remarkable musical pieces for the Karlax is Andrew Stewart's *Ritual* which is described in a paper written by the same author (Stewart, 2015).

  The Karlax is an interface which combines discrete and continuous sensors. Their values are sent to the computer in parallel for various controlling musical processes. For composing or improvising a piece with the Karlax, one has to map those parameters into notes or changes in the sound synthesis. Although the Karlax is a gestural controller, its deterministic nature makes performers having to be quite attached to the computational representation of their movements. That makes the instrument becoming quite hermeneutic. I value it with a five in a scale from zero to ten.

- the Tingle by Rhys Duindam is a tangible music controller which aims to bring back the acoustic touch and feel to digital music creation. Inspired by a pinscreen, the Tingle will let you mold sounds with your hands or anything else. Although the Tingle has not been released to the public yet, I was able to test it at the TEI Conference 2016 in Eindhoven.

  The Tingle measures how deep each of those pins has been inserted into the interface body. As the Tingle features sixteen rows and columns of pins, in total 256 pins, it somehow overloads performers with a huge amount of variables. Instead of individual control of the pins, the interface affords the tactile exploration of the pins surface as a whole. Therefore, the Tingle is less representational than for example the Karlax. For this reason I evaluate it with a seven.

- The Expressive E Touché is a highly sensitive multidimensional controller for the hand. It measures the sonic gestures, pressure and direction. The interface uses a mechanical combination of springs and cylinders to offer physical resistance.

  The E Touché offers a limited set of movements. Basically, vertical pressure and left and right displacement of the center of the interface. Its main characteristic is that it is extraordinarily sensitive to changes, making it very expressive for example to simulate vibrato. Unfortunately, it constrains the action of the hand to those movements. It is like a sophisticated plain joystick in which the movements are always produced towards controlling a well-defined represented parameter. For this reason I evaluate it with a three in the scale from zero to ten.

- the Linnstrument is an expressive MIDI controller for musical performance which incorporates RBG-backlit pads able to sense each finger's subtle movements in five ways.

  The Linnstrument's space of interaction consists of 200 multidimensional pads. Each of these pads represents a MIDI note and each note can be expressively modulated because the interface senses the way we press the pads. Although the instrument is totally representational in terms of the musical language it is partially embodied too. The issue of understanding that each note simply represents a note, like in an acoustic piano, affords the physical exploration of the pads in freedom. However, although the pads are quite sensitive and detect different ways of pressing, this way of exploring is also quite representational, we expect deterministic changes in some well-defined computational representations. Thus, its representational dimension is evaluated with a four.

- the Qgo by Chikashi Miyama in *Modulations* (2014), is a wireless glove-shaped performance interface, with an infrared sensor, a gyroscope and an accelerometer. The sensors detect the movements of a performer's hands in a three-dimensional space for controlling live audio and video.

  The Qgo is, in terms of representation, a similar device to the Karlax. The gloves of the Qgo broadcast the values of their sensors to control musical processes. Each parameter has a representational realm in a Pure Data or Max patch. When Chikashi Miyama performs with them, we see how the relationship between corporeal action and sonic outcome is not linear. We understand Miyami more giving energy to a complex structure of synthesizers, activating them in non-linear ways, than controlling parameters. For this reason I evaluate the Qgo with a six.

- the Xth Sense by Marco Donnarumma is a free and open biophysical technology. It captures sounds from blood and muscles and uses them to integrate the human body with a digital interactive system

[14]Description taken from Karlax's website `http://www.dafact.com/fonctionnalites.php?id_product=1`

for sound and video production. The new version of the XTH Sense is a consumer product, it is wireless and comes with spatial and inertial sensors.

The Xth Sense uses biophysical information to control sonic processes. The nature of these biophysical data, the sound of blood and nature, is not easy to interpret. The sound of a muscle can have infinite variation and it is not data we can parametrize. It needs some mathematical analysis for extracting some particular characteristic like timbre, shape, evolution, etc. which is also variable. Therefore, Xth sense is an interface which can only mediate transformation of some generative process in the computer. Performers, at the moment of performing, embody this information into their bodies without any reference to computational representation. For this reason I evaluate this interface with a nine.

- Tangible Scores has been extensively described in chapter five. When a performer approaches Tangible Scores, there is no information on how tactile exploration is mapped into sound. Basically, the instrument resynthesizes sonic gestures created on the surface. There is no way to change parameters except through exploring the materiality of the instrument, trying to change the timbre of the sonic gestures. There are not intermediate technical representations mediating action. For this reason, Tangible Scores are evaluated with nine in the scale of zero to ten.

These results are visualized in the following figure 7.9.

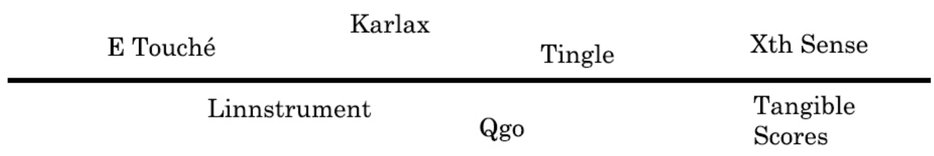


Figure 7.9: Representational dimension of various musical interfaces, from more hermeneutic interfaces (left) to more embodied (right)

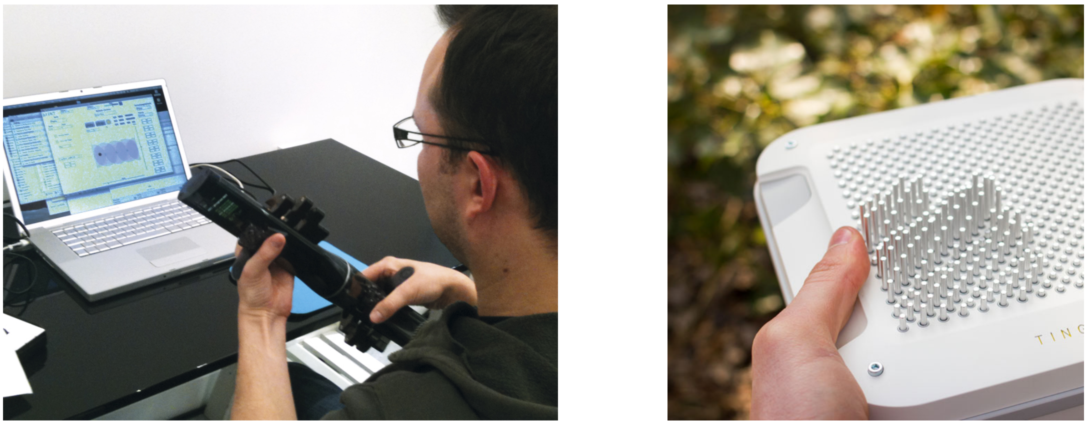
Two main conclusions are found from this analysis:

1. If the necessary computational representations are embodied, they won't be perceived as a parameter, but as physical affordances. This is in fact the principle of "data embodiment" used in tangible interfaces.

2. If one representational element is present and perceived, the vision about the instrument changes drastically and makes it hermeneutic. Thus, the representational mediation of this relationship is not linear, but exponential. It is possible to allude again to Derrida, referring to Charles S. Peirce's philosophy of notation, when he asserted (Derrida, 1974) that "from the moment that there is meaning, there is nothing but signs. We think only in signs".

A traditional approach to embodiment in musical interfaces has released certain responsibility of creating true embodied relations with the instrument to its performers (Gurevich, Marquez-Borbon, Stapleton, 2010; Fyans and Gurevich, 2011). Acquiring the habitus of working with musical interfaces, obtaining musical confidence in an effective way, also depends on those internal computational representations which are difficult to reveal and identify.

But, how intuitive is the representational nature of a musical interface? Can only a performer's habitus and the instrumental affordances of the instrument make a non-intuitive digital instrument be more intuitive? I defend that this perceived intuitiveness has much to do with the representational dimension of the instrument. In my opinion, the mediation produced by computational representations must be considered as an important characteristic defining our possibilities to engage with the instrument. Those computational representations can make us perceive a digital instrument as a text we have to decode, as a space of parameters we have to control. Digital instruments of this type usually need extensive user manuals. These user manuals explain us what this or that button represents, how to access hidden parameters and the precise

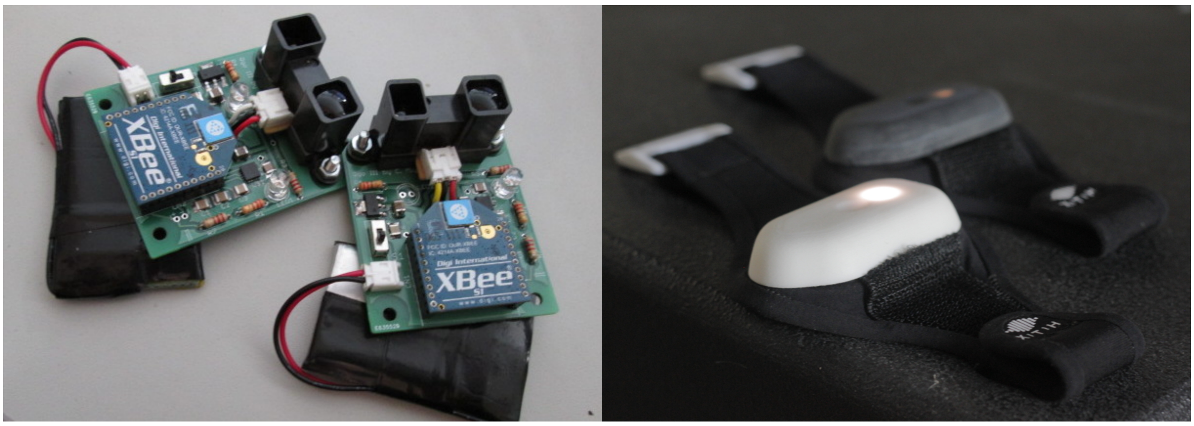


(a) (b)

Figure 7.10: The Karlax (a) and the Tingle (b)

(a) (b)

Figure 7.11: The Expressive Touché (a) and the Linnstrument (b)



(a) (b)

Figure 7.12: The Qgo (out of their gloves) (a) and the Xth Sense (b)

way of enabling or disabling ways of performing, which the instrument does not automatically offer. Would we imagine buying a guitar and getting its user manual too?

Instead, if those computational representations become embodied into the materiality of the instrument, we can start to perceive them as physical affordances. I am not referring to embodying a parameter into a knob or a slider. When we turn a knob we automatically allude to the parameter we are controlling. On the contrary, when we press a piano key we do not think of the mechanism actuating on the string. Our muscles do not know what is a parameter. But we learn the multiple ways of using our muscles to play different styles on the piano. This is a tacit knowledge which is not explained through a representation.

If our digital instruments were less representational, embodying those necessary computational parameters into the instrument materiality in an extensive way, our relationship with the instrument will also become much more similar to the one we have with acoustic instruments. Probably, this has to be done at the risk of reducing interface's efficiency and robustness. It would create other type of musical interface paradigms, more performative and therefore less deterministic.

7.4.5. A performative model for musical interfaces

Highly informed by Human-Computer Interaction, different frameworks for modeling and studying digital musical instruments have been proposed. The frameworks of Orio (Orio et al, 2001) and Wessel and Wright (2001) structure interaction through the layers of control, mapping and synthesis. Thus, the task of producing sound from physical gestures is subdivided into a hierarchical architecture of technical tasks. The perspective of Armstrong's enactive framework (2002) departures from an understanding of the production of music as a cognitive action. This model inherits from the field of embodied music cognition (Leman, 2007) and enaction theory (Varela, Thompson, and Rosch, 1991) and situates user´s cognition at the center of this model. For example, under this enactive model, musical interaction with a controller is modeled as a flow of relationships between human and machine: physical input, embodiment, representation, realization, reflection, etc.

Interestingly, none of these paradigms incorporate the representational dimension of the instrument. Therefore, I propose here an extension of these models towards including representation. Far from promising the 'last-revolutionary framework' for NIME, I perceive it as an change of perspective. My aim is building a mindset where it is possible to separate those pragmatic computational tasks -mostly linguistic- from others mostly performative -usually non-representational-. Because there are many computational tasks which can be only developed using linguistic communication with machines (e.g programming) it is crucial that many others non-linguistic (e.g. exploring the physical affordances of matter) find their place and a separate agency within our digital instrument models. These relationships will define radically the embodied relationship with the instrument. An important remark here is that when the notion of 'embodiment' is alluded to it always refers to the embodiment between musician and instrument, and not to other types: embodiment performance-audience, performer-audience, etc.

Before fully describing this model, it is necessary to explain the various representational phases or 'moments' during interaction with musical interfaces. As we explained earlier in this text, the type of relationship we hold with digital instruments is radically dependent on the stage of interaction we inhabit. It is not the same the moment of configuring the system than the moment of playing in front of an audience. It is quite surprising that there is a lack of literature explaining what I have called the 'moments' of a musical interface. From my vision, we can describe four moments of interaction:

1. Design/Implementation time: when a designer creates a musical interface: normally using digital and analog tools which can be linguistic and representational (e.g. circuit design, programming) but also embodied and typically enactive (e.g. hammering, screwing).

2. User-designer time: the moment when an interface, already implemented, is configured with a particular preset or status for an specific performative use. It is the case of configuring a digital instrument with specific parameters controlling control, mapping and synthesis. It is usually informed by HCI and thus usually linguistic and representational.

3. Learning time: when those representations are embodied or incorporated to our embodiment. We learn how to deal with the response of an interface and through this sensori-motor activity we gain knowledge about the instrumental and notational scheme of an instrument. New possibilities for embodied performance with the instrument are afforded from its functionalities and its defects.

4. Perfomative time: the moment of playing with the instrument, usually guided by a particular musical intention. Like in the other phases, it can be informed by non-representational uses (e.g. sculpting the sound with movements) or mediated by fully linguistic procedures (e.g. controlling parameters in the computer). This will depend on the type of interaction proposed by the instrument and by its performer. For example, a live coding session will be mostly linguistic while performing with Tangible Scores will suppose an enactive relationship.

These moments of musical interfaces are coherent with a multifaceted vision of musical interface design: sometimes we have to act as programmers, sometimes as performers, sometimes as artisans, etc.

As a conclusion, the nature of musical interfaces is highly dependent on the moment of its use. Therefore, for saying something about its nature, we also need to define at which 'moment' the instrument remains.

Once these 'moments' of the interface have been described, it is now possible to explain a model developed together with Martin Kaltenbrunner which includes the instrument's performative and representational dimensions. In this case, we escape from defining the digital instrument as a static entity without the agency to perform its nature. We see digital instruments as entities which can afford new and different performative uses at every iteration of use. Then, the instrument is not represented by its technical characteristics, but performed. Like in the case of human gender which is not represented but performed (Haraway, 1991), the instrument is defined by a performative act. This model incorporates three parallel layers (and not 'levels') since there is no hierarchical dependence:

1. Technical: all the entities defining the technologies for acquisition, configuration, mapping and synthesis workflow. It is independent, static and predefined. Working on them means dealing with the representational dimension of computers.

2. Instrumental: the layer of symbolic and material affordances and constraints making an interface being perceived as a musical instrument. This layer is responsible for affording instrumental and notational uses. It is also the layer defining the instrument-score. It can be purely symbolic and linguistic but also enactive and non-representational.

3. Performative: it defines the instrument at every performative iteration. It is defined by an artistic intention. This layer is dynamic and it depends highly on users and their reference-frame.

In order to inform the academic community about this model, a number of digital instruments are presented under this paradigm:

- The Hands.

  The instrument *The Hands* by Michel Waisvisz (figure 3.5) incorporate a technical layer of sensors technologies, communication protocols and programming defining data input, mapping and sonic synthesis. As Waisvisz many times declared, his digital instrument was never finished and he only froze its development when he had to give a concert. But *The Hands* are designed in a way that they suggest an instrumental use with the hands. A person who finds the instrument for the first time would think that it affords being taken with the hands. Therefore it simulates the use of the hand. Its instrumentality is defined by all these affordances oriented in this case towards playing musical contents. A series of embedded in the instrument metaphors inform us and we perceive it as a gestural instrument. The instrumental dimension depends intimately of those affordances and contraints. Finally, the performative level defines the different musical iterations of Michel Waisvisz performing with the interface. These are musical intentions, specific cultural roles embedded in the instrument or even personal, temporal or idiosyncratic values which are inherently added to the instrument by Michel Waisvisz.

- The reacTable.

  The reacTable defines itself at the technical layer by a the computer vision technologies, the protocols to communicate extracted information (TUIO) and the sound synthesis involved. The instrumental layer defines how to use those technical elements towards organizing their sonic outcomes in a particular way. For example, the rounded shape communicates us the idea of collaborative performances. The visualization of the parameters of cubes used to control the performance represent the status of the machine. A number of other visual elements represent functionalities we can access. Finally, the performative layer defines what a performer wants do with the instrument. We have seen many DJs playing the reactable with a similar idiosyncrasy. But I remember a student of Interface Cultures (Jure Fingust) who engaged with the instrument from the perspective of heavy metal music.

- The Tenori-On.

  The Tenori-On consists of a hand-held screen in which a sixteen-by-sixteen grid of LED switches are held. Any of these switches may be activated in a number of different ways to create sounds. Two built-in speakers are located on the top of the frame, as well as a dial and buttons that control the type of sound and beats per minute produced. The instrument technical layer is specified by the electronics necessary to capture interaction with the switches and produce sound. The instrumental layer starts with the shape, a hand-held format which affords taking the instrument and moving. Then a number of instrumental affordances, like the sequencers and modes of operation which are incorporated suggest us ways of interaction. And finally, the performative layer is defined by the personal use of the performer. Masaki Fujihata, a friend of Tenori-On's creator Toshio Iwai, after a performance I gave with his instrument in Linz, explained me that the performances that Toshio usually gave to his friends with the Tenori-On were especially predictable and not so creative. Thus he was happy to see other idiosyncratic uses.

I hope this model helps to explain the act of performing with musical interfaces. As it is shown, technologies are independent and static parts of a much more complete system impossible to separate from the agent or user performing it. Ignoring it, certainly affords models where technologies or interactions are put at the center of the musical phenomena, excluding the most important aspects mediating the act of using a musical interface: the interwoven nature of instrument, performer and reference frame.

7.4.6. Tangible Scores representational dimension

As I have described in previous subsections, so much has been said against representation by philosophers (such as Heidegger, Deleuze and Barad) and so many attempts have been made by contemporary artists (particularly postmodern, post-colonial and feminist artists), to eliminate representation once and for all. But representation continues. It blooms as the system that frames the way we understand the world.

In researching tangible scores, I recognize that the ideas I allude to, the examples and metaphors I employ, still situate me in the reign of representalism. Is not the the job of writing a PhD a representationalist task? I am required to find points of intersection between my theories and other reserchers of my field. I have to comment on the written ideas and analogies of other authors. I am supposed to quote and compare the positions of practitioners with my own insights about my practice. Is not the academic model itself trapped in representationalism? After Peter Kirn linked to his blog *Creative Digital Music* the video of a conference I gave on non-linguistic musical interfaces, a person commented in his blog[15] "if at least he would dance instead of presenting with a powerpoint..."

In my opinion, from a representational perspective, musical interfaces can be described as a collection of related symbols with a given and arbitrary meaning. How our musical interfaces are designed and work, they should be understood eminently as a linguistic technology. Importantly, these symbols, as representations of digital information, are decoupled from our cognition of embodied artifacts. Thus, I argue that a “non-linguistic” or "subsymbolic" communication with computers at the moment of perfoming music, which shifts the focus from linguistic and visual representations to discursive and embodied practices, is one such alternative for suggesting new musical practices of design.

The challenge is trying to design interfaces stressing non-linguistic communication with the machine. *Tangible Scores* are an effort to afford playing without representations, an impulse to perform in an specific way and context, using matter, which is not used to represent but to afford performances. Tangible Scores may be as an effort against the massive linguistic dimension of musical interfaces.

Why should *Tangible Scores* be considered less representational than other interfaces? I can maybe try to explain it transcribing into words the experience of an user I filmed during the Kunstuniversität Linz exhibition in 2013 (section 6.2).

The person, a mid-age man, enters the room and walks around the five surfaces. First he only looks at the visual patterns. He is interested in the technique used to engrave the patterns. He does not touch the surfaces. He looks under the panels and discovers part of the electronic components. Then he asks the info

[15] source http://cdm.link/2017/02/touch-feel-score/accessedon10/12/2017

trainer who clarifies that they are also musical instruments. The man asks how do these instruments work. The info trainer says that just by touching as with any other instrument. The man first taps the surface with his fingerprints. He understands the causal relationship between action and sound. He asks the info trainer if he can play with more energy. The info trainer says "yes". Then the man uses his nails to create textures first with one hand. Then with the second. Finally with both. He changes the surface he was playing and repeats a similar process with the other four instruments. After seven minutes, the man has played all the instruments and decides to leave the room. The info trainer asks him if he liked the instrument. The man replies "Yes, what I like is that I played and I didn't have to think while playing it. It was like playing with some other piece of matter".

I think this example summarizes many of the representational characteristics of *Tangible Scores*. The engraved surface of the instrument is not mapped into discrete parameters users have to previously know. As if it were an acoustic percussion instrument, the digital instrument performs a sonic response which is causal with the energy and gesture applied to its matter. When performers do not touch the interface, the instrument stops playing. There are not digital extensions or processes we need to learn. All the information needed to play the instrument is tacit. Every person knows how to touch and understands the effects of other person touching. Our brain simulates the causal effects of touching without the need of intermediate representations. We hear what a person is touching even if we see it through a camera without sound. There is no need to parametrize or create movement models because much of the information about those movements is captured through the sound produced into the surface. And finally, a machine learning algorithm is able to find the adequate pieces of sound fitting better to our input. These grains of sound are concatenated and sent to the speakers. As in an enactive relationship with matter, our brain is fed with information which suits to the internal model of how a tactile gesture may sound. And all this happens without having to think about any of the many variables that support this process in the computer. For this reason, I can assert that the act of performing with Tangible Scores is eminently non-linguistic and not mediated by the computational representations of the electronic system.

7.5. Musical Intentions

Digital musical instruments do not come from the direct observation of the world. Ideally, designers imagine them after contrasting novel musical concepts and interactions. Digital instruments can be created for one specific performance and fulfill the specifications of a particular artistic impetus. They can also follow mere commercial interests. In this section I try to understanding better the intentions behind the creation of new musical interfaces and how music embodies the creation of a new digital instrument. In other words, if new digital music instruments can inspire new musical models and interactions and how.

Often, musical interface designers configure the instrument in such a way that it becomes clearly limited. Even in this case, an adventurous performer can probably find creative elements to develop a musical plan much more than what the program offered in theory. For instance, let's reduce this possibility to the extreme. We can think of a digital musical instrument consisting in one button which triggers one sound, always the same one. This can be taken as a creative challenge by many musicians. As Thor Magnusson has studied (2009), constraints are also important sources of inspiration. Constraints, well designed and understood can sometimes help more than limit.

Another possibility is when the instrument program is left open to offer multiple creative avenues, even for those still not invented. In that case, we can say digital musical instruments are technologies which precede the music we can create with them. Every novel instrument, in theory, would be able to suggest new interactions, compositional models and artistic expressions. For example, the compositional poetics of Olivier Messiaen were highly affected by the development of the *Ondes Martenot* instrument. Works like *Oraison* from *Fête des belles eaux* (1937) composed for six *Ondes Martenot* impulsed Messiaen's approach to a static dimension of tempo, described by the author as "infinitely slow".

This quality to suggest new musical paradigms is not only characteristic of digital musical instruments. Traditional acoustic instruments can also trigger imagination and create novel musical affordances[16]. As a

[16] As an example we can cite how the compositional system of Lachemann is affected by instrumental means, exploring every instrument as a whole sonic universe

consequence, composers and performers will have to decide between two ways of acting with digital instruments:

- Embodying existing musical models (post-science) in the digital instrument
- Creating novel musical models suggested by new embodied interactions (post-science)

7.5.1. A Short Philosophy of Intentionality

The topic of the 'intentional process' has occupied the ontological status of thinking in contemporary philosophy (Davidson, 1963; Dancy, 2000). The problem of the conscious act of intention was central in the philosophy of Franz Brentano (1874), for whom "to think is to think something". There are no thoughts without an object to which thoughts are intentionally directed to in a mental movement.

From Brentano, Husserl took the idea of intentionality but introduced a relevant element: experience. Something would not be reducible to scientific observations or quantitative data without having experienced it. Husserl, though, develops a transcendental methodology, bracketing out the contingent properties of an intentional object. It would be something like if one could derive "its essence as a priori knowledge, i.e. the object as it appears to us before we mentally constitute them" (Magnusson, 2009).

For Merleau-Ponty, intentionality is embodied, as well as every aspect of the mind is embodied. For instance, 'hammering' for Merleau-Ponty is possible because the hammer acts as an extension of our body, but also because the nail, the wall and the hammer are extensions of the body too. The world appears to Merleau-Ponty as a catalog of open paths that the body decides to experience. Don Ihde (1993) writes that this bodily intentionality "extends our body through the artifact, into the environing world in an unique technological mediation". Our active, intentional bodily movement also incorporate into its primary experience a technology. This idea can be exemplified remembering the experience of type-writing or driving a car: we feel that the machine is an extension of our body. Or as Flores (2011) explained "this merging of living body with the non-living creates a hybrid that enlarges our body's powers".

When we talk about non-humans (i.e. a musical interface), we cannot talk about intentionality, we refer to agency. A traditional definition of agency is explained through action. Action follows agency as effect follows cause. Usually we think that people are supposed to act because they have acquired some agency to act. If agency is imaginatively bestowed on things, as we have seen in the context of New Materialism, then things can start acting like people. Certainly, music has been traditionally understood as an only-human activity. The traditional research agenda in music has supported the idea that only humans were committed to express musical intentions. This agency to communicate musical ideas seems to be clear: a composer creates a score and communicates her musical intentions to a performer and an audience. But we are progressively used to the fact that also non-human agents have this agency to suggest musical intentions. We only have to launch Spotify to see how an algorithm wants to change or accompany our Monday morning mood.

7.5.2. Musical Intentions as Design Parameter

Musical intentions are another type of intention (i.e like the ecological or biological). Obviously these musical intentions can exist as cultural and bodily intentions. For Leman (2007) musical intentions are "local goals or musical targets in the context of a performance. Intentional actions structure the physical development of the work". From a performative perspective, composing music, or improvising, it can be understood as a sequence of parallel flux of intentional acts. There are musical intentions happening at different scales of time and space, having to fit all to the overall structural intention. Musical intentions will be finally coupled with movements or other actions for playing the instrument. Thus we can talk of musical action-goals.

Playing music has been also traditionally understood as a very specialized and intense corporeal activity. It is a field full of embodied relations in oder to fulfill a musical intention which can be written or not on a score. And through this tradition it has been commonly accepted that expressive musical intentions are usually supported by the use of expressive physical gestures. Thus, designing a musical instrument has been imagined to enable interfaces to deal with as many corporeal gestures as possible. Obviously, this has been possible due to the generalization of very accurate sensing technologies.

Describing a performance as a mere sum of corporeal movements would be a very low level understanding of the task of playing an instrument. When we play an instrument we are not just only performing movements: we are immersed within our musical expectations and our expressive goals, all described by what we call musical intentions. If we deal only with the corporeal dimension of performing an instrument it would be the same as saying a dancer to reproduce body positions without any artistic information or context. Or the same as creating very sophisticated robots to reproduce human movements on a violin without intentions. If we analyze the case of composition or dance, we always imagine the composer or choreographer in the role of communicating particular musical intentions at specific moments. And these musical intentions embed also elements external to the corporeal activity: artistic and conceptual notions, idiosyncratic decisions, inspirations and expectations. A musical piece is thus, a sum of both the compositional and performative musical intentions.

For Godøy and Leman (2010), intentionality is conceived as an emerging effect of an act of "communicative resonance". For these authors, people would engage with music in a similar way they engage with other people: we understand other's behaviors by mirroring them in our own subject's action-oriented ontology of behaviors. The underlying process which makes this understanding possible is called "behavioral resonance" which would be responsible to produce corporeal responses. It is for example the case of the instinctive action of moving when listening to music: that would be our behavioral resonance in order to decode the information contained at some vibration. Thus, perceiving intention would be grounded in the coupling of a double process of action and perception. Through this coupling, our human brain would create an action-oriented ontology of the world that forms the basis of musical communication.

The adequate question now is, in the absence of an external musical score, can a designed musical interface embody and communicate musical intentions? Can musical interfaces have the agency to suggest a musical plan?

The idea that our memory encodes our sonic memories in the form of resonant movements would support this hypothesis. We could suggest movement for conducting interactions between the instrument and its performer. But only after the analysis of the communicative resonance of various movements (i.e. their power to communicate intention) we could start designing affordances.

We all have felt at some moment, probably more often during our childhood, inspired by some object or natural phenomena which has made us dance or play music. Intuitively we get inspired by the agency of some non-human agent, especially through some enactive process of action and perception. The tenure beat of a mechanical machine makes us move at the same rhythm. We discover ourselves moving, dancing in what Alva Noë (2013) calls "organized activities" (as we have seen in section 7.5) which are those tasks which organize our life without our previous intention. Obviously, the interpretation of that perceived stimuli is absolutely subjective. Every person will react with different actions to the same stimuli although they will all follow the same perceptive patterns. Can a machine, an instrument have the agency to organize our life? Yet, as Bruno Latour (1994) has argued, an ambivalence between human agency and the agency of machines is a common theme in considerations of technological inventions of all kinds:

> "*The label 'inhuman' applied to techniques simply overlooks translation mechanisms and the many choices that exist for figuring or de-figuring, personifying or abstracting, embodying or disembodying actors. When we say that technologies are 'mere automatisms' we project as much as when we say they are 'loving creatures'; the only difference is that the latter is an anthropomorphism and the former a technomorphism*"

Summarizing, it seems that for philosophers the agency to suggest musical targets is not anymore a human-only property. In the case of electronic music, musical intentions are often communicated to performers through sonic and material affordances and constraints. For example, when David Tudor builds the electronic system of his piece *Rainforest* (1968) he does compose only a reference frame in which specific materials can reveal their agency to suggest interaction. Or if we think it in the other way round, a context where Tudor's musical intentions can be communicated through these artifacts.

At this point, the reader may be asking where those musical intentions are physically encoded or inscribed into the instrument. One possibility would be making again use of the notion of affordance. It is interesting that the notion of affordance, as it was introduced by Gibson (1977), had a lot to be with the concept of intention. Affordances are features of an object or the environment allowing the observer to perform an action, a set of "environmental supports for an organism's intentional activities" (Reybrouck 2007). Thus, affordance can only be understood together with the notion of intention. If there is no defined intention, we cannot talk about affordance.

In our field, we often talk about physical and virtual affordances, sonic and musical affordances, cultural and sociological, etc. The notion of affordance is becoming inflated as almost everything can be considered an affordance. Then, I want to propose a shift in the discourse for analyzing musical interfaces not from the perspective of affordances and constraints (Magnusson, 2010) but from the perspective of musical intentions. Instead of studying users' corporeal movements or the interface affordances and constraints I suggest analyzing the instrument agency to communicate a musical intention. Obviously, this agency is not a quantifiable characteristic. It is again a characteristic which depends mostly on the instrument's reference frame.

It is important to remark that if the analysis through affordances and constraints has succeeded it is because they were easy to apply to traditional HCI mindsets. Affordances and constraints, although a characteristic of the relationships between users and agents, tend to emphasize the artifact. In contrast, intention gives more importance to human expectations and decisions.

In my opinion, the process of designing musical interfaces cannot exclusively be based on models focused on designing mappings between captured movement and sonic result. In particular, our main issue is not that we do not have enough good sensing technologies and expressive synthesis engines. Our issues in NIME, also in embodied music cognition as Leman (2007) affirms, is that we still do not understand human musical intention. As with Aloïs Riegl in the XIX century, as I explained in section 7.4.1, who already defended the prevalence of artists' will to create new styles over a technical and materialistic vision of the arts, we may not nowadays think that digital instruments are not interesting enough because we do not have adequate technology. On the contrary, I propose that we need to emphasize the notion of musical intention (or artistic intention) to suggest a more organic relations between performer and instrument. This is a relationship, without any doubt, in which our body is the main mediator. In conclusion, we need to formulate questions like 'how can I inscribe my musical intention in the instrument' or 'if there is there anything in the instrument which stops me from developing my musical style'.

Obviously, musical intentions are a subjective factor, a context-dependent aspect. Due to this subjective factor "many researchers have studied more extension than intention" because "corporeal gestures are measurable with sensors but intentions only exist in the mind of people" (Leman, 2007). We are still far from understanding musical intentionality but I hope that this section has helped to develop certain sensibility about this topic.

7.5.3. Case of Study: Cage's Instrument Contingency

Thomas W. Patteson explains in *The Critique of Technology in Electronic*[17] (2013), that in an interview in 1980, John Cage described what he called 'music of contingency', which was characterized by "a rupture between cause and effect, so that the causes that are introduced don't necessarily produce effects":

> *One piece, Inlets (1977), uses conch shells, for example; if instead of blowing a conch shell, you fill it with water and tip it, it will sometimes gurgle and sometimes not. You have no control over it. Even if you try very hard to control it, it gurgles when it wishes to...when it's ready to. Sometimes if you rehearse with it and think that you've got it down pat, you'll discover as I do, I'm sure, that it foxes you and gurgles when it chooses.*

Patteson gets interested in the fact that for a composer like Cage, used to work with chance and randomness, instrument indetermination was not not defined as random but as 'contingent'. Indetermination for Cage is always a notion in regard to representation, to the systematic act of fixing musical intention on a system of notation. For Patteson, this describes "a particular, non-linear relationship between the 'input' of the performer's actions and the 'output' of the instrument's sound production. It is neither determinate nor indeterminate, but something in between".

Could we develop a similar notion for digital instruments? For example, how contingent are computers and digital instruments? For Patteson:

> *The computer is used not because it is perfectly obedient to the composer's intentions, but rather because it is capable of transcending any possibilities he might conjure up. Rather than serving as*

[17] It is an online publication, last time accessed 10/12/2017 `http://www.thomaspatteson.com/uploads/7/3/8/8/7388316/the_critique_of_technology_in_electronic_music_(thomas_patteson).pdf`

> *the means of realizing a preconceived music in the mind of the composer, instruments figure here as probes to discover of new and otherwise inconceivable musical (sonic, formal, social) phenomena. In these works, the electronic instrumentarium becomes the forum for an approach to composition at once rationalistic and playful. The unexpected arises not from deliberate design, but from the sheer inscrutability of the technical and social processes that the composer has arranged.*

This is a great argument for finishing this section. Computers are revealed as not mere docile tools but as complex technical, social and cultural systems allowing realization. And for Patteson, it is also for "the self-assurance of our own aesthetic tastes".

7.5.4. Tangible Scores and Musical Intentions

The notion of 'musical intention' was included in this thesis after having already practiced extensively with *Tangible Scores*. My hypothesis was that the instrument was able to communicate particular gestures and movements. But how one would name this characteristic? A possibility would be 'non-human agency' in the neo-materialist tradition, but in fact that was not the exact notion. Agency is something matter has and not something we give to matter. Then I discovered that the field of embodied music cognition was busy understanding musical intention. Interestingly, it is a notion that researchers apply to both instruments and musicians. The key element is the body as a mediator of those intentions, expectations, decisions and idiosyncrasies.

In my opinion, *Tangible Scores* are a good example of instruments dealing with the notion of musical intention but not directly using it at design. The engraved patterns of the surfaces simulate actions of the body. Then, my impetus was engraving particular bodily movements into the materiality of the instrument but these must not be considered musical intentions. Then, in a second stage, this materiality would have the power to communicate movement.

Could this be understood as a type of representation? As I have explained in the previous section, one of the key aspects of *Tangible Scores* is that they are highly non-representational because when we play them we get organized by the action of touching. We find ourselves touching and following the surface's patterns before taking decisions. We would be immersed into its materiality first and the performer's intention would come as a posterior re-organizational action. Thus, this posterior intention is not inherent into *Tangible Scores*. They get re-organized, choreographed or instrumentalized, after a performer's musical intention.

Therefore, I do not run away from the fact that the practice with *Tangible Scores* is also intentional. Musical expression is mostly about communicating intentions. When I prepare an improvisation for my instruments, I have an intentional plan I want to communicate. I have spent many hours refining my intentions until I thought they are valid to be shown on stage. Instead, offering performers a frame for interaction liberated from computational representations, emphasizes in my opinion the chances to focus on musical intention. Performers, released from having to think on mappings and data structures, can project their musical intentions on the instrument. However, the instrument will always offer certain natural resistance. Through training, different strategies may alleviate this resistance: the instrument characteristics will be simulated and embodied. In conclusion, the *Tangible Scores* type of embodiment offers ample space to focus on intentionality and to communicate a particular performative plan.

7.6. Conclusions

In this chapter I have unveiled many characteristics of my embodiment with *Tangible Scores*. I have divided them among four main topics: materialism, touching, representation and intention. They are philosophical topics which have engaged researchers in theoretical discussion for many centuries. My practice as an artist should not be considered philosophical per se. However, as Heidegger explained, the vision the artist and the poet is necessary because we often reveal aspects of the world without having to frame it. In my case, many of the philosophical concepts I have described in this chapter came to my thesis after my practice. For example, I discovered how much *Tangible Scores* have in common with certain neo-materialists views without even being aware of this philosophical trend at the beginning of my research. For this reason, the *Tangible Scores* paradigm has not been designed towards proving the neo-materialist theory. Into my third year of research I discovered this theory. I have accessed it from my own artistic practice, being immersed in a cultural environment facilitating it.

In a similar way, I have lived with the other topics of this chapter, namely representation, touching and intention. My practice has revealed to me some notions, as the non-representational trend, which I later discovered they hold many decades of discussion. Obviously, this process was only possible complementing my practice with philosophical readings.

For this reason, I consider this chapter as *post-science* (section 7.6). I see how the embodiment with my instruments have created new paradigms for musical interface design. I have not applied the recipes of certain paradigms to construct my instruments, but to the contrary, the instrument has communicated novel concepts and relationships which, I hope, can inspire a new sensibility in interface design.

8 Conclusions

Logic is a systematic method of coming to the wrong conclusion with confidence.

Murphy's law

In this conclusion the central research questions and themes are revisited. My contributions are compiled and discussed in relation to the previous chapters of this thesis. Finally, the aspects I will have to leave for future work are described.

8.1. Thesis Recap

This thesis has explored the artistic and philosophical consequences of understanding musical instruments as artifacts embodying a 'score'. In other words, to which extent musical instruments can be perceived as musical scores.

I am artist who wanted to develop an artistic research process in musical interfaces. Obviously, both Art and the field of Human Computer Interaction had to inform me. The first problem I had to solve was clarifying what was my role in all of this. How can an artist contribute knowledge in HCI? In chapter two I exposed that artists, in order to be helpful to HCI, have to adopt a critical position within our research medium.We are the ones who can more easily challenge long accepted assumptions about our research field. We are there to question the pillars of HCI.

Being critical with the medium means, in the context of this thesis, designing critical interfaces which can visualize the paradoxes of HCI. Critical interfaces act to breakdown the standard discourses of tangible interaction design. They should allow us to discover new interpretations and notions, often unfolding the tension among established conceptions of our fields of study and their real value in our societies. The Arts create a type of knowledge which is not afforded by traditional HCI methodologies, especially in the case of embodied technologies. But research in the Arts should have a clear formalized structure and focus, it has to be discussed and evaluated.

My thesis then had to address the nature of musical interfaces. For that reason chapter three discusses the origins and effects of their decoupled nature. I contribute to an understanding of musical interfaces as cultural artifacts incorporating the apparatus of symbolic machines. I agree with perceiving musical interfaces as epistemic tools and I emphasize Magnusson's vision of musical interfaces as hermeneutic artifacts. However, I argue towards a certain post-structuralist and post-hermeneutic approach in his thesis. If interfaces are texts we have to decode, I would prefer rather performing those texts than decoding them. In my opinion, this is the only possibility to destabilize the interface representational dimension.

From another point of view, if we say that musical instruments are becoming symbolic machines, we may find the economical, cultural and political origins of this change. For this reason, I build on Vilém Flusser´s philosophy which explains that the end of industrialization has caused a symbolic conquest of the world. In the same direction, digital musical instruments have adopted an apparatus which produces symbolic (non-material) artifacts. I relate the appearance of the camera or technical image with the creation of musical interfaces. Digital musical instruments release musicians from 'work' in the industrial sense. This robotization of the work makes human being able to focus on the play with the apparatus. It is not necessary to stick to the creation of sound. We are now concentrated in playing with the apparatus, engaged with the play side of the device. This shift from the material to the symbolic is typical from post-industrial societies.

Musical interfaces are cultural interfaces. The notion of cultural interfaces is crucial because the cultural re-configures the technical. After being 'cultured', the interface becomes fluid, an object of interpretation and performance. The interface is used as a code to carry cultural messages. Interfaces have become aesthetic artifacts. Interfaces are entangled with non-neutral mediations between agents and this enacts unexpected but meaningful relations. Through artistic exploration, critical aspects of this medium can easily provoke imagination.

In addition, musical interfaces have become a political vehicle. We design them following particular politics. From my point of view, at musical interface design we can identify mostly two types of politics, the maximal and minimalist. The first one offers ready-made grandiloquent interfaces, interminable presets and interconnections but limited functionality out of those fixed possibilities. The minimal approach offers flexibility and customization at the risk of having to develop the interface on our own. But these politics are also quite fragmented and users do not always remain faithful to one side. I have crafted parts of *Tangible Scores* with minimalist environments but I have mastered the recordings with maximalist digital audio workstations.

At the end of chapter three I analyze how the digital era has created a certain disenchantment with digital technologies. The notion of the digital has been inflated and objectified. The digital is by default 'cool' and efficient. Against this position a post-digital sensibility has appeared. It causes individuals to look for new ways of social and technological engagement with others, on and off the stage. It is the case of controllerism, the application of musical controllers to build music upon mix, scratch, remix, effect, or any other technique. It has been developed mostly by digital DJs, whom have really created a theory and technique for this practice. Controllerism has shown the NIME community their euphoria towards live expression. They seem better organized, less worried about innovation and more interested in bringing 'liveness' to electronic music.

My research explores the possibility of understanding instrument as scores, and for this reason chapter four is focused exclusively on notation. Musical notation was redefined in the 20th century. Although traditional musical notation is still most commonly used, nowadays composers understand notation in a different way. The notational scheme has also become and interface, often specifying events which do not have to be with notes. For example, one could write a C quarter note on a stem, but that in fact means activating a video or making a robot jump. Then, the score becomes also an interface. Additionally, notation encompasses graphic scores, animated scores, situational scores, etc. This complexity has obliged me to define what can be notated in the 'world' and the mechanisms to create notations. In particular, in this chapter I have studied the creation of vocabularies of events. It is my perception that for creating a vocabulary we have to first listen and analyze the space of possibilities to decide which elements appear repeated, varied and developed. Those will be candidates to be part of a notated vocabulary. However, as it is necessary to identify those other elements which should not be notated, creating a notational system is mostly a process of filtering. It always creates a bias.

I also focused on dance in researching and writing this thesis. In my opinion, dance and musical interface design share common issues in regard to notation. Interestingly, dance has shown the other disciplines that it is not necessary to impose generalized notational systems. Through many centuries of practice, dance has developed its own mechanisms to communicate movements, concepts, intentions and choreographies. I see dance as the most important case of study to understand notation of movement in Human Computer Interaction. Although many HCI projects still seem to parametrize and notate dance. In this chapter, I bring forward the example of William Forsythe, who worked on a notational system to analyze and better understand the inherent complexity of his choreographies, but not with the impetus to notate them.

I have presented the origins of the first musical practices understanding electronic music instruments as scores. In the 1960s, artists associated with the *Sonic Arts Union* created electronic instruments, that this was equivalent to compositional practice. In fact that was the original concept of the collective *Composing Inside*

Electronics founded by David Tudor in the early 1970s. For example, Alvin Lucier affirmed that during those years, the circuit was the inherent-score of what they played. This inherent-score is equivalent to the notion of instrument-score that many other performers have described. For instance, for Collins the idea that the circuitry was the score was a mantra in the 1970s.

It is clear that during those years, the electronic instrument is given a central position in composition. For deeper understanding of this period, I have studied the compositional practices of Tudor who even gave us the terminology of what to call these instruments. For Tudor, his devices are 'self-composed instruments' as they compose themselves of their instrumental nature. These instruments not only would compose themselves, but also reveal themselves. The performer only had to configure the system and activate it. The instrument is left on stage as it is, without biasing its nature.

However, it was necessary for this thesis to circumscribe the inherent-score notion into some notational model. For that, I thought it was appropriate employing Nelson Goodman's notational systems from his seminal book *Languages of Art*. They have been widely used to describe the nature of different representations, not only in music but in other types of art. From my analysis, I have shown that the inherent-score is not a notational system. It is an 'analog' notational kind in which it is not possible to create vocabularies. The instrument-score is a kind of musical graph embodied into the physical and performative materiality of the instrument which requires the commitment of the performer to exist. The instrument-score is an effect of exploring, interacting, engaging with the affordances of an instrument. In this process, many aspects of the instrument shape our performance and this is considered by many performers a score. Therefore, I describe its form as a hybrid form, made of matter and the performative materiality that the affordances of the system provoke. Finally, I defend that the inherent-score, if it is a score, should be made of symbols we can decode. In my opinion, they are twofold, implicit or explicit. The implicit are those which we find in the artifact's body and the explicit are those produced from digital data embodied into the artifact.

In chapter five I describe the central artifact guiding my artistic research, *Tangible Scores*, a tactile score which is also a digital instrument. The paradigm of the 'tangible score' came to my mind six months after starting this thesis, when I was trying to find a solution to design the instrumental affordances of a physical artifact. I define a tangible score as the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements. I tackled this chapter in the middle of this thesis document because I first needed to explain my discourse to the external reader. That said, in chapter five I systematically describe the objectives for designing tangible scores, the patterns of their design and many decisions taken along these years. I explain that the appearance of these instruments was inspired by graphic scores. Tangible Scores extends these, by converting graphic marks into materiality.

My particular implementation of *Tangible Scores* is an acoustic interface which analyzes the sounds produced within the surfaces during tactile interaction. Through a mathematical analysis, a concatenative synthesizer is controlled and able to reconstruct in real time the original signal concatenating grains of other sound files. This strategy creates very intuitive instruments: the visual and tactile part suggest particular movements and the synthesis offers great variability of sounds connected to those movements. It also must be clarified that there are other possibilities to implement the tangible scores paradigm. Fortunately, through my academic papers I have been able to inspire other researchers who have imagined other solutions. This fact one of the most important findings of the thesis: my work has been able to inspire others to develop alternative methods utilizing tangible scores. Therefore, this paradigm which I credit has been able to create new knowledge about musical interfaces.

In order to explain the characteristics of these instruments, I have documented the process which any person may follow to create their own. Additionally I offer detailed information about the type of information the sound synthesizer expects. Making use of digital signal processing, I have shown that the spectral shape of a tactile gesture produced at different locations of the surface can variate harmonically. Tangible Scores may be considered as a type of idiophone able to mediate the sonic produced. But this characteristic shows something important: different physical tactile patterns also shape and control the audio synthesized. For proving my hypothesis I had to build a scientific system to isolate tactile gesture from other variables. Interestingly, the results obtained confirmed that my hypothesis was correct. However, when the system was out of isolation, the results were totally different. The human variability in touching the system was bigger than the effect of the idiophone. However, the sonic result was quite expressive and it was obviously not discarded. Finally, in this chapter I described the various materials I have used for fabrication: wood, paper, silicones, concrete, thermoplastic, etc. and various iterations of technical implementations. The system finally works embedded into a mini computer and incorporates a toolkit to create new tangible scores.

My practice with *Tangible Scores* is discussed in chapter six. I have described, in a chronological order, five years of concerts, installations, workshops and presentations with *Tangible Scores*. In my opinion, this is one of the central chapters of my thesis, as without this practice the thesis could not have come to an end. My methodological principle was reflecting after my practice with the instrument. That meant escaping from the walls of the lab and presenting it abroad to critical audiences. It is interesting that apart from developing the instrument towards being more expressive, I have also learned how to present it better, how to defend it better. I realized that different audiences emphasized the same issues regarding my instrument. This was a considerable help to test the validity of my assumptions. Finally, I found the mechanisms to make audiences engage with my research. For example, in lectures and conferences I realized that people did not understand how *Tangible Scores* work from my videos. The tactile sensation, the experience of exploring the surface has to be lived. For that reason I often had to carry my artifacts to every presentation.

Throughout chapter six it is possible to understand how and why the instruments have changed so much along this thesis. My decisions after reflection are documented. The feedback received at various user studies and workshops has also been systematically analyzed. This thesis finishes at some temporal moment but the evaluation and refinement of the project will continue as long as I will continue playing the *Tangible Scores*.

Writing chapter seven was important for me to discuss the extensive knowledge I have obtained from my practice with the instruments. There I detail how the embodied relationship with my instrument can be explained making use of various concepts and philosophical notions. Four extensive themes are visited from the perspective of my artistic practice: materialism, touch, representation and musical intention. First, materialism was a crucial among them. My interfaces do not look like any other instrument I know. I also make the claim that they emphasize the inherent score they contain. For explaining all these particularities I needed to understand the nature of *Tangible Scores* from a materialistic perspective. At some moment in 2015, in fact late in the context of this thesis, I discovered the philosophical trend of neo-materialism (or new materialism). Then, I was fascinated how many of the concepts I had learned from the instrument are actually inscribed in this philosophical branch. These concepts could be totally explained by new materialism. For example, I understand the materiality of *Tangible Scores* as performative. The actual nature of the instrument is only revealed when we perform it. Matter in the instrument is then a trigger to provoke a performance.

The second aspect of *Tangible Scores* which is studied in chapter seven is 'touching'. The instrument has taught me that touching is much more than a physiological action. Also that touching should be taken into more consideration in musical interface design, which often lacks tactility. Finally I learned that touching is a multi-modal action in *Tangible Scores*. Touching is the performative action which makes us understand the dependencies and relationships existing between the eye and the hand. The eye plans the movement but the action of the hand is the one which actually explores the artifact. But this exploration always creates small creative accidents. I defend that through touching we open our performance to the impetus of chance. Connecting it to the tactility of Riegl and Deleuze, I explain that touching *Tangible Scores* means a transition from visual to haptic and then to the aural. Touching becomes a sonorous object, another modality of causality supporting our experience with the instrument.

Representation is then covered. I depart from a critical view of representationalism. In my opinion, representations invade our way of thinking and often reconfigure our relationship with our world into a symbolic and linguistic interchange. As Karen Barad asserts, in our societies words ended up having more importance than matter, how did this happen? The same phenomenon affects musical interfaces and human computer interaction. These are fields saturated with representations. Learning the musical interface means learning how those representations work.

The representational dimension of musical interfaces mediates the possibilities to engage with the instrument in an embodied way. These representations transform musical interfaces into a collection of related texts and symbols with a given arbitrary meaning. In order to understand better this characteristic, I have proposed a framework in which musical interfaces can be modeled with a threefold system: the technical, the instrumental and the performative. The technical is static. It is constituted by all the technologies to make the instrument work, from gesture acquisition to mapping and sound synthesis. The instrumental is the layer of symbolic and material affordances making an instrument being perceived as a musical instrument or as a score. The performative is the layer which redefines the instrument at every performative iteration. With this framework I want to emphasize that the technical and instrumental layers are independent. They can be changed independently from each other.

Finally, the concept of musical intention is also discussed in relation to *Tangible Scores*. My standpoint is emphasizing musical intention as a parameter to guide design. I see musical intention as an aspect defining radically a performer's embodiment with the interface. I defend that innovation in musical interfaces does not only depend on the technological development of novel sensing technologies and the implementation of complex sound types of synthesis. If we evaluate the last thirty years of musical interfaces, it is clear that it has not been enough for solving the lack of embodied engagement with the instrument. I share the vision of the field of embodied music cognition which models the musical experience not only as a sum or sequence of movements in time. Researchers explain that for understanding the musical experience the only possibility is including into our models our musical intentions and expectations. For that reason, I also propose emphasizing the notion of 'musical intention' at interface design. The issue that we face is that we are still far from understanding what musical intention is and even further from knowing how to model it.

8.2. Research Questions and Contributions Revisited

This thesis originates from two research questions:

- Many musicians manifest that the instrument-score exists: it is the inherent and performative score available at every musical instrument. It suggests and mediates our play. Is it possible to define and study the instrument-score?
- If the instrument-score exists (hypothesis), can we create new interfaces for musical expression emphasizing their inherent score, designing their form, spatial distribution or uniqueness as an object? Which would be the mechanisms to do it?

This thesis has provided the following:

- The notion of the *inherent-score* was presented. It refers to the material and virtual elements of the instrument shaping and inspiring a player's performance. This notion gives us language to describe how the instrument mediates embodiment and musical development at the exact moment of performance. Although it is a context-based and subjective notion, I have shown how many musicians have previously described it, affirming that 'the instrument is the score of what they play'. The *inherent-score* notion also contributes to a performative-oriented understanding of interface design. Designers can emphasize elements of the instrument *inherent-score* for suggesting particular embodiments with the artifact.
- A novel musical interface design paradigm was presented, the *tangible score*. I have defined it as the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements. This paradigm has inspired the artistic production of a series of acoustic interfaces I have called *Tangible Scores*. This paradigm has already inspired other researchers in the community who have developed alternative implementations.
- I contribute to a methodology engaging artistic research in Human Computer Interaction. I defend that the way to help HCI is adopting a critical attitude with our research medium -tangible and musical interaction design-, avoiding the instrumentalization of our artistic processes and adopting the format of artistic research. I have presented examples of how the Arts can create a type of knowledge which is not afforded by traditional HCI methodologies. I present methods for formalizing the structure of our research and ways to evaluate it.
- I have addressed the cultural and political dimensions of musical interface design. I defend that the cultural reconfigures and redefines the technical and that only after a profound understanding of the cultural context of musical interfaces we can describe their nature. I have also contributed to a political vision of musical interface design. Musical interfaces are never transparent technologies. A full range of cultural and economical values are scripted into design excluding or obstructing certain capabilities.
- This research has been successful in practice. I have presented my artifacts at a large number of festivals, galleries, symposiums, academic conferences, etc, both in the format of a concert and installation. My practice has been reviewed and commented on-line. Curators, academics and festival directors have invited me to present *Tangible Scores*. Therefore, the project has transcended the walls of artistic academic research and lives its own life in the artistic scene.

- I have contributed to a vision of musical interfaces as *symbolic machines*. I have described the *apparatus* of digital musical instruments and the symbolic nature of its program. The importance of this contribution lays on having traced the origins of our digital instruments to the end of industrialization. Digital instruments are presented as an invention liberating us from the need of dealing with the real world limitations of acoustic instruments design. Under this vision, a musician's role would be releasing realizations of the digital instrument program.
- I have contributed to a *materialistic account* of musical interfaces. I defend that matter must not be only understood as the support for an interface's functionality. As I have shown through my practice with *Tangible Scores*, matter is an active agent able to inspire, provoke and shape performances. Therefore, my research wants to contribute towards developing a new sensibility with regard to matter at tangible and musical interaction design.
- The *representational dimension* of musical interfaces has been addressed. The interface symbolic realm has helped representationalism in conquering every aspect of functionality. Musical interfaces can be seen as a collection of related texts and symbols with a given arbitrary meaning. Tangible and musical interaction is saturated with representations mediating embodiment. In this thesis, I contribute towards a non-linguistic and non-representational vision of performing with musical interfaces. Only in that case, our relationship with digital instruments become similar to the one we have with acoustic instruments.
- I have imported to my discourse the Deleuzian notion of *the action of the hand* to explain the cross-relationships between the eye and the hand in musical performance. Informed by my practice with *Tangible Scores*, this thesis presents how the action of the hand becomes *manual* if it is liberated from the eye. Instead, it would be *digital* if the hand is completely subjected to the eye. Between these two extremes, I defend that it is precisely *the action of the hand*, left to the impetus of chance, which creates creative accidents during performance.
- I have contributed with empirical studies about the technical implementation of acoustic interfaces and the real-time control of polyphonic concatenative synthesizers. The academic publications explaining these details have already been cited by a number of authors in my research community.
- I share the results of my practice based activity. Through user studies, workshops and reflection after action, I have contributed to a better understanding of the possibilities of inspiring tactile gestures to general audiences. I share the results of these studies and the decisions taken in regard to design chronologically during this thesis.
- Finally, I have contributed with non-symbolic knowledge about musical interfaces. In the context of this artistic research project, I have obtained not only philosophical and scientific knowledge. I have also gained practical knowledge on how to better improvise with my instruments and a better understanding of the performative possibilities of matter. This working knowledge has been definitively incorporated into my general artistic practice, when I play *Tangible Scores* or any other instrument. For this reason, I can affirm that the research developed during this thesis has entirely shaped my artistic vision about musical instruments, scores and performance.

8.3. Why this thesis is finished

The objective reasons to considered this thesis ready to be published are fourfold:

1. Because the tangible score paradigm has been approved and adopted by other members of our research community who have defended the existence of a tangible score in their projects (section 5.13 *The Tangible Score Paradigm Adopted and Interpreted by Other Researchers*)
2. Because the research questions of this PhD have motivated the creation of a novel digital musical instrument: the *Tangible Scores*. In particular, the author has produced a series of 18 tangible scores (chapter five).
3. Because the research questions of this PhD have resulted in the development of a new artistic practice for its author, which have solidified in concerts and exhibitions at renown art and music festivals (Sónar, CTM, Ars Electronica, LEV, etc), academic conferences (NIME, SMC, ICMC, TENOR, ICLI, TEI, etc) and presentations at research institutions (IRCAM, Digital Humanities Lab Sussex University, etc).

4. Because the result of my practice within this PhD has gained knowledge about digital musical instruments which can be applied by the research community. Especially four topics (chapter seven) have been covered: the materiality of musical interfaces, their representational dimension, understanding physical touch on electronic music and the incorporation of musical intention within digital musical instruments.

8.4. Future Work

This is a multidisciplinary thesis written by an artist making incursions into human computer interaction, philosophy, musicology, organology, performative arts, crafts and cultural studies (at least). Certainly, not all these fields have been explored in totality in my theories or at my practice. Therefore, a number of topics are still waiting for investigation:

- Alternative implementations of the tangible score paradigm. My personal implementation as an acoustic interface is only one of the possibilities one can propose. The paradigm is open to any other implementation using different sensing technologies and synthesis engines. In fact, others have been already produced by researchers of our community. I want to leave for the future exploring the consequences of implementing a tangible score towards other types of technical and interactive solutions. Comparing these solutions would definitely enlarge our knowledge about many of the aspects explained in this thesis.

- Exploring materials and form in greater depth. Although *Tangible Scores* have incarnated many different forms and materials, the exploration of matter is crucial in this thesis. The issue of crafting matter is that it is time consuming. Many prototypes are necessary to have a piece and usually fabrication only succeeds a small percentage of the times. In order to develop my practice, I have frozen material investigation a number of times. I am sure that new explorations will lead me to interesting artifacts I can apply to tangible scores. For this reason I have decided to organize workshops in the future in order to explore others' opinions about materiality and its bearing on my project.

- The embodied music cognition theory. At various sections of this thesis I have referred to this theory. It seems to me crucial to dedicate future work to a deeper study of it. The reason is that it incorporates the notions of musical intention and personal expectations into models to describe musical experience.

- An investigation on the relationships between tactile gesture and artifact. One aspect left open in my thesis is *gesture*. I have shown that matter inspires particular gestures but it is necessary to understand better how and under which circumstances this is true. This suggests the development of a study on how materiality, not only two-dimensional but also sculptural, inspires tactile gestures. However, I presume that if the artifact is a musical instrument, digital or not, it will be much more complicated to elucidate the results. Sonic mappings will also suggest new gestures and the relationships will be multiplied. When all is said and done, I am sure the pragmatism of the artistic approach can solve many of these complexities.

9

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