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Rethinking Interactive Arts
a viewpoint based on social embodiment

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1. Introduction

For the last couple of years I've developed artworks, games, research applications and educational tools. Not only did I do this to give form to and improve the techniques used to further develop my artistic ideas but also to help facilitate the ideas and needs of colleagues and friends.

The common goal, for me, has always been to improve an interactive experience, whether it be artistic, educational or purely entertaining. I believe that a more artistic way of thinking can contribute in all those application fields. My artistic practice, on more than one occasion, influenced my ideas and those of my colleagues. Sometimes we added small details to the design strategies while at other times we started over with a clean slate.

My aim, in this thesis, is to illustrate how I have handled the issues concerning interactivity, encountered in my artistic practice, and to describe the associated development in hard- and software, focussing in particular on the artistic installations I have made throughout my doctoral research. This thesis will explain the choices I have made concerning interactive experiences and design. Additionally, I will explain at what times I experienced difficulties or, with equal enthusiasm, I hope to clarify how I've found (partial) solutions to the problems. In doing so, the role of the artist will inevitably be questioned, and as a result, a reassessment of the role of the audience and art object will be pertinent.

However, the aforementioned depends on an established clarity of how interactive art differs from other forms of art, both in the fine-arts as in new media art. This is a subject that has continued to prompt a lively debate in all fields concerned with interactivity without delivering a one-size solution. Evidentially, this thesis won't provide this either, but it will clearly reject a value judgement that says that new equals better.

A recent anecdote sums it up rather nicely: At the end of February 2012, I attended a lecture on the role of the curator and the arts in a digital culture. The lecture was part of the IBBT-SMIT lecture series, organized by the Digital Arts and Cultures research group of the Vrije Universiteit Brussel.

During the lecture, a member of the audience raised the question of what actually was meant by new media art, and how it differs from old media art. Another member of the audience replied, saying that there shouldn't be a difference. According to him, there is only good or bad art.

While this may be true, defining new media art, or at least deciphering what the *new* is all about, can certainly have its merits. In this thesis, I will argue, following Lopes' idea, that what is *new* in new media art, is the computational interactivity in arts.

This computational interactivity sets interactive art aside from painting, sculpture, photography and others. All of which can be extended using digital techniques but are not *new* art forms or disciplines. In contrast, interactive art is a truly new discipline, but will be labelled old too on day. With the popularity of interactive media in everyday life, I feel, that interactive art will be attributed a more substantial role in the art scene and in life in general. Interactive art will become a more important and familiar art form in the future. Similar to all established art disciplines, within the interactive arts both good and bad art will be made.

With this thesis, I hope to contribute to the creation of good interactive art works. These are art works that engage an audience and communicate artistic intentions in an efficient manner, with their makers using carefully created technological mediators and well-crafted art objects and interfaces. They will, hopefully, find some inspiration in the conceptual framework for interactive arts discussed in this thesis.

2. Problem Definition

2.1.   Summary of the problem

In the past decennia, interactivity has played an increasingly important role in all the different facets of media and media-use and it is not surprising that everyday life has become obsessed with interactive technology. Since the beginning of the computer age, interactivity has resulted into a new research field, called Human Computer Interaction (HCI), in which marketeers and product designers insist on the importance of interactive technology for daily life. In addressing new design paradigms for everyday objects, new forms of advertisement are employed using technology and computer-aided systems to refine and reach the target market. This approach to interactivity is characterized by fusing concepts such as intuitiveness, accessibility and usability. The market is characterized by a strong business that fully supports the idea of the artist as a programmer and visa versa.

Also in contemporary art, interactivity has become a recurring term. In the 1960s, during the Avant-Garde period, interaction was considered to be one of the key concepts that could facilitate the introduction of art into everyday life (Bishop, 2005; de Oliveira, 2003). However, the concept of interactivity, as it is most often applied to art, is far less developed than the concept of interactivity applied to design. Indeed, while the artistic field and the design field may appear to be complementary (fueling a beneficial synergy), it turns out that in reality there is so much crossover between both fields. In fact, the art world and the design world only partly aspire the same goal of interactivety, and this results in an alienated relationship between the two.

In this doctoral thesis, I will address how the concept of interactivity in art is used. My goal is to increase artistic interactivity, both in concept, in technological implementation, and in artistic expressivity, so that its further development can again measure up to the most advanced developments in

design. In particular, I believe that the current artistic use of the concept of interactivity is rather poor. It doesn't imply a more advanced and integrated concept of interactivity, in which other concepts such as usability, feasibility, entrainment, and social aspects are addressed.

Despite an accord on the primary definition of interactivity as stated in the Oxford Dictionary, namely, "two people or things influencing each other", its implementation in art practice is often limited to the last cited meaning there, namely "responding to a user's input" (Interactivity, n.d.). It is my belief that the separation between the so-called fine arts and new media art largely suffers from this constrained view. Fine arts tend to remain very strongly rooted in tradition, while the new media tends to have an overly enthusiastic focus on the novelty of technology, often forgetting its roots. It is furthermore fueled by an exponential technological evolution that increasingly focusses on entertaining an audience in contrast to experiencing art itself. Therefore, common practices in contemporary interactive art often minimize the Avant-Garde idea of implementing art into everyday life, and this undermines the potential richness of the concept of interaction when applied to the art field. I believe that interaction in art has the potential to create a highly valuable communicative experience for the activated reader. This experience is marked by a sense of 'being there', which later inspired the Avant-Garde artists but it is an experience they aspired but never fully reached.

Based on the above critique, I am fully aware of how ambitious this is. This ambition involves the development of a new concept for interactive arts. I believe that in this thesis, I have been able to explore new paths that may contribute to interactive arts.

In view of the concrete realizations, we have deconstructed the problem in three following parts.

2.1.1. What is meant by interactivity in art?

The first part addresses questions such as: What is meant by interactivity in art, and how does it differ from other art and practices using interactive technology? If there is a notable difference, does interactive art require a new aesthetic, taking into account the specific requirements of such an art form? How can an artist incorporate interactivity in praxis?

2.1.2. What are the steps artists need to take to implement this approach

The second part addresses questions such as: How can an artist incorporate interactivity in his art praxis to enhance the communicative process? Does this communicative process differ from the established one, and are there novel aspects concerning the narrative that define and expand this process differently? What are the concepts on which an integrated approach of interactivity for the arts should be based?

2.1.3. What are the advantages of an integrated approach combining Art & HCI Design?

Finally, the last part addresses the questions: How does an artist benefit from implementing a form of interactivity that unifies the principal concepts laid out in art and HCI? Would it improve the art experience or would it only diversify the experience? Does interactive art require a different art praxis, and will such a praxis imply change in constructing the art object?

2.2. What direction should we take to solve the problem

In addressing the above mentioned problem, I adopted a problem-solving strategy that is based on analysis, concept development, and practical implementation of an interactive art installation. In what follows, I will explain this strategy in three subsequent parts. However, in practice, the three parts have been developed more or less in parallel.

2.2.1. Interaction in historical-analytical perspective

At first, a more elaborate analysis of the definition of interactivity in the arts is in order. I will start by explaining a historical view on the underlying concepts. This view addresses the introduction of the term interactivity and how it came into play in the arts, where it is linked to the experience of the audience. In contrast, I will also discuss how the paradigm of interaction is regarded from a more purely technological viewpoint in the HCI research field. This analysis will introduce a debate on the use of interactivity in the different connected fields, in which the key concepts that form part of the debate will be clarified. This analysis will be done while retaining the scope on each of the individual goals of the research areas that I have set out, since all do pose very valid solutions in their research field.

2.2.2. Conceptual development for interactive art

Secondly, my problem-solving strategy is concerned with concept development. This will be based on different foundations. The media theory's concept of mediality will be employed to address the significance

of the medium in the creation of meaning. The embodied music mediation technology paradigm, rooted in systematic musicology, will prove to be the foremost encapsulating and integrated research area to formulate guidelines. Deciphering the theoretical issues at hand will of course not always solve the problem. In fact, theory may often complicate the concrete realization of things considerably. However, the aim is to illustrate how the concepts have been inspiring the art work, and how art has inspired the development of these concepts.

2.2.3. Practical development of techniques for interactive art

Thirdly, I aimed at developing technologies that could help us in bringing about this new concept of interactivity.

In the practical part of the thesis, the evolution in the design of my artistic praxis will be described, while at the same time hinting at the parallel development of research and educational tools I've used and developed. This more task oriented development of tools and applications has to a great extent influenced the artistic approach I have adopted. The art praxis started with an old-fashioned approach, driven by solely subjective choices, only informed by personal ideas and knowledge. Many questions arose out of this practice: I wondered how and why people reacted the way they did when confronted with the art works. I found myself constantly adapting new ideas, trying to tighten the envisioned artist-audience communicative relationship, and I finally adopted an Iterative Design approach, borrowed from HCI. In the end, I tended towards the developments of a Participatory Design, originally found in design studies, where the audience is included early on in the creative

process. A substantial part of the practical description will focus on the latter, since it is my belief that this approach has awarded me the best results.

On an artistic level I've been constantly trying to better my understanding of the mediums I've been working with, which has been mainly two-folded. On one hand, the scientific approach, often applied while creating research tools at our research department, has challenged my knowhow of usability studies and user-oriented evaluations, and gave a better insight in the concepts of embodiment and computational processes. On the other hand, the artistic approach has evolved into a praxis based on a participatory design, through working closely with target user groups and fellow artists and researchers. At the same time, the cross-pollination between both fields has proven to be invaluable .

On a side note I want to remark that in the following work I don't mean to express a normative judgement on the quality of the different interpretations of the term interactivity, neither is it an absolute ode to new media arts, even though the topic of this thesis is the importance of new media and fine arts. It is neither an apotheosis of interactivity in art, nor do I want to diminish the importance of other art forms, each presenting inspirational, though different, discourses.

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2.3.   Outline of the thesis

The following chapter introduces the different research topics of the thesis. These topics and their related research fields serve as the starting point to identify the issues laid out in section 2.2. Further on in the thesis, these concerns will be discussed in detail. The following chapter will begin with a discussion about the differences and similarities between (1) installation, (2) interactive (3) digital, (4) new media and (5) computer art found in the literature. Subsequently, the most important key concepts relevant to this thesis will be introduced and the difference in interpretation in different fields will be summed up, and a methodological concept for interactive art will be proposed.

Next, a more step-by-step description in chapter 5 will exemplify how this methodological concept was implemented in practice, using artistic installations, research tools and educational tools as resources. The development of which resulted in *SoundField*, an artistic installation and usability study environment developed during 2010-2011, that serves as a use-case to thoroughly test my methodology.

Finally, in the discussion, a summary of the thesis will be given, clarifying why HCI and art are sometimes incommensurable, and how to address this in future research, formulating guidelines for prospective users and developers of both HCI and art. At the same time, the discussion will point at those features in HCI that can be beneficial for an interactive art praxis and vice versa.

3. Interaction in historical-analytical perspective

3.1.   Interactivity in the avant-garde

In this section, a brief overview of installation art is given. This historical overview starts with the foundations of installation art in Dada and Surrealism. It continues on how installation art grew in popularity within the Avant-Garde and ends with installation art being coined as the art movement Installationism in the 1990s.

Installation art is relatively new in contemporary art, as such there is a lot of debate on its heritage, its history and its praxis (Bishop, 2005, de Oliveira, 2003). Although installation art has been around since the early twentieth century, it took almost 70 years for critics to finally regard it as a movement within the arts. The reasons for this late recognition are myriad, but one of the main reasons might be that Installationism, as the corresponding movement is called, clearly has a different conception and discourse when compared to prior artistic movements, that build on the thesis-antithesis dynamic. Inspired by Dada and Surrealism, Installationism criticized the institute of art, the economic reality of the museum/gallery context, whereas earlier art movements mostly criticized the preceding art movements.

The thesis of the triumph of imagination and individuality of Romanticism (1780-1850) was answered by the antithesis of Realism (1848–1900), celebrating the working class and peasants through means of 'en plein air' and rustic painting. The true-to-nature style of realism was followed by Impressionism's (1865–1885) wish to capture the fleeting effects of natural light. Postimpressionism followed as a soft revolt against impressionism. One can clearly see an onwards push in Fauvism (1900-1910), e.g. the use of harsh

colors, and Expressionism (1900–1935). These are well known facts in the history of art (Janson et al., 2004).

In contrast, installation art is less well understood from a historical perspective. Julie H. Reiss defines installation art very loosely as "a wide range of artistic practices", only acknowledging the fact that it "overlaps with other interrelated areas including Fluxus, Earth art, Minimalism, video art, Performance art, Conceptual art and Process art" (2001, p. xiii). By defining installation art, however loosely, in this fashion, Reiss summarizes what the literature has hinted at before her, namely that installation art in fine arts is often regarded as *'Expanded Sculpture'*. A notion that was first introduced in Rosalind Krauss' landmark essay *Sculpture in the Expanded Field* (1979).

Most contemporary critiques (de Oliveira et al., 2003; Bishop, 2005) evaluate installation art in the same way as Krauss, focussing on the expanded nature of contemporary sculpture. Nicolas de Oliveira follows the path laid out by Krauss but points out that this is a too limited view. He acknowledges that there is a lack of clearly defined installation art but states that "its history, ..., grows out of the individual narratives presented by architecture, painting, sculpture, theatre and performance" (de Oliveira et al., 1996, p.7), marking conceptual influences from Constructivism, Dada and Surrealism to explain the hybrid quality that installation art has. Adjacent to this, Claire Bishop (2005) clearly distinguishes three key characteristics of installation art: (1) the aspiration to involve the viewer directly in the work of art, (2) activating the viewer, by presenting fragmented objects that need to be assembled by an active viewer and (3) the tactic of deconstructing the traditional concept of the precious work of art via the use of found objects and materials.

Installations come in many shapes, and therefore they often lack formal classifications, in contrast to painting or photography. For example, not all installations are image-based or rely on sculptural elements, even though

many incorporate these as part of their display. Despite the fact that there is not a general description of what installation art entails, most critics seem to agree on the importance of three key concepts regarding this art form: (1) site specificity, (2) institutional critique and (3) the activation of the viewer and the resulting importance of temporality. These aspects will be further illustrated by the concepts of site specificity, institutional critique, and activated viewer and temporality.

3.1.1.   Site-specificity

The Russian suprematist El Lissitzky created with *Proun Room* (1923) (arguably) the first installation (Bishop, 2005). In this installation, he uses the walls and corners of the venue to allow an involved viewing of the two and three dimensional *'Proun motifs'* on the walls. In doing so, the location introduces specific, meaningful elements of the installation. He explained that "the image is not a painting, but a structure around which we must circle, looking at it from all sides, peering down from above, investigating from below." (Lissitzky, 1923). He defines and claims space as a physical material with its own properties, necessary to allow visitors the intended viewing experience. *Proun Room* can be seen as a herald of installation art, a trend that turned into the predominant movement in postmodern art in the 1990s, since Lissitzky's use of space made the use of the spatial characteristics of the exhibition room explicit.

3.1.2.   Institutional critique

At the same time, Lissitzky attributed the viewer with an active role, but largely retained the retinal character of the art work. Installation art, however, is meant to evoke a multi-sensory experience with its public, forgoing the

retinal character that was predominant in the museum world in the beginning of the twentieth century. Expressing this wish, leans heavily on Marcel Duchamp's use of transgressive aesthetics, favoring works of art that appeal to the active viewer.

According to that concept, one could argue that Duchamp's *Fountain* (1917) has become the most influential works of art in the twentieth century. Serving as an icon of deconstructive art, *Fountain* questions in a very facetious fashion what role galleries and museums play in the validation of art. Encompassing the discourse of Dada and Surrealism, the Readymade revealed the true relevance of the gallery/museum; an aesthetic regime determining what is and what is not art, by including or excluding works of art. Peter Bürger regards Fountain as a genuine anti-institutional gesture, proposing that "Dadaism, the most radical movement within the European avant-garde, no longer criticizes schools that preceded it, but criticizes art as an institution, and the course its development took in bourgeois society." (Bürger, 1984, p.22). The institutional critique that was so pertinent in Dada and Surrealism proved valuable for installation art, where through the use of found objects and materials the high art praxis was being questioned. Art was becoming more socially oriented, breaking down the barrier between the work of art and the viewer, entailing a critical stance towards elitism and institutional art. The Avant-Garde movement held a promise of a bright new future where art would exist in everyday life, where readers were encouraged to engage in the creative process (e.g. *how to write a dada poem,* Tristan Tzara).

3.1.3.   Activated viewer and time-dependency

The most recurring key concept for defining installation art is that of the involvement of the viewer. At one hand, this resulted out of the hope to reintegrate art with life-praxis [Lebenspraxis] (Bürger, 1984). Claire Bishop

noted the artists' need to forego the conventional gallery and museum context (Bishop, 2005). On the one hand, in doing so, artists allow viewers an immediate response to art, not determined by the marketing of the gallery. On the other hand, activating the viewer is often attributed to the introduction of space and consequently time as imperative elements in the meaning creation of installation art. The increasing accessibility of time-based media like video and film led to a more profound incorporation of temporal elements, creating an expectance of viewers spending time inside the installation while exploring it spatially. This also contributed to a reevaluation of the spectators position and role towards the art work. As one of a myriad of examples, de Oliveira affirms that "the spectator becomes an integral part of the work by virtue of the duration of a common experience" (de Oliveira, 1996), when describing Bill Viola's *He Weeps for You* (1979) and Gary Hill's *Tall Ships* (1992). *He Weeps for You* consists out of a brass valve out of which a drop of water emerges. The drop of water is magnified through the lens of a videocamera and projected onto a large screen. The projected close-up reveals that the viewer and part of the room are visible inside each drop. When the drop finally falls, it creates a loud resonant sound as it lands on an amplified drum below. In Hill's *Tall Ships,* the audience enters a pitch black room, where 12 different people are projected on the walls. If the spectator walks towards any of the 12 figures, the figure approaches the spectator, stops and looks back at him/her.

This common experience attests to the immersive character of installation art where interaction with the piece is key. Reiss attests with regard to interaction "[that] the viewer is required to complete the piece; the meaning evolves from the interaction between the two" (2001, p. xiii).

In summary, installation art has a wide range of praxis, combining media both conceptually and technically from the traditional arts. It follows a discourse that breaks with the thesis-antithesis tradition, where one art movement reacts to the previous one (cf. Romanticism and Realism), that was predominant in

art history. It does so by attributing the viewer with a direct involvement with the art piece. Installation art seeks to activate the viewer, by using scattered objects placed in the exhibition space that need to be examined from different perspectives, and thus introducing a non-linear narrative. It criticizes 'l'art pour l'art' by deconstructing the notion of precious work through the use of found objects and materials. It actively questions, in the tradition of Dada, the role that museums and galleries have in validating art. By removing art from of the gallery/museum bound praxis and placing it in everyday life, installation art seeks to be more socially oriented. The use of space as a material, with properties similar to wood or stone, is a necessity to transcend the retinal character of art in favor of art targeting the mind. It enables a multi-sensory experience where the creation of meaning becomes a responsibility of the viewer. The involvement of the viewer is further acknowledged by the site-specificity of installation art and the introduction of time, as a direct result of the use of space. Central to this resulting multi-sensory experience is the notion of immersion and interaction as key elements in the creation of meaning.

3.2.   Interactivity in new media art

The origin of Media art is usually attributed to the widespread availability of video as a new mean for artists to express themselves in the 1960s. Others go further back in time, looking back at film, kinetic and sound art since the 1920s (Popper, 1993, p.16). Most literature mentions new media art, rather than media art, addressing new media art as the generic term for the collection of sub genres within new media, of which a few will be discussed into detail in the following sections. Whether one talks about media art or new media art, is a question of viewpoints.

In his essay *What is the point of art in the media age?* (2005), Dieter Daniels insists on a broader conceptual scope for situating the origin of (new) media arts. According to Daniels, media art can be linked to the invention of two key media technologies, telegraphy and photography, by two artists-turned-inventors. S.F.B Morse developed telegraphy in 1835, while M. Daguerre astounds the world in 1839 with his first photographs. Daguerre, being a panoramic painter, sought for a better method of making panoramas than the available tracing of camera obscure images, and invented the *Daguerreotype*, a first commercial photographic process. Morse was driven by the dead of his wife soon after the birth of their fourth child. Morse, traveling at that time, was notified by a letter his father wrote, when he rushed home he found his wife already buried. The event led him to search for a faster means of communication, which eventually became Telegraphy. Both are typical cases of a crisis of artists' self-confidence. At the start of the modern age they radically changed professions from artist to inventor, and doing so they claimed immortal fame. They were, according to Daniels, the first to substitute art with media. As such the interplay of art and media precedes the common time horizon by far, hinting at the shifted role, that of an inventor, of the artist in media art.

This substitution, where one practice is interchanged with another, can of course also be found in fine arts, where the anticipation of technological development led to modernism at the end of the nineteenth century. Modernists, greatly inspired by the rapid developments in technology, did however, unlike Morse or Daguerre, not necessarily incorporate new technologies, like photography and film, in their praxis, instead they rather focussed on the thematics and promises of these technologies.

Even though the introduction of media art follows the development within technology, there are numerous examples where the borders of technology were pushed by artistic ideas. Often art proved to be a guide in the development

of new technologies, anticipating forms of perception that eventually nested themselves in everyday life. Consequently, one can question whether media artists are visionaries of new emerging technologies, doing explorative usability research or are merely involved in the creation of their own art.

To summarize, I will focus from now onwards on the *new* in new media art, a newly born art form which shall prove to initiate a few pertinent changes in the discourse of arts. As already stated, the conceptual outlines for media art could arguably be traced back to the 1920s, during which artists became inventors, embracing the possibilities that are presented when new technologies emerged. Technologically however, the introduction of the computer is key in the distinction between art and new media art, not only for formal expression of artistic ideas but evenly for the relationship the artist will have with its public through the medium used.

3.3. Interactivity in computer art

Few generations are as fortunate as ours to witness the birth of a new art form; architecture is as old as building structures for housing, there are paintings on the walls of the caves at Chauvet or Altamira dating as early as thirty or forty-thousand years ago and music, and consequently dance, has also been around since then. All of these art forms have developed over the ages into the fine arts, with photography, film and video as the latest additions. Some might argue that both photography and video are indeed new media. I choose not to include them, since they can be seen as merely technological improvements of the already established art praxis, catering for the artistic wishes that were already expressed, using very similar aesthetic conventions and discourse. To polarize the difference with fine arts even more, I will address only a subsection of new media arts, reintroducing the term Computer Art, following

the path that Dominic McIver Lopes laid out in A Philosophy of Computer Art (2010, p. 21-27).

New media art is an encompassing term that entails many different art forms, some of which are clearly defined while others might be considered rather vague or too generally described. Digital Art is one of those vague terms, a nowadays fashionable term which is used almost as a synonym for new media art. The term Computer art, which earned Lopes' preference has been pushed to the background by the encapsulating Digital Art. Both relate, in the common sense, to art that involves the use of a computer. However, they both use computer technology differently. According to Lopes, Digital art hints at the use of a common digital code, but can include myriads of media; music, film, text and images can all be perfectly stored using a common digital code and can be encoded by a computer.

Lopes defines digital art as:

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[A]n item is a work of digital art just in case (1)
it's art (2) made by computer or (3) made for display
by computer (4) in a common, digital code.
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(2010, p. 3)

Lopes argues that, since digital code can store, generate or manipulate old media, digital art isn't necessarily a new art form. Even though most photography is at present digital photography and movies might be recorded digitally, they are not new. Nor are they initially meant to be displayed on a computer screen. The discrepancy comes from a mix up of terminology. Instead of digital art, we should focus on digital art technology, this being emerging technologies that are used to show or create art works and that enhance our appreciation of art. For example: streaming music in a digital display *technology* from Soundcloud, such as the MP3 format, is not a digital

display *medium*, since it is irrelevant to our appreciation of the songs whether they are recorded in MP3, FLAC or WAVE.

In contrast to arguing why digital art is not a new art form, I will illustrate why computer art is a new art form. In essence, it should hold some common feature that can not be found in other kinds of art. Lopes distillates this feature out of five real-life examples; Jeffrey Shaw's *Golden Calf* (1994), Ken Goldberg's *Telegarden* (1995), Damian Lopes' *Project X* (1997), Scott Snibbe's *Boundary Functions* (1998) and Hisako Yamakawa's *Kodema* (2004). All of them are very different in imagery, some have an actual digital display, while others have not. All of them relate to traditional art forms; they include pictures, cinematographic elements, poetry and music. Until now they are archetypical examples of digital art, using technology to facilitate the appreciation of the art work. What sets these works apart, according to Lopes, is the fact that all of these are interactive: "What happens with the work is a result of some activity on the part of the audience" (2010, p. 26)

Lopes describes his theory as follows:

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[Computer Art Form]: an item is a computer art work
just in case (1) it's art, (2) it's run on a computer,
(3) it's interactive, and (4) it's interactive because
it's run on a computer." (2010, p. 27)
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Unlike digital art that uses a computer to encode media in a common digital language, computer art exploits computational technology. This allows computer art to be interactive which differentiates it form digital art. It has been pointed out that computer art works not necessarily require a digital display. It does however use images, sound and text in combination with traditional art forms, but their use is not the final display, neither does its use

constitutes the whole discourse of computer art, they should merely facilitate interaction.

In Lopes' working theory, the first premise is that computer art should be art. What is characterized as art, is the subject of much debate among traditional art critics, and there is no reason why this debate should not be held with the same caution among new media critics. Without dwelling to much on this heavily contested subject, it is suffice to say that if computer art integrates digital media technologies into a new art form by harnessing its computational potential, the interactive component should be considered a necessity in the discourse of the art work. In other words, the narrative embedded within the art work should benefit from its interactive aspect and at the same time surpass the experience of merely (inter)acting.

To summarize, computer art integrates technology at a micro level. This has radical consequences on the way we experience these integrated technologies. Whereas digital art uses a digital platform at a macro level, influencing at most the formal qualities without changing its discourse.

4. Conceptual Development for Interactive Art

In this chapter, I go deeper into the conceptual background of interactivity. The goal is to obtain a clearer, more substantial and thoughtful insight on how interaction is used in computer art, thereby honoring the Avant-Garde spirit that initiated it. I will also briefly touch upon some concepts related to interactivity and discuss how interactive artworks are appreciated.

4.1. Interaction and activation

Following Lopes' line of reasoning in which computer art works are predominantly defined by their interactive component and based around the computer as a central hub, a more in depth look at the definition of interactivity is necessary. Lopes' argument to differentiate computer art as a new art form that is different from digital art, which merely uses new technology to facilitate the creation of art works, entails the promise of a new aesthetic that addresses the novel role of the audience in interactive art. This desire for a new aesthetics for the activated viewer is widely shared in contemporary art critique and has already a substantial tradition in both fine and new media art (Bishop, 2005; Bourriaud, 2002; Ascott, 2207; Hammel, 2005).

During the Avant-Garde, the spectator already became an integral part of the art installation, and the experience of being immersed in the piece has been noted (e.g. by Julie Reiss and Claire Bishop) as being a key issue in view of the new aesthetics. Attributing the spectator an active role in art works on a larger scale, dates back to the beginning of the twentieth century when for example Duchamp and Man Ray gave specific instructions on how the viewer should experience their *Rotary Glass Plates (Precision Optics)* (1920). When the viewer was asked to turn the optical machine and stand one meter away from it, the viewer became an active participant in the art work. In a similar way, during the Fluxus period and the Happenings of the 1960s, audiences became

actively involved in the art work, often following precise instructions of the artists (e.g. *18 Happenings in 6 Parts,* Allan Kaprow, 1959). Throughout the evolution of installation art, the viewer has been attributed an ever increasing active and participative role. As such, the audience was involved in portraying the artist narrative through execution of precise instructions, in breaking the linear character of the narrative, and in being granted the spatial freedom to access different viewpoints in installation art.

However, it is still possible to question the interactive character of this type participation. In fact, the artists provide specific instructions to the audience, and audiences are engaged in the narrative according to a scenario. In that sense "the spectator, who is in the act of experiencing the work, acts as catalyst and receptor" (de Oliveira, 2003, p. 11) , but he is not really a participant that interacts with the art work. The actions may affect the narrative, but do they also really affect the content of, the expression of, and in general, the art piece? The shift from spectator to active participant necessitates a deeper analysis of what it means to interact with art, and of what it means to interact with computer art in particular.

One of the early sources on computers, art and interaction is *The Creative Process where the Artist is Amplified or Suspended by the Computer* (Cornock et al.), which dates back to 1973. In this article, Stroud Cornock and Ernest Edmonds argue that one should speak of *art systems* rather than art works. When considering art systems, that incorporate the totality of the art object, its surroundings and its public, one does not only acknowledge the spectators indisputable importance to interactive art, but it also stresses on the novel role of the artist within this system. Stroud and Edmonds regard an art system to be a *dynamic situation* (a term they leave deliberately open to interpretation) during which the participants are treated as one of its key elements. An art system is referred to as a *matrix*, in which there is an information exchange between the computer and the participant(s). The participants are, thereby,

involved in the decision-making processes during their art experience. The shifted role from spectator to participant also fundamentally affects the design of above mentioned matrix, so the artist should keep the expanded role of its audience in mind when using it. Stroud and Edmonds believe that "an interactive situation can [,...,] be much more productive than a passive one," (Cornock et al., 1973, p. 13) and they mention three such situations, based on the way the participant interacts with an art work.
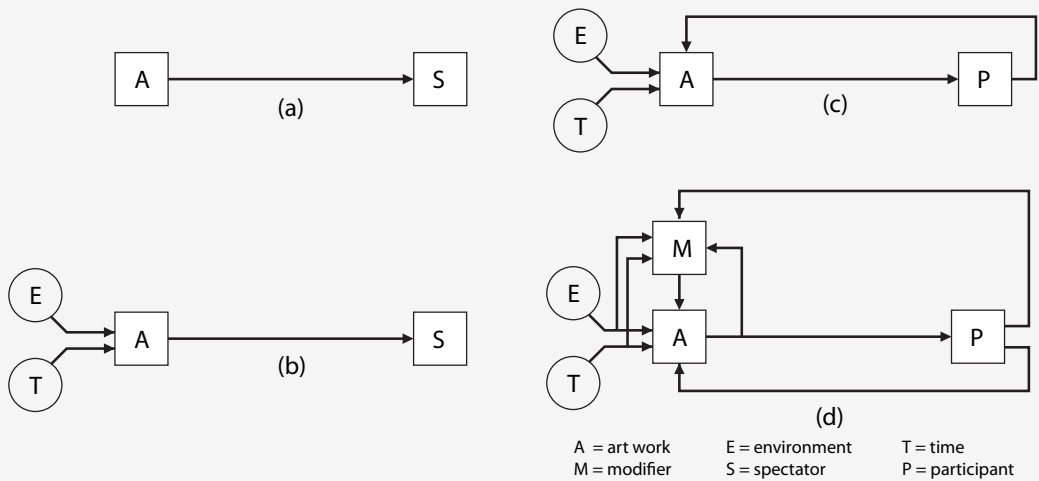
Figure 1: (a) Static system. (b) Dynamic-passive System. (c) Dynamic-interactive System. (d) Dynamic-interactive System (varying) (Cornock et al., 1973)

According to Cornock and Edmonds, Figure 1(a) represents the traditional way of how art objects are related to spectators. The art object (A) is just a static system that has a certain impact on the spectator who perceives it. Obviously, the art work is not affected by this perception. Figure 1(b) represents a Dynamic Passive System. This scheme illustrates how the art object (A) is changed over time (T), due to environmental factors (E). Eventually, the spectator (S) can be considered part of this environment (and as such it may affect the art object), but the art object as such will not really be altered by the spectator. A typical example of such an art object is kinetic

art. In contrast, Figure 1(c) represents a Dynamic Interactive System. This scheme illustrates how the spectator is addressed as a participant (P) whose actions generate some sort of input for the art object (A) to process, creating a feedback loop. In line with this, Figure 1(d) can be conceived as a special case where the artist modifies the art object in a unprescribed way. In other words the artist would change the original meaning of the art work. The latter is called a modifier (M).

Cornock and Edmonds hint at a shortcoming of this model when they describe the participant as "simply to be seen in terms of the input of that subsystem (as an exogenous variable), for to try to design a system that takes a total account of a participant would present an incommensurable problem." [paraphrased] (p. 13).

I believe that the special case of Figure 1(d) holds the potential of anticipating on the public's actions and modifying the art work accordingly. However, to regard this as a truly interactive system would imply the feedback loop to be an intentional communication process, rather than just physical sensor/ actuator loop. The intentional level is the level at which anticipations are handled, and as we will discuss later on, where empathic involvement that is so essential for art experiences plays a role, at least for the human participant in the interaction.

Since 1973, there has been an exponential growth in technological possibilities and experimental art. Due to the continuously diminishing cost of technology, the number of artists and technologists working in the interactive art scene has multiplied. Apart from myriads of organizations promoting and archiving computer art, a corresponding research field has emerged. The Human Computer Interaction (HCI) has become an extensive multi-disciplinary field,

combining new developments in interactive technology and the associated human issues.

Currently, most research on interactive arts is done in HCI, and related fields, like media-theory or musicology to name a few, rely heavily on its research output. In today's art, the computer plays an immensely important role and holds great potential for future development. This is true for all art forms but it is especially true for interactive or computer art. Interactive art has been further developed since Cornock and Edmonds published their article in 1973 but the categories they described are still widely used.

Almost 30 years later, Linda Candy and Ernest Edmonds brought their model up-to-date (Candy et al., 2002). The static situation described in Figure 1(a) remained as static as before, without any interaction between the art object and the spectator. When considering the Dynamic-Passive system of Figure 1(b), the wide range of newly developed temperature, light and sound sensors allow for more refined and subtle changes of the art object to happen. However, according to this concept of interaction, the viewer still remains a passive observer within a predictable responsive environmental system. The Dynamic-Interactive system still expands the functionality of the Dynamic-Passive system, as it attributes to the participant an active role in influencing the changes in the art object. Candy argues that the work 'performs' differently, acting upon the participants presence. According to the new Dynamic-Interactive (Varying) system, the conditions of both preceding cases apply. In addition, the modifying agent changes the original specification of the art object. In 1973, this modifier was conceived as being the artist, while nowadays this is either foreseen as a human or a software agent. The author concludes that because of this modifier, the performance of

the artwork cannot be predicted, as it will depend on the history of interactions with the work.

Up to this point, the discussed literature addresses interactivity mainly from the point of view of Human Computer Interaction. Such a viewpoint mainly focusses on the functional relationship with technology, while the intentional relationship with technology is often neglected. However, I strongly believe that the mapping of artistic goals to digital methods requires a change in the artist's thinking and designing process that goes far beyond the functional relationship. What I mean is that the interaction should add to the human experience, in addition to the added technical aspects. In this respect, it is of interest to consider the work of media theorist Andy Cameron, who defines interaction as something that goes beyond the scope of a person acting upon an apparatus (Cameron, 1998). He acknowledges that the possibility of an audience actively participating in the control or representation of an artwork is what interactivity currently refers to. However, he adds that in culture "the audience is given a space for interpretation". In that perspective, he states that we have been granted "a space for reaction", but "not for interaction". In Dissimulations, he explains interactivity as follows:

```
[I]nteractivity means the ability to intervene in
a meaningful way within the representation itself,
not to read it differently. Thus interactivity in
music would mean the ability to change the sound,
interactivity in painting to change colours, or make
marks, interactivity in film the ability to change the
way the movie comes out and so on. In its most fully
realised form, that of the simulation, interactivity
allows  narrative  situations  to  be  described  in
potentia and then set into motion – a process whereby
model building supersedes storytelling, and the what-
if engine replaces narrative sequence.
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For Andy Cameron, what makes art interactive goes well beyond providing input data that an art installation interprets in order to change the sound or images. He clearly identifies that what makes a medium interactive is the ability to interfere with the narrative. An artist should as such grant its public access to the process of meaning creation, leaving the narrative open-ended. Cameron promptly points to a contradiction in the idea of an interactive narrative. As the dominant cultural form since early drawings, the narrative has been fundamentally linear and non-interactive. However, an interactive story requires a form that is not a linear narrative, but an open-ended form in which a displaced temporality and altered spectatorship are at play. In an interactive story, the idea of literature merges with that of a game.

The connection between games and interactivity seems to be widely spread in the discussion about interactive art. As previously mentioned, Cornock and Edmonds already expressed the necessity for a feedback loop between art object and public. To Roy Ascott, this feedback loop leads to a perpetual state of transition, one in which contemporary art could be seen in the context of a game. In the past "the artist played to win." By setting the conditions, the artist ensured he always dominated the play. The spectator, left without a strategy of his own and only predetermined moves at his disposal, was positioned to lose. Ascott argues that todays art is "moving towards a situation in which the game is never won but remains perpetually in a state of play." (Ascott, 2002, p. 103) Although the artist continues to define the general context of the art experience, he does so to guide the actions of the spectators, not to enforce them. The experience is unpredictable and depending on the total involvement of and the choices made by the spectator. As Cameron argues, making a story interactive requires forking paths, all of which need to fit together. The more pathways there are, the greater the sense of freedom of the reader, and the greater the amount of work for the writer. However, each additional point of interaction results in an exponential increase of the volume of the story, leaving the author with an inevitable tradeoff; sacrificing the

time spend on developing the narrative and texture of the story for an ever increasing interactive complexity.

Cameron warns us against the tradeoff between interactivity and richness of content. Additionally, approaching interactivity from the point of view of the narrative, doesn't seem to overcome the shallow response of dealing with an apparatus. What authors may end up with, when insisting on the readers role in authorship while still writing the individual scenes of the story, may appear an interactive story, but can easily turn out as a mere outline of a story, not the story itself.

In short, Cameron discusses interactivity primarily in the context of the narrative, and the consequences it has on writing stories. He introduces forking paths, allowing choice by the audience to influence the development of the story, as a key element in interactive storytelling. At the same time, he hints at the contradiction of the interactive narrative, leaving an underdeveloped narrative that presents itself as a browsable outlined story. Where interactivity promises the spectators freedom and choice, it is precisely the absence of such freedom and choice that interactivity would appear to conceal.

In *The Language of New Media,* Lev Manovich (2001) refines this branching-type concept of interactivity as a closed interactivity: the user plays an active role in determining the order in which the already generated elements are accessed. However, this only allows for what Cameron noted as reading the story differently. A more complex open interactivity can be imagined, in which both the elements and structure can be reordered, changed or generated instantly, adhering to Cameron's intervening with the representation itself. An all to literal interpretation of interactivity, equating it with physical interaction

between user and a media technology, holds the danger of neglecting the psychological aspect of the interaction.

According to Manovich, interactive computer media support the modern trend of externalizing the mental processes of reflection, problem solving, recall and association. These externalized mental processes are offered to us when we follow a link or when we move to a new scene by clicking a button or acting upon an event in interactive (art) works. We are granted an apparent freedom of choice that leads inevitable to following one of many preprogrammed existing associations. According to Manovich, we are asked to mistake the structure of somebody's else mind for our own.

Dominic Lopes thinks there is no need to assume that interactivity in computer art is exactly the same as interactivity found elsewhere. Even though one could argue that computer art works by listening and responding, this is not the same interactivity in which we engage when having an inter human conversation. Moreover, social interaction among many users in multi user installations is not necessarily social interaction. According to Lopes, computer interaction at present mostly works at the level of user choices. In addition, it is not unthinkable that interactivity in computer art does not match what is in general conceived as computer interaction (Lopes, 2010, p. 36).

So far, interactivity has been considered from a physical interaction with an apparatus or art object (Cornock and Edmonds), or from a more thematic point of view targeting the narrative (Cameron), while Manovich already hinted at the flaws of solely looking at interactivity in such a way. However, Lopes choses to look at interactivity in yet another way, namely by considering the display of computer art. A computer art work's display is a structured entity, resulting from the artist's creativity. However, it also serves as a point of focus to which an audience interacts. In that sense, a computer art work's display, is not the equivalent of a computer display. In the examples he gives

(*Golden Calf, Project X, Boundry Functions, Kodema* and *Telegarden*), the audience does something which affects the work's display. If the audience acts differently, the display would be affected differently too. Lopes translates this idea into two formulas:

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A work of art is interactive just in case it prescribes
that the actions of its users help generate its
display. (p. 36)
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A work of art is interactive to the degree that the
actions of its users help generate its displays (in
prescribed ways). (p. 37)
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Central to these formulas is the idea of user interaction. As a key component for computer art, user interaction can be formulated as follows:

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A user interacts with a work of art just in case
he or she acts so as to generate its display in a
prescribed manner. (p. 37)
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User interaction implies a prescribed action, and the work needs to allow and even invite certain user actions. These actions would ideally guide the user, educating him in how change in the display occurs. For an audience to be perceived as users, their actions need to be significant, the users need to have an impact on the display, and the work needs to be designed for its display to change accordingly. In order to do so, computer art works need input devices, that relay their information to an output. As such, Lopes states that "interactivity requires a mechanism that controls input-output transitions and computers accomplish this by running computational processes." (Lopes, 2010, p. 45). The display of a computer art work is generated from the input, there is a defined path leading from input to display.

To summarize, interactivity is a concept that has been approached from different angles. These angles are influenced by more technological to open ended conceptual ideas. All these viewpoints have their own merits and flaws. Therefore, I believe that one single definition of interactivity may prove to be problematic. Instead, what is within our grasp is an open but tailored definition of interactivity within the arts, including ideas from other fields that may enhance their applicability within the arts in general.

After all, I believe that Lopes' definition of interactivity might not be as clear cut as he suggests. Focussing solely on the variability of the display may neglect some of the essential ideals that were initiated during the Avant-Garde period. In particular, the focus on the display may again reduce the ability of an activated user to a control variable in the process of interacting. It is true that "active appreciation does not imply interaction", since it does not help generate a work's display. However, I am doubtful that changing the display through acting implies real interacting.

Interestingly, both Manovich and Cameron warn about the consequences of dehumanizing the user into a variable stream of data. Indeed, a user choice makes a work appear to be interactive, especially when there is so much choice offered so that the user loses its grasp on the structure. However, the true creation of meaning (changing the narrative) implies that (part of) the story isn't told nor created at the moment of creation.

In my opinion, there should be an emphasis on the narrative within interactive art, although I acknowledge that the way the narrative is traditionally approached is counter productive, leading to a contradictio in terminis when speaking about interactive narrative. The narrative of interactive art doesn't need to be identical to that of traditional art. I believe that a new narrative can be found for interactive art, focussing on artists attuning to the expectations of an (uneducated) audience. The audience should be largely responsible

for the creation of meaning through acting, and the artists need to anticipate how the audience will act, provided that the artist wants to steer this process. Interactive art would consequently use an open narrative, guiding the users in acting in a prescribed way, rather than contextualizing their actions as part of the story, even when it isn't necessary to speak of a story.

4.2.   Audience

One of the most noted consequences of introducing interactivity into art has been the shifted role of the audience. Computer art works require an active audience, who engages in the art work and changes its display through actions. One could say that without touching the art work, there is no experience of the art work. In a similar way, Michael Hammel states that "[b]y touching the artwork you fall through a magic [trapdoor] and become a tactile user connected to the interface and mentally absorbed in the depths of the visual environment." (Hammel, 2005, p. 58) By touching, the user should become involved, not only acting at a practical level and engaging with the interface, but also retaining the same mental involvement that was intended for the 'activated viewer' in early twentieth century fine arts.

All art works are opportunities to evoke actions, but only interactive art works thrive on the necessity of these actions to occur, folding in elements of creation, performance and appreciation. Traditionally, these three elements are distributed to three different groups of specialists; creation is reserved for artists, performers execute art works and the audience appreciates the display of it.

To many, in computer art it is hard to distinguish between artist, audience and performer. Michael Hammel argues that the audience co-creates the artwork

(2005, p. 64), David Rokeby writes that "the audience becomes creator in a medium invented by the artist" (2002, p. 6) and Roy Ascott believes that creativity is shared and authorship is distributed (Ascott, 1990).

I believe that users don't necessarily rely on the knowledge of a work to change it's display, because the users learn from the work while generating its display. In doing so, the user discovers the work, and (hopefully) its meaning through interaction.

In this context, performers (musicians, dancers and actors) serve as a specialized group of users. They have the knowledge that enables them to fully generate the intended display. Often, they are closely working with the artist creator, or they are relying on elaborate descriptions of how a work should be displayed.

Ideally, long-term (non-specialist) users of a computer art work will also adopt characteristics of these performers, just like a critic acquainted with an oeuvre of an artists becomes privileged in appreciating the oeuvre. In the context of interactive art, I believe that a user gathers knowledge about a work partially by considering the effects of actions. Typically, users rely on what is known about the work and to a large extend also, by interacting with it. While interacting, the user assesses the art work. Despite the notion the user has of the artist's intention, the process of interacting automatically assumes evaluating their own actions, relating them to what they experience, learn and know.

When art is interpreted as a practice that is based on communicative interaction that is mediated through the art work, it becomes possible that the intentions of the artist are conveyed while interacting (Iseminger, 2004). Moreover, in our opinion users creating the work while interacting do so using communicative intentionality, these intentions can also be conveyed to the artist. In that sense,

interaction is an exchange of intentions, based on the art work that serves as a mediator for this exchange. Consequently, it can be stated that the way an artist formulates the symbiosis between the narrative and prescribed user actions will undoubtedly identify and formulate the specifics of a computer art work. This fundamentally affects how interactive art works are conceived, constructed, perceived or better yet performed.

To conclude, the role of the audience in interactive art differs from that of a traditional art audience. The difference between artists, performers and spectators are blurred in interactive art. Consequently, their functions are transformed, which leads to a novel way of art creation. The novelty is related to the way in which the audiences' actions will influence the design of the art work. Therefore, in order to determine how an audience react when they are confronted with interactive art installations, an artist will need to consider the possible intentions of the audience and consider these intentions as an integral part of the creation process. Performers, being a specialist group of users, can help in doing so. A specific task driven process can be the foundation of such research, evolving into a more explorative investigation with less specific tasks to determine what constitutes a prescribed action and what does not. The results of this quest will determine how an artist creates the narrative and builds the art object.

4.3.   Art object and interface

The newly defined role of the audience may cause a shift in what constitutes a computer art work. When Rokeby (2002) assumes that the artist invents a medium in which the audience creates, one can ask oneself if the art work exists if there is no audience to create it. If the audience and the artist have

a new role, does that imply that there is a new role for the art object has one too?

In the following section, I will discuss three concepts that are key for a novel design of interactive art objects. These concepts deal with (i) the opacity and transparency of an interface, (ii) the affordances comprised in the artifacts that constitute the interface, and (iii) the degree of mediality, where the characteristics of a medium influences the message.

4.3.1. Opacity and transparency of an interface

Transparency of an interface contributes to the illusion of non-mediation. This is often heralded as a premise of an expressive interface because it allows a user to fully invest in the intentions of his or her artistic expressiveness, without being limited by the way these expressive intentions are constrained by the medium. For example, when film was first introduced as a new artistic medium at the end of the nineteenth century, it was still a very crude medium due to its technological imperfections. The medium evolved over time from being something very present to almost invisible, as illustrated by the way in which the early black and white cinema evolved, through the inclusion of sound, (techni-)color, HiDef, IMAX screens and finally 3D, to an almost lifelike experience. In other words, the medium, in the hands of technologists, often evolves from something opaque towards something that appears more transparent. In general, the research field of Human Computer Interaction focuses on this process. The medium is conceived as a blind spot (Krämer, 1998, p. 73), where the mediatized comes to the foreground, in contrast to the medium that, despite its material presence (e.g. the form of the technological apparatus), fades into the background. With its emphasis on transparent

interfaces, HCI hopes to focus on offering a user practically no distance between intent and outcome.

However, artistic interfaces differ from HCI interfaces, even if there is a great overlap in design paradigms. Very few artistic interfaces are transparent and almost no artist, me being one that can certainly attest to this, aspires to make a transparent interface in a strict HCI point if view. Transparency in HCI is conceived in such a way so that a user's intention is transformed to an outcome such that another user, who perceives the message, can ignore the technology and the transformations that were necessary to generate the message. The situation in art is different in the sense that an artist may be inclined to use a certain degree of opacity in order to guide or inform the audience about certain usages and intentions.

Let me further clarify this point.

In HCI, an interface is often defined as a part of a machine that communicates with an environment. An interface thus mediates sensory and motor processes of a user, making external symbolic activities accessible to a machine. How a machine interprets this input data is coded using different mapping strategies. As such, interface design becomes a joint effort between the hardware design and developing an appropriate mapping strategy.

Figure 3 depicts a human computer interface, enabling a human (user) to interact with a computer in order to provide the users with feedback for their actions. The interface consists out of an input device, capturing a stream of data. The interface will eventually generate an output using an output device. In between, a feature extraction categorizes the data and a mapping strategy, adhering to the application's intent, translates these features to an output device.
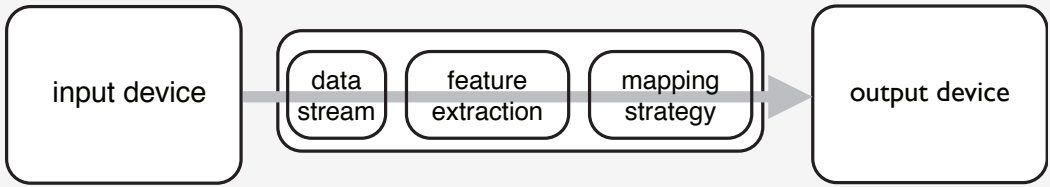
Figure 2: a HCI interface

In HCI, the developer assures that the user's intent and outcome are synchronized. When creating the interface, an HCI developer hopes to make the relationship between the user's intent and outcome of an optimal fluidity, as such the actual interface becomes transparent, as depicted in Figure 2.
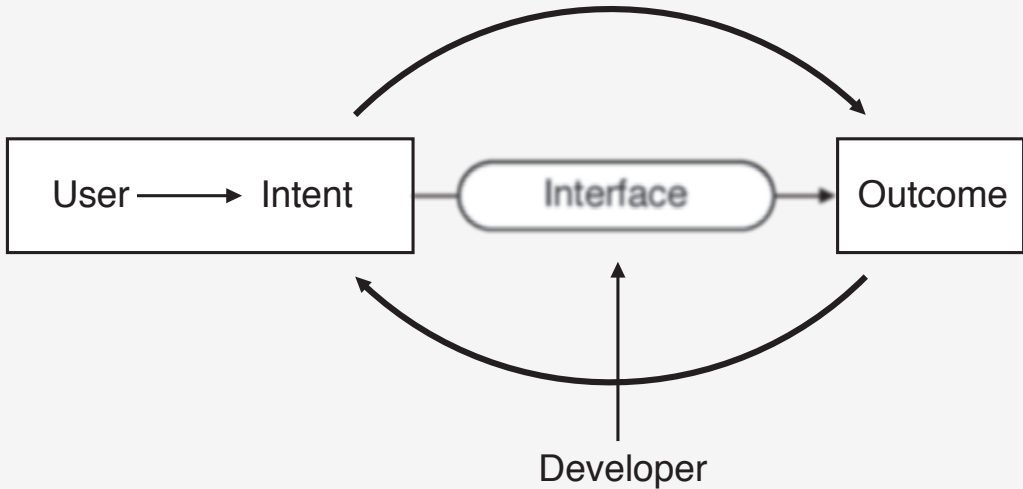
Figure 3: a transparant HCI interface mediating intent to outcome

The ideal of a transparent interface is one that relates a user's input both immediately and predictably to an output, or as Rockeby puts it "The proof that will most easily satisfy the audience is 'predictability' (i.e. if one makes the same action twice, the work will respond identically each time)" (Rockeby, 2002, p.8).

The notion of the necessity of an immediate response is clear, when there is a delay between action and reaction the process of mediation becomes visible, making an interface and its internal processes visible too. As such the transparency of an interface becomes directly related to the effectiveness of the mediation.

In the arts, I feel that an interface should be defined as part of a broader human communication system. Such an approach needs more components than the traditional HCI model, including the user's intention, the developer and/or artist and the formal output of the whole process. The model consists of a user, who connects to the interface through use of an input device. The computational process, described above, transforms the user's actions into output, such as sound, visuals and mechanical output.
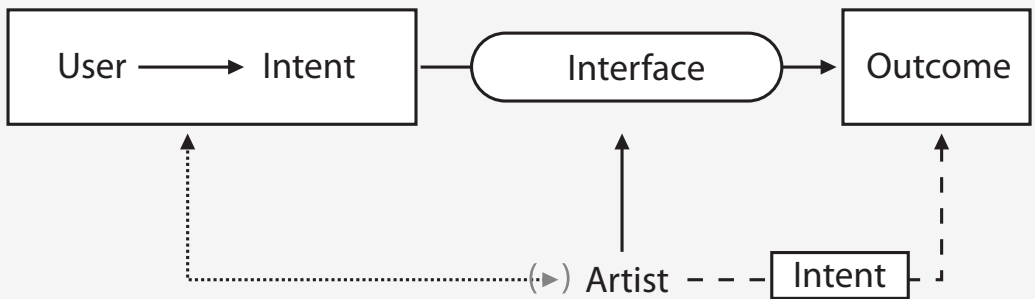
Figure 4:   an artistic interface

In contrast with the HCI approach, the art interface itself may serve as a medium for an experience, incorporating information technology and artistic strategies of mediation. In addition, interactive artists often express themselves through the opacity and idiosyncrasy of the media they use and create. They use the formal aspects of a medium, repurpose the form and function of every-day objects, and reflect upon, guide and transform the gestures of the users. Therefore, when creating an art work, we believe that artists typically

have a certain outcome in mind, and this outcome may traditionally be interpreted as the narrative. However, they convey their intent, in the form of the narrative, through the use of different media. Figure 4 shows how, in interactive art, the artist/developer uses the interface as the medium in a way that is different from the traditional HCI model. When creating the interface, the artist automatically should take the target audience into account, while at the same time assuring that the intent of the artists is presented in the outcome of this interface and accessible for the user, who has an intent of his own when using the interface.

In other words, in interactive art, the creation process of an art object can be seen as threefold: (i) it can focus on the design of custom input and output devices, (ii) it will certainly involve a mapping strategy that is especially developed for the art object and, (iii) finally, the creation process will need to assure the user's experience. Most of the time, the creation process consists of a combination of those three elements.

In this context, it is instructive to mention the work of Graham Coulthar-Smith, who argues that interactive input devices (2005, ch. 3, para. 4) function as "tools" and "are not works of art", because they are "replaceable accessories to the work of art." Coulter-Smith does seem to follow a different line of thought, speaking of interactive input devices rather than of an interface, detaching the computational process, feature extraction and output devices from the input device. To him, these devices give a user access to the work of art, through a physical tool or by means of sensors detecting the human body, enabling an embodied participant. He, however, does not specify out of what the artwork constitutes and where the lines should be drawn.

Coulthar-Smith exemplifies this using Jefferey Shaw's *Legible city (1984)*. Here, the input device is a bike and this bike has been notably altered in between different exhibitions before reaching it's current form. The latest

version of *Legible City*, which is part of the collection of ZKM Media Museum, I saw when it was exhibited at Ars Electronica in 2004 and STRP 2011 and employs an abstraction of a bike rather than an actual bike, as it did in the first version. More than likely, the current input device is designed and constructed especially for *Legible City* by Shaw. This device may still resemble a bike and does indeed afford biking, but it is not an actual bike. Based on our model, we would argue that input devices are often an integral part of the art work and as such not easily replaced without having consequences for the experience of an art work. Evidently, when an interactive art work merely uses of-the-shelf hardware as its input and output device, their function precedes their form, making it more easy to exchange them with similar hardware objects.

Finally, it should be noted that both HCI and artistic developers aspire a fluid mediation. Nevertheless, artistic developers use the transparent quality of an interface a different ways than their HCI developer colleagues would. HCI developers would pursue to obtain a closer connection between a user's intent and the outcome through the use of a transparent interface, whereas artists would aim at transparency of (a part of) the interface in addition to favoring other opaque qualities of the art work. When artists use the opaque quality of an interface they do so to evoke a certain reflection of this interface, or to guide the user towards the prescribed actions, needed to induce an art experience.

4.3.2.   Affordances

Finding new ways of interfacing with novel devices is always exiting but also frightening, because audiences have different profiles and their intentions are not always clear. Therefore, a right balance between new technology and a natural way of interfacing is important. This natural way of interfacing can be guided, by the concept of affordance. An example is provided by the input device of Shaw's *Legible City*. Although the interface is not a bike, it

clearly affords biking. The function of this apparatus is directly visible and the user automatically understands how to act because of the information that is supplied by the design of the interface. Affordance is a term the perceptual psychologist James J. Gibson introduced in his 1977 article 'The Theory of Affordances' (Gibson, 1977). Gibson defined affordance as "an action possibility available in the environment to an individual, independent of the individual's ability to perceive this possibility" (p.12). Donald Norman applied the term to HCI in his book 'The Psychology of Everyday Things' (1988), and differentiates from Gibson's theory:

```
...the term affordance refers to the perceived and
actual properties of the thing, primarily those
fundamental properties that determine just how the
thing could possibly be used. A chair affords ('is
for') support and, therefore, affords sitting. A chair
can also be carried.
(Norman, 1988, p.9)
```

The big difference between these two viewpoints is that Gibson addresses affordance from a perceptive point of view, while Norman refers primarily to the fundamental properties of an object. When defining it, this is a logical distinction if we take their goals into account. Gibson was primarily interested in how we perceive the environment, while Norman's interest lies in manipulating or designing the environment.

In POET (The Psychology of Everyday Things) Norman states that "understanding how to operate a novel device has three major dimensions: conceptual models, constraints and affordances", emphasizing the role of past experience and culture. With regards to design in HCI, Norman makes a distinction between 'real affordances' and 'perceived affordances', although

design is about both. He states that "the perceived affordances are what determine usability" (Norman, 1988, p.123).

Gaver (1991) sees affordance as 'properties of the world that are compatible with and relevant for people's interactions' and addresses the chair example as 'perceptible affordances'. Designing easily used systems is making affordances perceptible. To Gaver, the concept of affordances can be regarded as follows:

```
It implies that the physical attributes of the thing
to be acted upon are compatible with those of the
actor, that information about those attributes is
available in a form compatible with a perceptual
system, and (implicitly) that these attributes and
the action they make possible are relevant to a
culture and a perceiver. (Gaver, 1991, p. 81)
```

All the aforementioned viewpoints on affordance imply action-reaction possibilities, whether invoked by culture, memory or functional design. A well designed object will lead to the user acting upon it. This is certainly true for utilities but is it equally true for artistic interfaces reacting to it?

I assert that the creation of meaning in interactive art is of an explorative nature, and that what is known about the work can been learned by interacting with it. When interacting, the audience values the art work and despite the notion it has of the artist's intention, this interaction automatically leads to an evaluation of the own actions, relating them to what they experience, learn and know. Gaver addresses a similar notion in reference to affordances when stating that "Affordances are not passively perceived, but explored... Exploration of afforded actions leads to discovery of the system, rather than

knowledge of the system metaphor leading to expectations of its affordances." (Gaver, 1991, p. 82).

Therefore, in interactive art works, often a great deal of the time is spent on designing the visual identity of the input and output devices. Installations can be minimal in design or visually exuberant, small or huge, depending on the intended user experience. Often, designs that gush a myriad of new technological features are technically ecstatic, but their usability may be overlooked. Designs based on users' current articulated needs and tasks fall behind on the potential nested within new technology. Consequently, whether or not one is designing a computer interface, a new music instrument or a fully multi modal artistic environment, one should keep in mind that the exploration of a new yet (strangely) familiar world is the key for an intimate artistic experience. Therefore, an artist should use a common language, embedded in the functionality of an object as affordances, to instruct, inform or even mislead the users, aiding them in their experience.

4.3.3. Mediality

The previous section made clear that the affordance of an object aids a user in the exploration of an interface. A link to the section on transparency is that the knowledge a user has on how to operate an interface aids at the level of transparency of an interface. The interface will undoubtedly focus a user's actions, and the symbolic actions used when operating a novel device will often appear intuitive. However, the common language that guides a user is not always solely embedded within the affordance of a specific object. Often the medium will help in the process, with a proper kind of language. When a medium influences the mediatized it is called 'mediality'. This can be seen as an operation mode of a medium, referring to the relation the medium has to the mediatized (Seifert, 2008). The message, or what is mediatized, of

an artwork is clearly influenced and even partially defined by the specific medium it uses. A medium participates in the shaping of the message and goes beyond acting as an indifferent means of conveying the mediatized. Considering this, it becomes apparent that an interface can never be fully transparent, because a medium will always require a certain knowledge about its possible modes of operation and the feedback it generates. As pointed out before, formal elements of an (artistic) interface may act as a functional guide for users, exploiting its opaque qualities. These qualities may be understood as affordances, shaping the transformation of the user's intent.

In HCI, the intent of a user is often considered to be pre-existing, and as such does not depend on the interface he or she is confronted with. This intent is externalized by motor actions when operating an interface. However, the presumed pre-existing intent will need to be be focused on the available interface, adhering to its modes of operation and formal qualities.

In a previous section, it was argued that key to a transparent interface is diminishing the distance between input and output of a device mapping. In an attempt to solve this distance, composer and researcher of computer music F. Richard Moore introduced the term 'control intimacy':

> Control intimacy determines the match between the variety of musically desirable sounds produced and psychophysiological capabilities of a practiced performer. It is based on the performer's subjective impression on the feedback control lag between the moment a sound is heard, a change is made by the performer, and the time when the effect of that control change is heard. (Moore, 1988, p.21)

Other than in current HCI trends, Moore stresses on the consistency of a feedback loop, stating that an interface needs to be capable of responding "in

consistent ways that are well matched to the psychophysiological capabilities of highly practiced performers" (Moore, 1988, p. 21), enabling an instrumentalist to learn how to perform musically through aural and tactical feedback. To establish a consistent feedback loop, it is crucial for a user that the outcome of his actions are conveyed in an (semantically) understandable manner. Ludwig Jäger proposes a model in which a communicative process, key to any artistic practice, can be in at least two states of aggregation (Jager, 2004). The state of the communicative process is either a state of non-disturbance or a state of interruption. According to Jäger, non-disturbance can be interpreted as a state of medial transparency, while interruption of the transparency can be used for the purpose of fixing the attention on sign sequences communicated. As such, the material presence of a medium comes to the fore. Jäger calls this communicative state a state of disturbance, marking those moments in which the medium itself becomes the object of communicative attention. Both transparency and disturbance are transgression states of visibility and are mutually exclusive, either making the medium or the mediatized perceivable.

I have argued in favor of the idea that artistic interfaces are different from those in HCI, even though they rely on similar design strategies. Both types use the affordances of the apparatus and the mediality of the medium to guide its user. However, on top of the intention of the user, an artistic interface needs to convey the intention of the artist. In this respect, one can say that HCI hopes to close the gap between intent and outcome of a user by focussing on a transparent interface, while artists on the other hand use the opaque qualities to introduce certain elements that are imperative to the meaning-creating process. An interface may well be transparent and boosting recognizable functional characteristics at the same time. Opacity is reached when there is disturbance, focussing a user on the specifics of a medium or interface. This state of disturbance is temporal and users learn and adapt to this new or altered functionality by experience. In the end, artistic and HCI interfaces are similar, aligning intent and outcome into a fluid communicative

process. The difference being that there is a dual intent in art that is not readily perceivable in HCI, combining an artist and a user. The artist, therefore, needs to ensure that this intent can be reconciled with that of his target audience.

Interactive art, in contrast to a HCI's aspired sense of control, is about encounter. Balancing the controllability of an interface with a rich interactive experience, improves a user's artistic experience while ensuring a user a sense of identification. This asks for an interaction design where interaction evolves over time, challenging the audience to partake in the unfolding narrative, while retaining a sense of control. This makes the bond between art object, art participant and artists as intimate as possible. Fundamentally, it boils down to an artist's responsibility to foresee and guide the possible actions of his audience. These actions are embedded in the embodied character of interactive art.

In the chapter on the practical part of this research, I shall exemplify how I have applied affordances, transparency and opacity to my own work. Often I did this to guide the audience towards certain aspects of the work. As I already pointed out, artists express themselves through the opacity and idiosyncrasy of the media we use and create. I use affordances essentially to guide an audience and hint at prescribed actions needed to experience interactive art. In order to guide the audience from one transitional state to the next, I play with the opacity and transparency of the interface. Entering a state of disturbance will often require an audience member to reflect on what is happening. This sudden visibility of a medium points out the formal characteristics of a mediator to the audience. By gradually introducing new elements an artist can introduce the users to a guided learning trajectory, which will eventually enhance their experience of the work. Instead of having all features of the work present during a first explorative phase, an artist can choose to introduce elements to support the narrative over time, while making sure the audience does not loose its sense of control.

4.4. Embodied music cognition paradigm

Musical instruments are arguably one of the best examples of iterative interface design, since they are routed on a long historical tradition and are primarily user oriented. A discussion about the specifics of such a design will not only help provide a better understanding of how interface design could benefit from the concepts mentioned in previous sections, it will also introduce a new theoretical paradigm that can better our understanding of interactivity in general. Interactive art can build upon this long tradition of specialized interface design in music. Particularly interesting, is the insight provided by the embodied music cognition paradigm.

4.4.1. Action-reaction cycle

A cornerstone of the embodied music cognition paradigm lies in the action-reaction cycle (Figure 5) introduced by Leman (2008). This model is used to clarify the subject/environment interactions. It specifically caters for musical expression but, as will be argued further on, may also be applied to multi-media environments.

Leman exemplifies this dynamic model by means of a case study of designing a musical instrument, which entails "action and perception in relation to the natural and cultural environments" and a sensibility to "the action-relevant value of sounds in view of musical ideals, and shaping the physical environment that produces sound" (Leman, 2007, p. 53). During the first stage (Play) physical vibrations are generated in an object, causing energy. This energy is processed by the auditory system in the next stage (Listen). A perception is built in the mind and a judgement is made about the quality of the perceived energy in the next stage (Judge). During a fourth phase (Change),
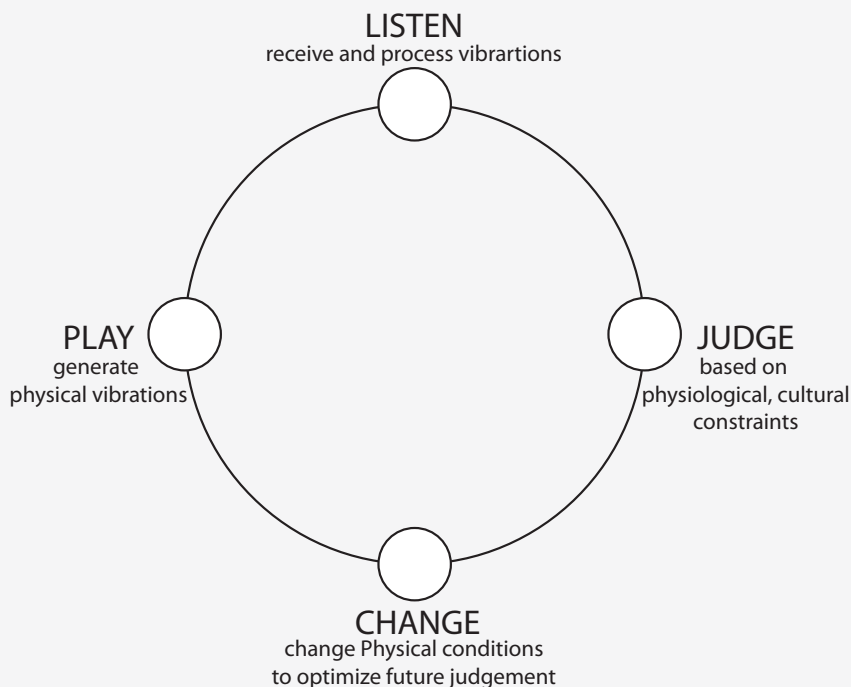
Figure 5: action-reaction cycle

the subject can make changes to optimize the judgement in terms of his/her needs. This repeated cyclic process not only results in the actual process of instrument-making (ontogenesis) but also inspires the evolution of musical instruments (phylogenesis). As such, it becomes an invaluable source for an iterative interface design process, which I will expand on later in this section. Leman argues that "[w]hile a musical instrument is built, a set of action-reaction cycles [...] transforms matter and energy into a cultural artifact for making music" (Leman, 2007, p. 54). This process is often goal directed. In the case of music the goal may be closely related to the improvement/alteration of an existing instrument, determined by a set of cultural needs or constraints, transforming the physical instrument into a reminder of the values and characteristics of the culture it was made in. The constraints determining the development of an instrument can be characterized as either being related to culture or to nature. Natural constraints involve the laws of physics and biology, while cultural constraints involve appreciation, acceptance and

cultural validity, both constrains will ultimately impose some limitations on what is possible or feasible. Within the action-reaction cycle, there is a constant cross-pollination between cultural and natural constraints, shaping the instrument-making over time. The study of such a cultural artifact and the understanding of its evolution can aid contemporary interface designs considerably.

4.4.2. Model for musical communication

Building an instrument also depends on natural constraints that, in case they are related to biological factors, often are more influential than the cultural constraints. Apart from the obvious constraints arising from the limitation of the human body, natural constraints relate to the material characteristics of the instrument. I will focus on the role of the human body, since the constraints related to physics are less important in this case.

Since instruments need to be played, the development of a novel musical instrument should focus primarily on an insightful design strategy regarding its playability. The focus on playability instead of the quality of the sound is a recent evolution and can be related to the exponential improvements of technology making formal demands for instruments more lenient.

In the paradigm of embodied cognition, musical instruments may be perceived as a natural extension of the human body (Leman, 2008, p.75), since the performer becomes one with his instrument while playing. Instruments facilitate the mediation of musical intentionality from performer to audience. This musical intentionality is not so much embedded within the artifact itself, but greatly benefits from the activity of playing. There is a total embodied involvement when playing a musical instrument, often surpassing the mere functionality of playing an instrument. This musical intentionality

is conveyed on several levels, including the visual, aural and haptic. How musical intentionality is conveyed is illustrated by the model of musical communication developed by Leman, depicted in Figure 6.
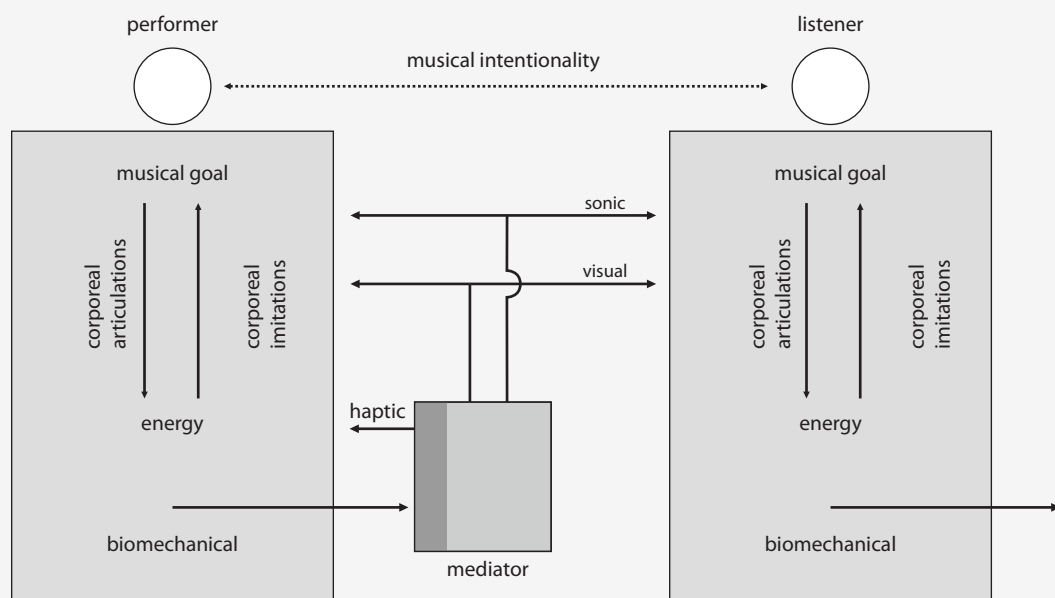
Figure 6: model of musical communication between performer and listener

The starting point is a performer who has a musical goal or idea in mind. This goal or idea is realized through sound energy, using the human body and an instrument or mediator. More precisely, the mediator requires certain prescribed actions or corporeal articulations from the performer and translates this into sound energy on the one hand and haptic energy on the other. The closed loop of haptic sonic and, perhaps, visual feedback facilitates the control over an instrument. A physical interaction with an instrument can be enhanced by corporeal imitation processes, giving meaning to the interaction. At the same time, the mediator transmits the sonic and visual energy to the listener, who, through mirror processes, can make sense of it.

Key to this model is (1) corporeal imitation, which is crucial for musical involvement, and will ultimately lead to understanding musical intentionality. Another important factor is that the development of instruments is, indeed, based upon (2) the idea of an instrument as a natural extension of the body. Additionally, the interaction between performer and instrument needs to be natural, giving him or her the illusion of (3) non-mediation. In sum, the relation between sound-generating gestures and the actual sonic energy, and its visual counterpart, needs to be easy to understand or intuitive. This intuitiveness must be perceivable for the listener too, since only then the corporeal imitation will be understood as musical intentionality.

A performer makes use of sound-facilitating gestures to communicate musical intentionality, in addition to sound-producing and accompanying communicative gestures (Jensenius et al., 2010). These sound-facilitating gestures, or ancillary movements (Cadoz et al., 2000), are used to help communicate expressive content and are clearly present in the techniques of highly skilled performers. The visual aspects of performance as expressed by the movements, gestures and other somatic information have been found to accurately convey the expressive intentions underlining the performance, sometimes more accurately than sound (Davidson, 1993). Sound-producing gestures are generally focussed on the interface, they are necessary for performing music. Ancillary movements, however, are not. Still they are an essential part of expressive playing and emphasize at a corporeal level intent, making communicative intentionality more dependent on corporeal articulations, rather than on sonic form.

Traditional musical instruments are highly specialized interfaces for musical expression, developed over many iterations that were both inspired by nurture and nature. A musical goal, often initiated by a composer, is conveyed by a specialist user, the performer, as musical intentions through the use of his instrument. The musical instrument serves as a mediator and facilitates this

musical communication by directing and focussing on aural, visual and haptic elements, making it understandable for both the performer and the listener. The performer receives haptic feedback from the interface that is attuned to his own corporeal articulations. He perceives this as natural when this is done through corporeal imitation. The quality of interplay between corporeal articulations and corporeal imitations determines the quality of the expressiveness of the instrument. Although a musical instrument will certainly define the repertoire of gestures used, the musical intentionality and communicative layer can not be linked to the musical instrument as an artifact. Instead, it is embedded in both sonic energy and corporeal articulation. Part of the sonic energy is instigated by how the instrument is played, which is in tune with the (formal) characteristics of the instrument. The relation a listener has to the performer, and hence the musical communication, is defined by the knowledge or understanding one has in order to make sense of the performer's corporeal articulations. The required knowledge and understanding is embedded in the cultural concepts of acceptance, appreciation and validity, and in nature when dealing with (an embodied) self-awareness. While playing an instrument, a high transparency level, a feeling of non-mediation, expressiveness and intuitiveness may be perceived. This is in fact the result of an equilibrium that has been tested and improved by many iterations in the instrument's design.

4.4.3. New interfaces for musical expression

Musical instruments fulfill a specific need for a composer or performer, which may be inspired by cultural demands or subjective artistic ideas. I believe that the reason why they function as such exceptional examples of iterative design is because the initial relationship between the composer, the artist, and the

performer, being a composers first public, is of a symbiotic nature[1]. Both the performer and the composer have an identical goal, namely communicating musical intentionality. Leman has argued that the action-reaction-cycle is used over many iterations to make an instrument. In this process, which can be spread over time and space, a myriad of people can be involved, suggesting and incorporating fine-grained improvements to the initial design. At present, the design of novel musical instruments and controllers is a bipolar domain. On one hand this design is routed in a historical tradition, as mentioned before, on the other hand it incorporates the full range of possibilities that came with the introduction of (personal) computers and the HCI research domain.

Even before the widespread availability of computers musicians and composers have redefined the traditional concept of of musical instruments, by applying any number of extended techniques to them, prepared piano being just one example. This evolution has brought forth several (new) artistic domains in music production in which instruments have been expanded with both mechanical and electronic elements to alter the sound or playing technique.

Since the introduction of personal computers, there has been an exponential increase in computer centered interfaces for musical expression, enhancing the already considerable tradition of hyper instrumentation. Most notably is the *Hyperinstruments project*, led by Tod Machover, at MIT. This project started in 1986, aspiring to provide virtuosic performers with extra power and finesse by designing expanded musical instruments. Since 1992, the focus of the hyperinstrument group has expanded in an attempt to build sophisticated interactive musical instruments for non-professional musicians, students, music lovers, and the general public.

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1   When distinguishing between a composer as the artist and a performer as the public I am well aware that this may be problematic. Since there is certainly a second stage in which the performer will play a composers music for an audience of non-specialists. Rather than a composer writing music for specialists, he wants to reach the same non-specialist audience.

Machover points out that "[c]urrent hyperinstrument research is attempting to push the envelope in both of these directions", creating on one hand "high-level professional systems" and, one the other hand, "building ever-more-powerful, interactive entertainment systems for the general public" (Machover, 2012). The main research lies in finding a balance between intuitive mapping strategies and relatable (gestural) interfaces.

Leman points at the problematic nature of novel musical interfaces when dealing with interactive music systems:

```
These [interactive music] systems are equipped
with sensors and sound synthesizers, and they
allow the transformation of all possible gestural
controls into sounds. Yet musicians often have the
feeling that a fine-grained control over the music
performance is missing, and that mediation technology
stands between what they want and what they get.
(Leman, 2008, p. 2)
```

In my opinion, it seems that the sense of control one has over a gestural interface is diminished by the lack of relatable (haptic) feedback and focus. The focus points to characteristics of a physical interface guiding the user embedded within its affordances. Additionally, the current trend in the creation of novel musical instruments, regards composer, performer and developer as the same person, which might also be one of the difficulties at hand. Musicians playing these novel instruments are confronted with a very steep learning-curve, in contrast to the developer who through many iterations has learned the process gradually. It stands to reason that if musicians, being expert users, can't exploit the full potential of the instrument, non-specialist users are left without any chance. If pushing the envelope in both direction means dumbing it down for the general public and including musicians earlier on in the design process to

insist on them adhering to the design strategy taken, the gap between the two worlds will never be closed.

4.4.4. Electronic musical environments

According to Leman (2008, p. 174) musical instruments' main purpose is transmitting performer's musical actions to a listener whereas a music environment aims at establishing an interaction between a technological and a human agent. The intentions of the performer are no longer mediated through technology, which forwards the performer's musical intentions, but the technology is used to generate actions on its own.

Leman continues stating the following:

```
[S]uch an agent [the musical environment] is typically
equipped with capabilities of synthesis and analysis,
conceived in terms of artificial composer/performer
modules and listening modules. These modules typically
simulate the behavior of a real human musician and a
real listener because this may allow interaction at
the level of intentions. (Leman, 2008, p. 174)
```

An electronic music environment thus should behave as an autonomous virtual social agent and an audience should be able to communicate via the exchange of physical energies.

In my opinion, when dealing with an interactive musical environment, it should interpret the actions of its audience and act according to its internal computational processes. Consequently, the audience may become the performer of the musical piece, when considering the musical environment as an instrument. The composer in such a situation is represented by the instrument's computational processes. A composer can allow for the musical environment to act 'on its own' to a certain degree by readjusting the role of interpreter of the environment. In order for a musical environment to become an autonomous virtual agent, a composer can include randomness and fuzzy logic to give it more 'personality'. To ensure controllability, as noted in section 4.3.3, the composer must ensure a relatability between the actions of the user and the feedback provided by the system, as argued in section 4.4.3. He can choose to incorporate imitation, as presented in section 4.4.2, and an environment's ability to adapt and to evolve will keep an audience engaged and curious to interact further, as pointed out in section 4.4.3.

4.4.5. Expanding the embodied music cognition paradigm to interactive art

From electronic music environments, it is a small step to sound art objects and sound installations. A successive inclusion of interactivity brings (sound) installations towards interactive installations, as defined previously.

The exchange between installation and audience should remain to be through physical energies which, as argued previously, can be largely understood as corporeal articulation and intentionality. By including different computational process and strategies, such as fuzzy logic, randomness, imitation, adaptation and evolution, an interactive artist aims at creating a compelling user experience. Often this will lead to installations showing emergent behavior that even surprises their creators. Krueger writes that "one of the strong

motivations guiding this work is the desire to compose works that surprise their creator" (Krueger, 1991, p.89). Instead of programing, artists try to produce a kind of patterned personality, where machines can surprise you as much as a person can. While an engineer might consider this as bad design, interactive artists share this common taste for surprise.

As has been pointed out repeatedly throughout this thesis, essential to interactive art in our opinion is the participation of the audience. A key characteristic of interactive art is that an audience's physical actions are crucial in the artistic process and will largely define the whole artistic work and the resulting user experience.

An integrated approach is needed, according to which the potential audience is incorporated early on in the development process to formulate design choices and strategies. The role of musicians can be, as we suggested in section 3.2, that of early contributors in the design process. They can provide an artist with valuable insights into the usability of his/her work, while having a non-specialized audience in mind.

An analogous idea should likewise serve multimedia installations, in which sound is not the predominant medium. For example a group of choreographers and dancers can, as a group of specialist users, provide cues on how movement can relate to form.

Leman suggests that in musical communication intentions are embedded within corporeal articulations and that these can be understood by a listener through, among other things, mirror processes.

I argue that all communication in interactive art may be understood in function of corporeal articulations, and that the novel approach to the narrative of interactive art is to be found in a profound understanding of these corporeal

articulations. In analogy with musical instruments that should ideally be conceived as natural extensions of the human body, interactive art works need to fulfill a role where the experience is conceived as natural, unobtrusive and intuitive. Consequently, an interactive artist needs to construct his work in such a manner that it leads, aids and contextualizes a user's actions. Making these actions prescribed through the timely introduction of well-thought-of elements into the embodied narrative.

This can be established through an iterative design process based on an action-reaction cycle that serves at creating a mediator or interface which is in line with both an artist's as an audience's intent. These mediators, interfaces and art objects should adopt the specific language of their medium and an artist's playful use of the transition from transparency to disturbance and visa versa in accordance with the embedded affordances of (everyday-) objects attributes to the overall corporeal experience of the user.

4.5.　　Conceptual model for interactive art installations

A first premise for a conceptual model for interactive art installations is that communication is central. Although this may seem self-evident, communication is of the utmost importance to the notion of interactive art, I would even claim that the quality of experience a user has is directly linked to the effectiveness of the communication.

In the light of the above discussion, I believe that Cornock's idea on the art system and Lopes' concept of changing display do not fully facilitate the inclusion of interactivity in art. I believe that Cameron's idea on narrative is interesting, provided that it can be merged with a more embodied view,

based on Leman's model for musical communication. In fact, I am inclined to expand Cornock's idea on art systems to include the artist, and use Cameron's focus on the narrative to further contextualize the experience. The inclusion of both makes up a model that is much more inline with Leman's model for musical communication, but is now applied to interactive art.

The model of musical communication can be modified to fascilitate new media environments, where musical intentionality is extended to different media. Central to this idea is that the communication remains primarily embedded in corporeal articulations of the performer, which can now also be understood as a software agent and corporeal imitation of the audience. The reverse is equally true, in the sense that the audience in interactive installations may act as performers, while the installation may imitate their corporeal articulations through its computational processes.

A following notion is that the whole art work exists to support and enhance the user experience. Consequently, meaning is created through audience participation and the audience's engagement becomes imperative on a practical (interface) and a mental (narrative) level. Therefore, the narrative needs to remains open and should only be understood as a contextualization of a participant's experience.

As a result, much of the audience's knowledge of the work will be the result of interacting with the art work, reflecting on its own actions rather than the characteristics of the art work, even though the characteristics of an art work play an imperative role in guiding the audience.

Consequently, an interactive artist's role is to shape this experience by meticulously steering the audience actions. By using affordances, the artist is able to ensure that the actions of the audience are understood as prescribed. This is essential for the artist, if this fails there is no way he can anticipate the

audience. Through the immediacy of the art object response on their actions, participants should feel in control, while the affordances of the art object can ensure that the actions of the audience can be predicable, or at least to some extent reduced to a smaller range.

In this way, I believe that the artists can use the transitional states of transparency and disturbance to enrich the experience over time. This can be linked to an art object's affordances, making different parts of the interface visible at different times.

Interactive art works require a praxis that is based on streamlining the user's experience. Traditional music instruments may indeed provide an incentive on how to further increase this experience. Traditional instruments can be seen as natural extensions of the body, hence as transparent mediators, providing a musician with a sense of non-mediation (Leman, 2008). Consequently, the communication through such mediators becomes more free and the instrument as artifact helps the audience to make sense of their experience. In contrast with traditional instruments, novel instruments are often perceived as opaque and the communicative intent is identified as disturbed. Consequently, it may be less clear to the audience when confronted with novel instruments what the communicative intent of the art work is.

In line with this idea I believe that interactive artists should aspire to make art works that function as natural as traditional music instruments. The user experience should be fluid and the mediation should not be perceived as something that hinders the experience. Like traditional instruments, their work, as artifact, should help structure meaning. The later implies non-mediation as well as interaction.

To conclude, it should be clear by now that interactive art can be myriads of things. Interactive art needs to cope with the imperative character of user participation, not only at a physical level but also at a psychological level. While there are many interpretations of interaction both in HCI and art, they all consider the user or participant invaluable. The mere fact that art often deals with participants rather than users marks a difference in the use of interactivity between both fields.

To summarize my point of view even more, I believe that the following components or viewpoints are essential to interactive arts:

- **Communication is key to interactive art**

- **The main components of an interactive art work are: artist, audience and art object**

- **Communication within interactive art works depends on embodiment, that is, on corporeal articulation of expression**

- **Interactive art objects support and enhance user experience and guide corporeal articulation**

- **Interactive art artists shape and steer experience**

- **Artists steer experience by using different levels of transparency and opacity**

- **Interactive art artists use affordance to make actions prescribed and an open narrative to contextualize the actions**

- **Interactive art artists timely evoke transitional states of disturbance and non-disturbance to challenge the experience**

- **Affordance, embodiment, and technology aim at facilitating the transformation of the communication at the physical level (based on audio, visual, haptic, movement information) into a intentional level which is all about meaning and experience**

5. Practical Development of Techniques for Interactive Art

In this chapter, I will address how, in the course of the last few years, my artistic practice has inspired the proposed model for interactive arts. This will be done by exemplifying how the different aspects introduced in the previous chapters have steered the sonic and visual identity of my work.

To contextualize this process, I want to acknowledge the fact that the artworks discussed in this chapter can often already be seen as iterations of earlier concepts. At times the works are variations aiming at similar experiences or came about through the conversations I had during art shows, lectures and exhibitions with the public describing their experience. Consequently, my artistic practice is not limited to that described in the following chapter. There were many other artistic activities I was engaged with that are not dealt with in this thesis.

Because of the more artistic emphasis, the next chapter will, on one hand, be written in a more prosaic manner than the previous chapters. On the other hand I will take the opportunity to clarify the choices I have made from a more pragmatic point of view, referencing the papers that were published during the course of my research and summarizing the more scientific foundations of my artistic process.

As a research member of the multidisciplinary Institute of Psychoacoustics and Electronic Music, I've been engaged in many projects other than my own. While these collaborative projects often are not primarily aimed at producing artworks, I believe they have contributed considerably to my artistic practice, making methods known and available to me that I would never have discovered on my own. I hope that the reverse holds also true and that my artistic view has led and inspired my fellow researchers to new insights in their research topics too.

The artworks, (art-) experiments and art systems described in this chapter are:

- **The Heart as an Ocean**

- **playing_robot**

- **Lament**

- **DIVA**

- **SoundField**
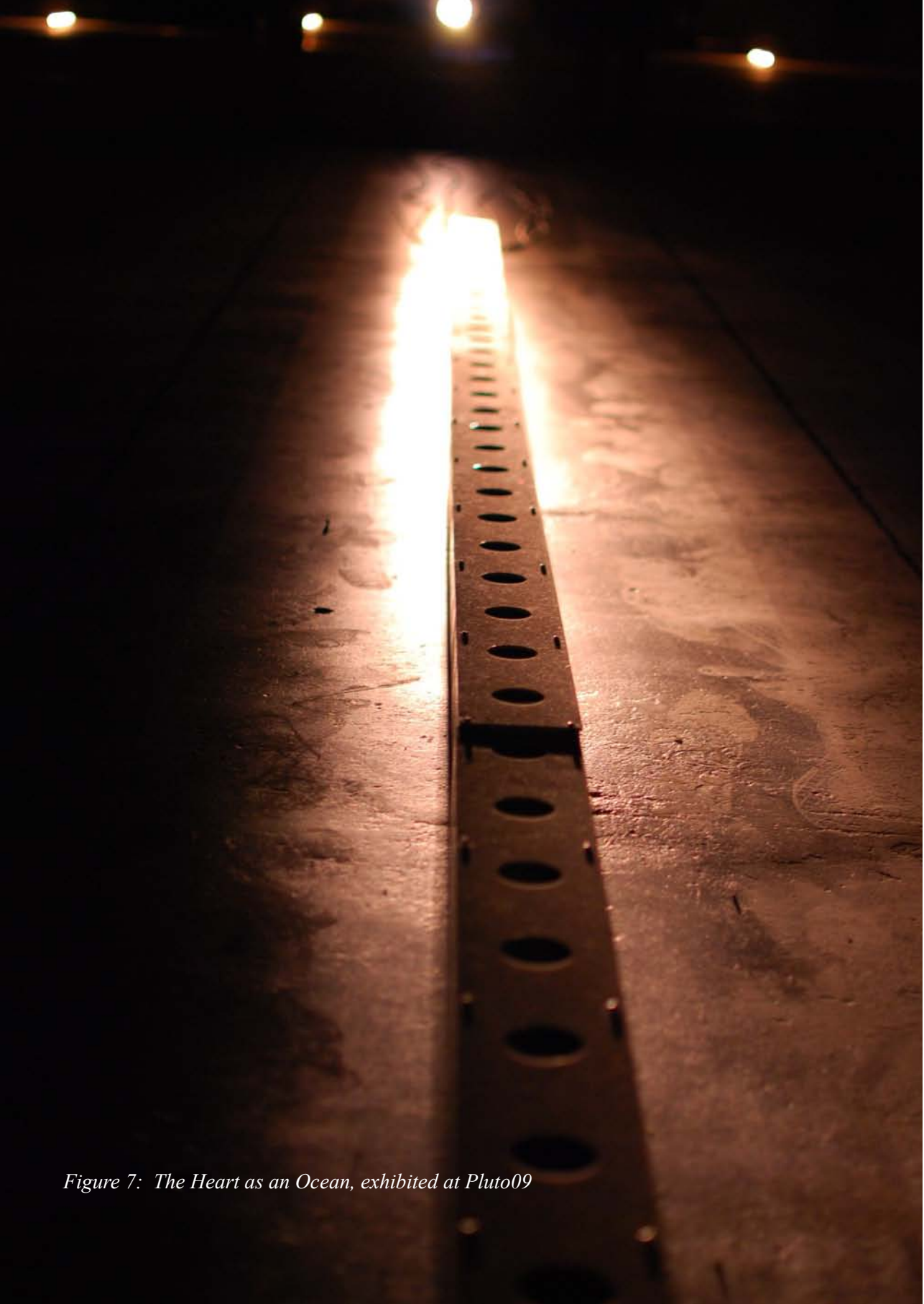
Figure 7: The Heart as an Ocean, exhibited at Pluto09

5.1.   The Heart as an Ocean

The Heart as an Ocean in its current form is the second iteration of the art work. It was first exhibited at Gallery Jan Colle in Ghent, Belgium in February 2007. Since then, it has been repeatedly shown at festivals and group exhibitions. A detailed list of exhibitions is given in section 9.1. It is described in the paper "The Heart as an Ocean: exploring meaningful interaction with biofeedback" (Coussement, 2008).

5.1.1.   Artistic background

There are two events in my personal life that instigated the creation of this work. The first occured during a quiet night at a Mediterranean beach while the calm waves of the sea gently reached the shore. I ended up sitting there far longer than I intended to, listening to the interplay of the waves. The second key moment occured at the Normandy coast almost a year later, where, in contrast to that time at the Mediterranean, the waves of the North sea violently crashed against the shore. At that time, I felt uneasy and upset but I found comfort in the roaring of the waves. It seemed to calm me down, overpowering the world behind me.

I found the contrast between the two events remarkable, both where very different in execution, the first one was gentle, the second one was harsh, but both seemed to have a similar calming effect on me. It was my intention while creating *The Heart as an Ocean,* to share this experience with others. In order to do so, I searched for a way to unify both situations in a single artwork that would present a dynamic situation for an audience to explore.

I started to question why both natural events had such a calming effect on me and wondered if this was due to my personal predisposition towards open waters, or if this experience could be shared by others.

The conceptual approach of *The Heart as an Ocean* started to take a more practical form after reading a quote from Michael Wenger, the Dean of Buddhist Studies at the San Francisco Zen Centre, on a website describing the therapeutic use of water (Shiff et al., 2001):

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Moving water is 'white noise', in which you can hear
many things. Each individual may hear a different
song in the water. Just listening to the sound--
not tying it to anything, just letting sound wash
over you--is a way of letting go of your ideas and
directly experiencing things as they are.
```

Indeed, white noise and waves crashing against a shore do sound very similar, since both sounds contain the full frequency spectrum. What makes a sea sound more enjoyable to listen to than white noise is the temporal and spatial spread of all those frequencies, making it more diverse than the constant equal flow of all frequencies characterizing white noise. Additionally, using a broad frequency spectrum makes it possible to mask other sounds, since two sounds of the same frequency can't be distinguished from one another. Because of this, the installation largely filters out all other surrounding sounds, resulting in a very personal auditory space where participants tend to lose themselves in the experience.

In creating this sound installation, my aim was to establish a natural flow of communication between the art object and the public, without the restrictions of having a too technical interface that could distract the intended interaction.

No sophisticated explanations should be necessary to interact, and user feedback should be based on a very strong homogeneity in 'experiencing'.

I designed the media piece in a way that the heart rate, symbolizing calmness or nervousness of any person who interacts with the installation, could be sensed. I hoped to influence that person's physiology, more precisely lower their heart rate, through sound in a way that the outcome would be similar for every participant. In other words, I wanted the public to reach a similar calm state, forcing their body to adjust to the lowered heart rate and attuning to this almost meditative experience.

To achieve this utopian goal, a synthesized ocean was created, imitating the breaking of a wave on an imaginary shore through a sonic representation. The intensity, level, duration and amplitude of a single wave are all derived from the heart rate of the person interacting with the installation.

An agitated participant, with a strong and fast heart rate, would generate strong loud and fast waves. This means that the speed with which the wave travels will be greater, moving the wave faster through the spatial placement in any of the twenty individual audio channels spread over the five meter long speaker array. Such a wave would build up more energy, sound louder and have a more high frequency content at the moment when the wave crashes against the shore.

In contrast, a calm person, with a slower heart rate, would generate slow and gentle waves. These waves would move spatially slow over the twenty audio channels. Since there is little build up of energy, they would hear a more gentle roll-off, with a more low passed white noise sound quality, at the moment when the waves reach the shore.

Since a new wave is generated at every third heartbeat, the auditory illusion of a sea breaking on a shore is created. I chose not to sonify every heartbeat, because it would easily oversaturate the whole soundscape. Additionally, this provided a mean value over three heartbeats, made the system less prone for error.

This experience is emphasized by the spatial movement of each wave in a setup with twenty speakers. Each wave starts its cycle randomly at one position and moves through the auditory space using the other speakers.

5.1.2.   Aspects of the conceptual model

The Heart as an Ocean is developed according to an iterative process over several exhibitions and inspired by the numerous conversations I had with the participants after the initial exhibition. Even now the installation's core functionality tends to differ with each exhibition. As such, it is a key example of the action-reaction cycle described in section 4.4.1. The development process of *The Heart as an Ocean* diverges from the action-reaction cycle only by the inclusion of the judgement of the public to guide the changes made.

The installation evolved from an eight speaker setup, described in section 8.1, to a setup with twenty speakers and four subwoofers. The speakers in the first iterations where hidden in the exhibition room while in the second iteration the speakers were incorporated in a single art object.

The increase of independent audio channels made it possible to improve the

spatially distribution of the sound, retaining a detailed sense of direction for each of the waves.

More importantly, making the speakers visible as a designated speaker array made interaction more centered around the art object. This compelled me to integrate LED lights, subtly reacting to the amplitude of each audio channel.

By integrating the LED lights, I wanted to maintain the fluidity of the sound, and break the rigidness of the art object. The art object itself is made out of opaque translucent perspex, the lights embedded light up the structure. When it is exhibited in a semi darkened room it dynamically alters the perceived form of the structure. The lights intent to help focus the public attention to the sound and enhance the experience by relating intensity of light to the intensity of the audio and hence the participant's heart rate.

Another key difference between the two main iterations of art work is the heart rate sensor used. The initial heart rate sensor was wired, forcing the participant to remain stationary. I provided a small white bench for them to sit on, which might already caused the participant's heart rate to slow down. In all other exhibitions the heart rate sensor was a wireless Suunto Comfort Belt connected to a Suunto PC pod[1] receiver, hidden in the middle of the speaker array. The initial choice was based on availability and cost effectivity, but greatly influenced or even disturbed the experience. It did have a considerable advantage compared to the wireless heart rate sensor, since it provided a full EKG signal, while the wireless sensor outputted a single BPM value. Since then I have been experimenting with an i-CubeX wi-microSystem and BioBeat sensor[2] to take advantage of the full EKG, but the usability of the Comfort Belt continues to outweigh the precision of a full EKG for exhibition purposes.

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1   produced by Suunto: http://www.suunto.com
2   produced by Infusionsystems: www .infusionsystems.com

5.1.3. Experience

After the first exhibition, the experiences the participants described were for the most part similar. The participants found the installation to have a meditative and soothing effect. They expressed they liked to listen to themselves, identifying with the sound as it attuned to their heartbeat. Some reported that they physically tried to feel their own heart beat, making the experience even more proprioceptive.

Some of them fantasized about what kind of beach they were on, by analyzing the sound and some even assured they could hear the distinct sound of either a rocky or a sandy beach. Most of them wanted to walk around in the exhibition space, instead of sitting down, what has led me to change the sensor into a wireless one for future exhibitions.

The ability to walk around has, on one hand, greatly improved the experience for those who interact with the installation. On the other hand it has also caused people to 'test' the installation. Since then I've seen people run around, jump up and down, and do flights of stairs as fast as they could.

While it may not be the experience I had in mind when creating the installation, it does have its own merits. For each participant challenging the installation, I had several participants who were willing to let the installation lead their experience and took considerable time exploring it. Many of them returned during the course of an exhibition, either alone or with friends, and reported to value the experience as meditative and soothing.

5.1.4. Technical description

5.1.4.1. Hardware

The Heart as an Ocean currently consists out of four modules measuring 10 x 10 x 125 cm. Each module has 10 small speakers fitted in pairs, providing 5 independent audio channels per module. The four modules, made out of opaque translucent perspex, are interconnected and are displayed as a 5 meter long speaker array with 20 individual audio channels. Each individual audio channel has an amplitude sensitive array of 20 ultra bright white LED lights attached.
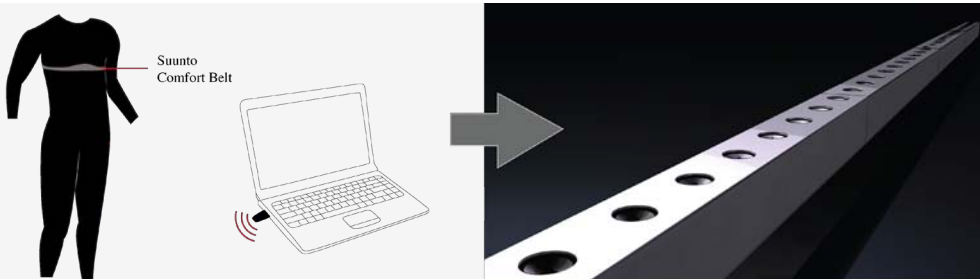
Figure 8:   Schematic overview of The Heart as an Ocean

The initial heart rate sensor used two measuring points on both wrists and a third reference measuring point on the leg. An op-amp circuit boosted the signal and an Arduino board was used to establish the serial communication with the computer. The wireless sensor consisted out of a Suunto Comfort Belt, widely used in sport monitoring, connected to a Suunto PC Pod which connects to the computer using USB. A schematic overview is depicted in Figure 8.

An M-Audio ProFire2626 external audio card and a connected ADAT interface is used to provide the audio outputs needed. The outputs connect to the amplifiers embedded in the Subwoofers of the Logitech X-540. In total four of these 5.1 multimedia sets are used, providing a total of 70W per set. All satellite speakers were disassembled and their enclosures were discarded. The drivers were rewired and glued directly on the perspex.

5.1.4.2.   Software

The heart rate is captured by the Suunto Comfort Belt and PC Pod. Using the provided Suunto Software Development Kit, my colleague Drs. Nuno Diniz created a data parser, formatting the heart rate to an Open Sound Control protocol. Since the SDK is Windows only, a network connection between a Virtual running Windows OS and the natively running Mac OSX was created, to make the data available in Max/MSP.

The audio software is developed using Cycling 74's Max/MSP and runs on Mac OSX. The software provides interconnected patches for input filtering, sound processing and spatialization.

The patcher in charge of monitoring the heart rate, filters out any unwanted signals. When the Comfort Belt doesn't register a heartbeat, the PC Pod sends out a zero value, these false readings are deleted from the input stream. When there are ten consecutive false readings, the software assumes there is no one wearing the heart rate sensor and no more waves will be generated. Small errors in the signal are leveled out by sending the last known value to the synthesis patch when there is a single false reading.
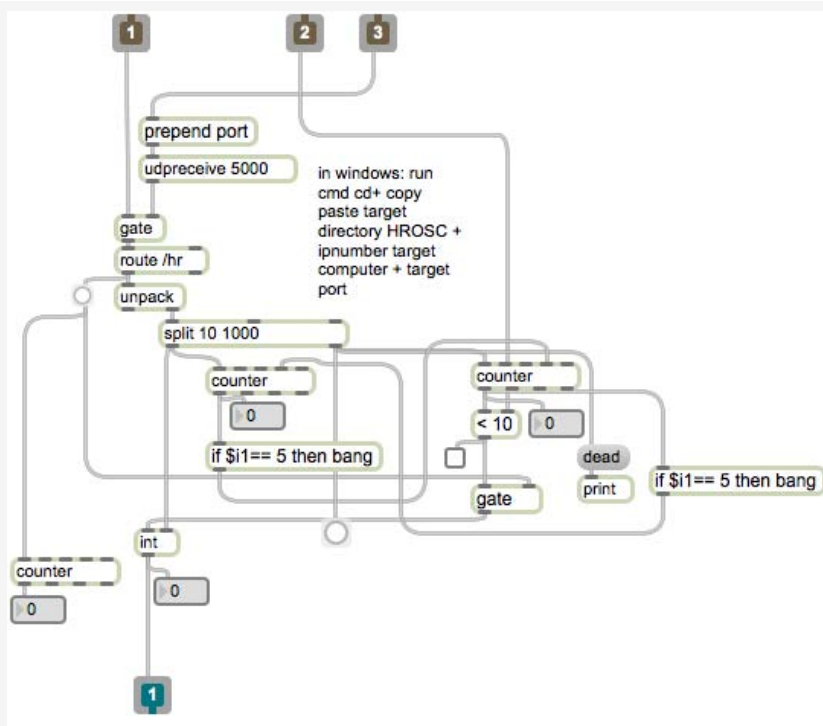
Figure 9: Patch receiving the Heart rate through OSC

Each third heartbeat, a wave is created. White noise is fed into two independent envelope driven filters in parallel. One of the filters is a resonant lowpass filter, while the other is a resonant bandpass filter. Each of the filters connects to an envelope driven amplitude amplifier. The two signals are mixed into one sound before output. The balance between the low frequency content and the band-passed signal is determined by the heart rate. The envelope time of both filters and amplitudes is dynamically changed according to the heart rate.

The spatialization of each wave is initialized at the time of the creation of the wave and travels through the speakers using a vector based amplitude panning algorithm, and a two dimensional placed array of virtual speakers.

Rethinking Interactive Arts - a viewpoint based on social embodiment
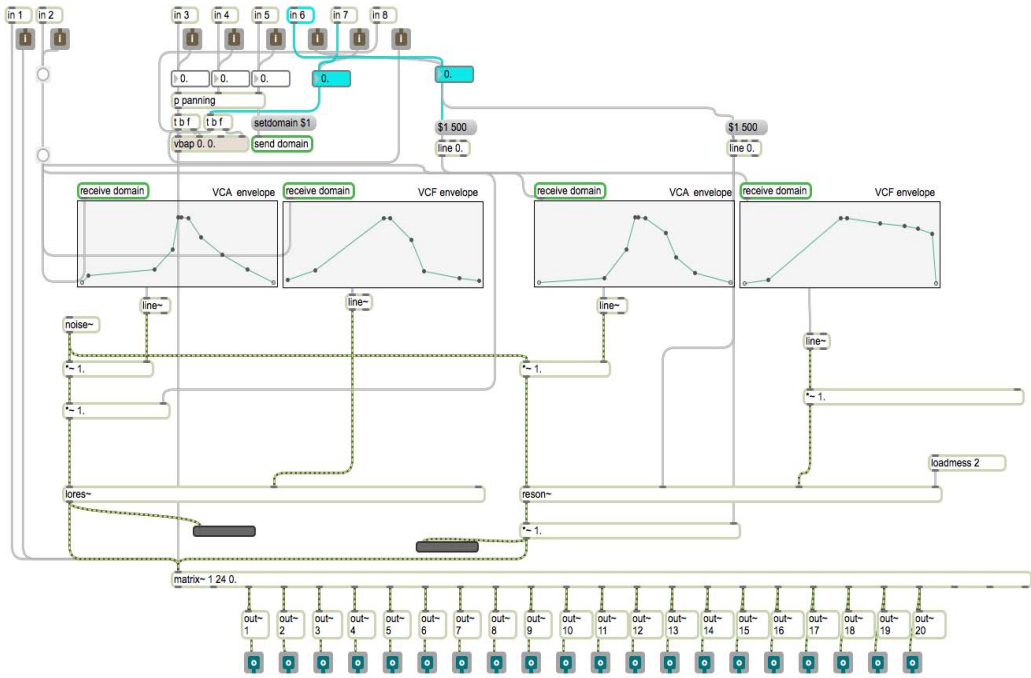
Figure 10: a single voice responsible for the creation of the wave

5.1.5. Future planning

David Rosenboom's *Biofeedback and the arts* (Rosenboom, 1976) serves as a key work in the integration of biofeedback in the arts. Biometric sensors have undergone a considerable evolution since 1976, making them much more affordable and available. Nowadays, they can be easily integrated in installations and an increase of installations using biofeedback can be seen. On the one hand, they are often used in a rather illustrative way, where there is little perceivable correlation between a subject's actions and the biofeedback. On the other hand, the captured biosignals are used in a mainly symbolic way, where the relation between the participant's physics and the installation's reaction is hard to read. While both implementation strategies may result in impressive and poetic art installations and performance applications, they do not follow the same discourse as presented in this thesis. I have tried in *The Heart as an Ocean* to make the effect the heart rate has on the sound synthesis

as clearly perceivable as possible, without making it a mere demonstration of it. While most participants share a common experience, there is little research that indicates that they fully grasped this connection.

Since then, I have been working on a variation of the art work in which the software would in time decrease the succession of waves, offering a slower rhythm and hopefully triggering a response in the participant. With this research, I hope to get a better grasp on the possibilities and limitation of this body and sound relationship, hoping to be able to provide an even more in depth coupling of sound and heart rate. Since then, I've come to the conclusion that a more in depth understanding of the biometric signals is key when using them as input for an interactive installation.

To facilitate this, the new version's software records every session for further off-line analysis, which may lead to a better understanding (and implementation) of proprioceptive stimuli when interacting.

The experimental setup determines a mean BPM value throughout the first five to ten minutes. The delta time between consecutive heart beats is compared (to detect if people where straining to affect the installation more by, for example, running), after which the software gently lowers the presented heartbeat and makes a prediction on when the following beat will occur. When the trend of the following heartbeats is as predicted this process is repeated, further lowering the tempo. If not the installation adapts to the participants heart rate again. The installation imposes a different rhythm upon the participant in an attempt to lower that participants heartbeat, relaxing him/her without causing any strain on the body. This is very much in a conceptual stage, only some preliminary tests are conducted on this. The conducted experiment is described in the paper 'Coming from the heart" in section 8.2.
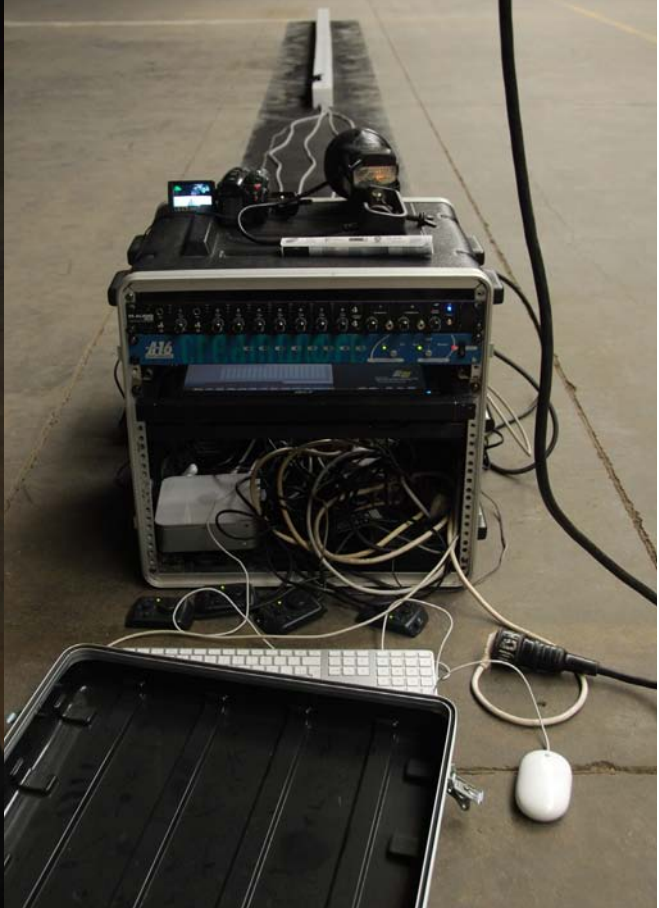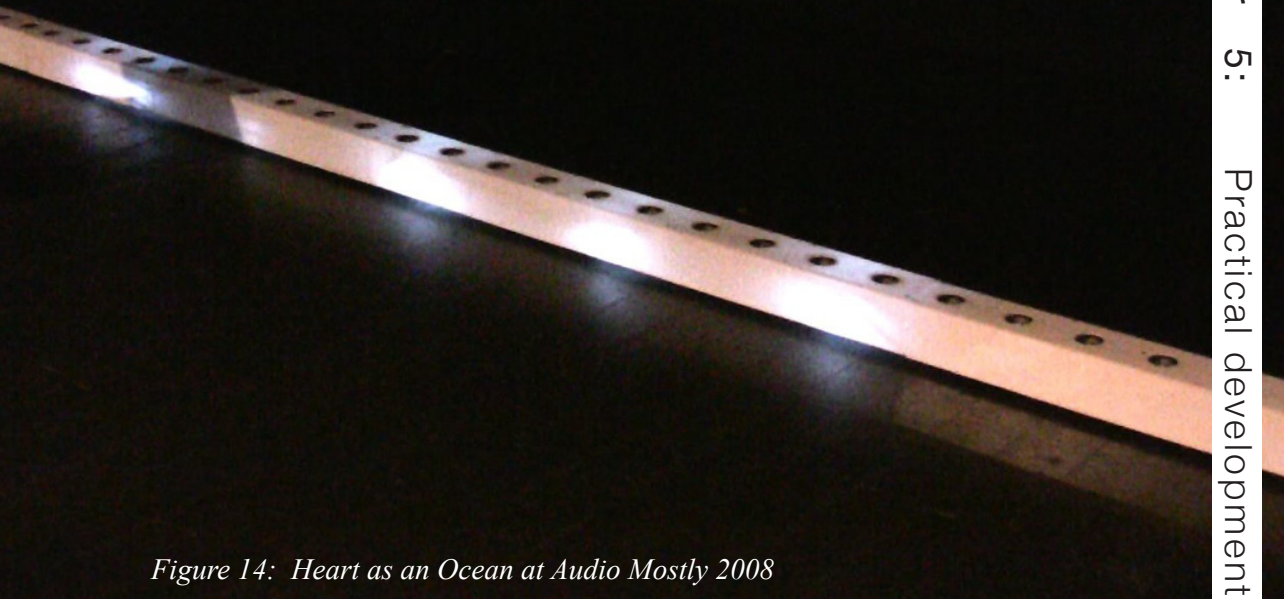
Figure 14: Heart as an Ocean at Audio Mostly 2008
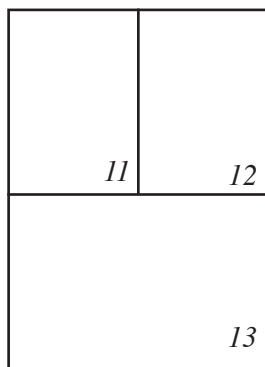
Figure 11: Heart as an Ocean at Pluto09

Figure 12: Heart as an Ocean control unit

Figure 13: Heart as an Ocean at Pluto09

Top view

45 mm
cut out

1250mm

12.5mm

10 mm

Side view

100 mm

End Plates

100 mm

100 mm

22 mm

28 mm

20 mm

33mm

d:12mm
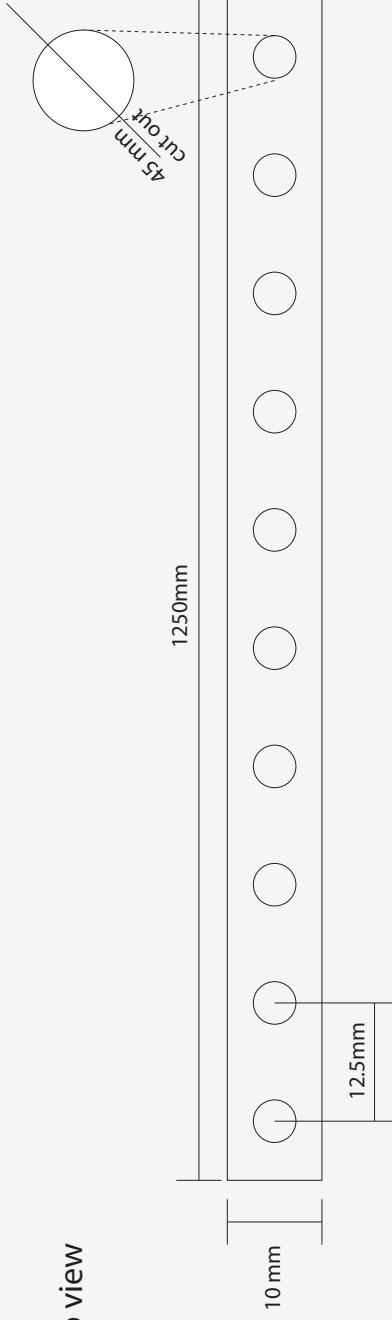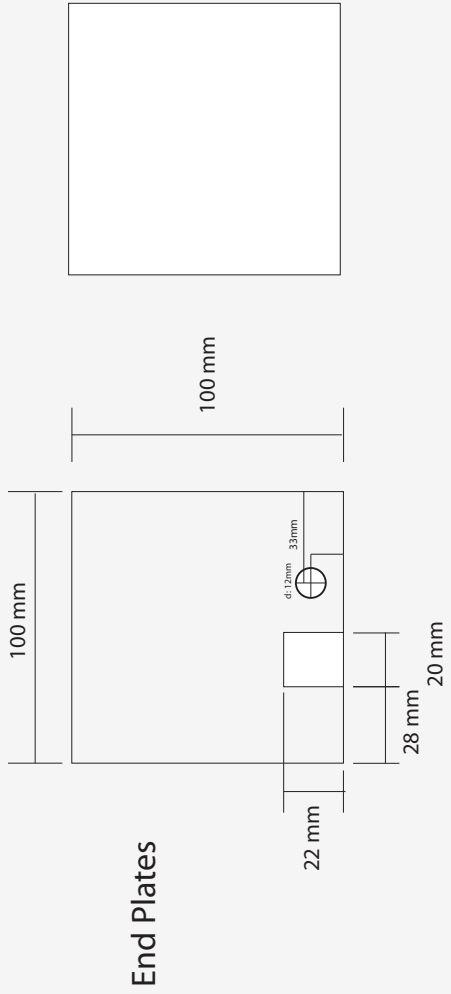
Figure 15: technical drawing of speaker module

5.2. playing_robot

playing_robot is an art experiment in artistic human-robot interaction design by Benjamin Buch and myself. It was developed during the International Summer School in Systematic, Comparative and Cognitive Musicology (ISSSCCM-09) which took place in Jyväskylä Finland in 2009, and it was first presented at ESCOM 2009.

The development was a joint effort between IPEM and the Musicology Department of the University of Cologne. Additional contributors to this work were Prof. Dr. Uwe Seifert, Son-Hwa Chang, Jochen Arne Otto and Jin Hyun Kim.

Special thanks go out to Erika Donald (McGill University, Montreal) and Jan Richter (Universität Hamburg) as co-workers and Mikko Leimu (University of Jyväskylä) for technical support.

A publication on playing_robot can be found in section 8.3 (Buch et al., 2010).

5.2.1. Artistic background

When developing *playing_robot* we envisioned an environment where people could musically interact with robotic creatures. Its main goal was to provide an insight into how people react to robots. Consequently, *playing_robot* served as an environment for an observational study in human-robot interaction, as a first step towards (artistic) human-robot interaction ((A)HRI). (A)HRI design is an integrated research methodology combining empirical-experimental research strategies with computational modeling. It additionally serves as an application of embodied cognitive science to human-computer

Figure 16: playing_robot presented at MeMCA in Cologne (opposite page)

and human-robot interaction in art and entertainment. Its goal is to establish a methodological foundation for the idea that New Media Art is a testbed for scientific research (Seifert, 2008, Seifert et.al, 2008).

The artistic purpose of the (A)HRI design is to explore the creation of interactive art and entertainment with robots as a completely new medium. *playing_robot* is the first experiment we set up to further exemplify these ideas.

The installation holds two small embodied agents (robots): one of them, Khepera III, is cheerfully playing, while the other, Turtle, is rather shy, sits still in a corner and watches the other play. A children's song is played as an artistically inspired choice to contextualize the robots' playful behavior. Approaching the robots affects the behavior of both; when disturbed, the playful Khepera III becomes scared and traces back on the same circular path it was on, the shy Turtle becomes scared too and starts to make erratic movements, producing mechanical sounds due to its motors. In addition, the children's song is altered in such a way that the resulting sound doesn't support the previous playful state anymore, startling the audience.

When the visitors insist on staying close, following Khepera III on its backwards trail, Khepera III changes behavior again, and starts to trust the visitor. Seeing Khepera III interact with the visitors, Turtle starts to move slowly towards them. When Turtle is approached, the playful Khepera III is no longer bothered by the audience, and keeps on playing. Turtle will move its head back and forth randomly to avert the visitors.

5.2.2. Aspects of the conceptual model

A first aspect of the conceptual model for interactive arts incorporated in *playing_robot* is the requirement of a methodology to interpret peoples interactions in a more quantitative fashion. While the previous work's evolution was mainly based on direct feedback from participants, we realized that this way of working was rather atypical, requiring the artist to be present at all times. The artist's presence may (unwillingly) interfere with the interaction. Often, participants asked me beforehand what the concept of the installation was, and while my answers to this were deliberately vague, the participant's uneducated exploration was already to some extend guided. Consequently, a framework for establishing an unhindered interaction is needed. Additionally this leads to a necessity for an off-line analysis of peoples interactions.

A traditional scientific approach to human-computer and human-robot interaction aims at the evaluation of systems by looking at whether clearly defined problems are solved and whether performance criteria such as accuracy of task completion and time required are met (Norman, 2008). In interactive arts, these performance criteria are hard to describe. Instead, reference is made to general notions of interaction and to the quality of observed / experienced interactions e.g. in terms of emotional affection or the time and intensity of involvement (cf. Rye et al., 2005).

These informal descriptions do not suffice for further scientific investigation of behavior in interactive artistic contexts. (A)HRI needs, like all interactive art, a methodology that does justice to the freedom of possible interactions, while at the same time providing a way to ensure rigorous analysis.

playing_robot was foremost an experimental setup examining what would be feasible to make such a methodology. When we presented *playing_robot* we considered the adoption of structured observation (Bakeman et al., 1997) as one possible approach. In order to initiate the development of a coding scheme that is appropriate for the observation of behavior in the context of New Media Art informal observations and video recordings were collected during the playing robot installation. These videos where later analyzed to provide us with a better understanding of the interaction modalities in (A)HRI.

A second aspect to *playing_robot* was to develop meaningful and diverse interactive behavior. In particular, one concern in the design of *playing_robot* was to avoid stereotypical system responses in favor of a dynamical mapping of visitors' behavior to robots' reactions and sound changes, which was based on the state of the system. The intention was to keep the visitors engaged with the interaction process. Therefore, the interaction modalities need to evolve over time, creating a better dynamic.

In *playing_robot,* we facilitated this using finite state machines, since they have been recognized as a powerful means to generate complex and interesting interactive behavior (Rye et al., 2005; Trogemann et al., 2005). Additionally, the idea of finite state machines is discussed in the context of modeling (human) behavior within cognitive science (Burks, 1973).

In order to obtain the artistic goal to structure and organize interactive behavior, finite automata appeared to be a good starting point. However, the FSM we used lacked the features of hierarchical structure and concurrency, which are deemed to be important to achieve interactive or reactive behavior in interactive art. Moreover, from the development of the installation *playing_robot* arose the necessity to clarify the interpretation of the concept "state" and its relation to the observable behavior of a system.

5.2.3.   Experience

While playing with the robots in the installation, part of the visitors apparently became involved beyond the point of merely understanding their (technical) functionality, exhibiting what may tentatively be called playful interaction. The structure of installation behavior appears to be reflected in visitors' behavioral patterns, although for a more rigorous comparison the tools still need to be adapted.

In developing a coding scheme for structured observation which may serve this purpose, conclusions may be drawn from the observation that some aspects of behavioral patterns implemented in the robots were also displayed by the visitors, such as backing away from each other and avoiding close contact or gently approaching one another.

In contrast to previous attempts at observational studies of human-robot interaction (e.g. Michalowski et al., 2007), it should be taken into account that visitors' behavior was not only directed at the robots, but also included co-visitors. Ultimately, an interpretation of these behavioral patterns in a broader ethological context appears desirable.

The human-robot interaction should be initiated by the robots or more generally by the designed system. In regards to this, two main observations can be made:

- the functional role of the robots' appearance

- the importance of sound for contextualizing the situation

The physical appearance in connection with meaningful movements, directs the visitors' attention to the robots. An appearance or behavior vestigially being animated, perceived as a natural movement, may serve to elicit empathy in humans.

This anthropomorphic structure of a robot in connection with some "provoking" (sound) activity directed towards the visitors of an installation seems useful to attract their attention, interest, and to stimulate interaction. Using a children's song helped identify Khepera III's behavior as being playful and the contrasting sound when she was interupted, contextualized her startled reaction.

In *playing_robot* the robots' identity and the context of the installation were adapted to the robots' physique and not optimal for human-robot interaction. The robots were to small, forcing the visitors to crouch. While, this may be intentionally done in some art installations, here it was a result of the unavailability of larger robots than Turtle and Khepera III in *playing_robot*.

5.2.4. Technical descriptions

A technical goal of the installation was to have the two robots communicate with each other. One notifies the other if it changed its behavior due to interaction; sensor data derived from human interaction with one robot should also be accessible to the other one.

Since the Lego Mindstorms NXT's communication is based on the Bluetooth protocol and Khepera III communicates via wireless LAN, a direct connection could not be established. Instead, both robots were remotely controlled by a set of computers. As such, each robot's 'brain' was virtualized, and the sensor data was processed here to produce the motor control commands of each robot. The processing of the motor control commands and the additional sound generation was done in Max/MSP. OSC was used as a general protocol for the communication among different applications running on the computers.

As OSC is not natively implemented in the Lego NXT software package, we relied on the Java-based LegOSC[3] for communicating with the Lego NXT. LegOSC works as an OSC gateway and allows any software implementing the OSC protocol to exchange data with the Lego NXT using the built-in bluetooth connectivity.

While the Khepera III is capable of wireless LAN communication, there exists no interface for the OSC protocol. A custom interface[4] was used which enables UDP-based access to the low-level read and write commands of the internal Khepera III control using a PureData patch.

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3   by J. Cardoso, http://diablu.jorgecardoso.eu/
4   written by T. Grewenig and R. Becker

Due to performance reasons, robot control and sound generation were distributed to three computers. The first one was running PureDate and communicated with the Khepera III. The second one was running Max/MSP, did the processing of the data and communicated with the Lego Mindstorms NXT via bluetooth. The third computer was running Max/MSP to process the sound.

5.2.5. Future planning

The development of *playing_robot* made clear that finite state machines offer a way of increasing the complexity of interaction, introducing different behaviors at different times. What is key in this programming paradigm is that the scenarios envisioned using FSM are state dependent and not time related. This assures that the interaction has no fixed start or ending point, as a time-dependent scenario would have. The use of FSM, therefore, serves as a conceptual starting point for an interactive narrative.

The way in which the visitors react to robots may be inspirational on a broader scope too. The experiment proved that the anthropomorphic appearance of a robot may be key in facilitating a close interactive connection between humans and robots. While both robots where in no way constructed to appear to be a person, they had sensors that resembled eyes. Future experiments in (A)HRI should focus on what the limits are of anthropomorphic appearance or on whether behavior a robot displays is still perceivable as natural.

A direct result of this experimentation can be found in *Lament*, discussed in the next section. *Lament* is an installation, which was partly developed in parallel with *playing_robot*, in which a simple FSM is implemented in five cohabiting entities. While they may have just a few states, the interaction with the installation is very intuitive. The FSM in *Lament* is mainly used to weigh the input data differently according to what state it is in.

Figure 17: Lament exhibited at De Bijloke during the Lamentatieweek 2009

5.3. Lament

Lament was commissioned by music centre 'De Bijloke' in Ghent to accompany the musical program around the Lamentation week in 2009, where it was first exhibited. The installation was set up near the entrance of the concert hall, which ensured plenty of passage near the installation.

Lament was visually and part conceptually inspired by a previous work of mine, *Ohm* that was exhibited first in 2007.

In its totality, the installation consists out of the five megaphones that are suspended from the ceiling in a circular way, as depicted in Figure 20. These five megaphone 'listen' to their surroundings and 'perform' a composition based on this input data.

5.3.1. Artistic background

In basic terms, Laments are songs, poems or musical pieces created as calls for help (to the Devine) in times of distress. As the name of the installation suggests, *Lament* is all about this expression of grief, regret and mourning through music.

The conceptual background of *Lament* may, at first sight, appear rather illustrative: Five megaphones, continuously outputting a subtle dynamic background sound, that react when someone talks into one of them. However, in contrast to the visitors expectations, assuming that his or her voice will be amplified by the megaphone, the megaphone starts to 'sing' when talked into.

The idea behind this altered expectation and the resulting interaction is that,

by using a very iconic object such as a megaphone, the visitor is encouraged to express his or her feelings. The megaphones altered functionality, however, doesn't allow this to happen and the visitor's thoughts are not heard. The visitor as such entrusts his or her ideas and feelings to the megaphone, while the megaphone expresses its own feeling in response, singing a lament.

The total of five different voices are represented by five laments, representing five different cultures. The laments chosen for *Lament* were provided to me by the organizers of the festival at De Bijloke.:

- the opening section (Alap) of an Indian lament in Dhrupad style performed by Rag Shri

- *Nunc Dimitis*, a contemporary lament composed by Sir John Taverner

- A Japanese lament accompanied by a Heike Biwa

- *Introitus: Requiem aeternam* from Johannes Ockegem's, mid-fifteenth century, Requiem

- A lament from the Solomon Islands

Each of these pieces of music sounds distinctively different. As such, each of the megaphones is easily identified. In *Lament,* I hoped to point out to the public the differences and similarities between these different cultures, when dealing with distress by means of a common art experience.

The set up of the installation, the fact that the five megaphones are suspended from the ceiling in a circular way, further emphasizes the interaction. Because the microphone of each megaphone points outwards, the public is immediatly

invited to interact with the megaphone when entering the space. The circular set-up also encapsulates visitors standing in the middle and listening to the atmospheric composition. Since the atmospheric layer is distributed over five megaphones, each 'performing' a part of the score according to their processing and listening algorithm, the resulting composition is also spatialized, giving a more dynamic listening experience. The spatialization of the sound, also encourages the visitors to move around in the installation in order to listen in a more detailed manner to any of the five 'performers'.

In *Lament,* the surrounding music program is very influential to the design of the installation and consequently the experience is in line with this too. The sound and laments used in this installation clearly help shaped and contextualized the experience.

While this dependency worked well at De Bijloke during the special program on Lamentation, it might be to influential or illustrative in future versions.

5.3.2. Aspects of the conceptual model

The sonic and visual components of the installation support each other to some extent. Clearly, a megaphone can be used to produce sound, making the relation between what you hear and what you see self-evident. At the same time, the visual and sonic aspects somewhat contradict one another, since megaphones are not commonly used in music, certainly not when this music is used to express sadness or mourning. Instead, megaphones are often linked to uproars and (violent) protests, where they are often used to express sloganesque ideas. As such, a megaphone becomes almost an artifact with a firm set of cultural implications linked to its use.

Therefore, a megaphone has very large affordance, since its function is immediately and clearly perceivable. Additionally, the visual identity of this installation emphasizes the megaphone's functionality and every visual element has a clear function.

By using clearly recognizable visual elements, I guide the visitors and their actions, giving clues to what actions are prescribed. All connotations related to megaphones favor interaction. Because of this, the public easily connects to the installation.

The sonic layer, however, has a somewhat different, more ambiguous nature. What is heard when entering the room is detached from the initial expectations one has when one sees the megaphones: no loud sounds or harsh slogans are heard. Instead, there is only a subtle singing sound present.

This atmospheric layer has a very distinct tone quality and sets the tone, giving a peaceful impression. The sound heard is a granular synthesis of Sardinian throat singers, resulting in a pseudo monotone sound bed that is rich in overtones. Although the sound has a very monotone feel to it, it is continuously changing, both in volume and in timbre, by interpreting the noises the public moving through the space makes. I will elaborate this in section 5.3.4.2.

This draws visitors closer to the installation and increases the interaction between the art work and the public. The sound is again used to guide the visitors by imposing the subtle changes and the low output volume. In addition, the contrast between the formal elements of a megaphone, often used to express protest, and the calm sound it produces, requires the visitors to adjust their expectations regarding the installation. The monotonous nature

of the sound helps to contextualize the public's experience further, hopefully stimulating them to listen more closely to the delicately evolving atmosphere.

All of these elements generate an atmosphere of tranquility, putting the visitors at ease and making them more inclined to react to the installation when talking in any of the megaphones.

I deliberately introduced some disturbances in the installation to emphasize the context of the narrative in the installation when activating the second state of the megaphone. This layer is activated when a visitor talks directly into the megaphone. Unlike in the overall atmospheric back drop where the influence the public has on the resulting composition is somewhat ambiguous, the interaction here is more clear. However, the physical immediacy of the action reaction cycle, initiated by someone talking into the megaphone, is contrasted by the mental distance between action and reaction. A person talking into a megaphone expects to hear his own amplified voice. In *Lament,* this is not the case, instead the participant listens to someone else's voice.

With regards to the conceptual model proposed in this thesis, the megaphone has, up to the point of the activation of the second sound layer, acted as a transparent interface where sound is mediated by the megaphone. As such, the interaction takes place in an undisturbed state. This state quickly alters into a state of disturbance, when the visitor hears the response of the megaphone when he or she directly speaks into the megaphone. By introducing a disturbing element in the interaction, the mediatized is made visible. This visibility instantly draws the attention of the visitor and initiates a mental process of association in which the participant is asked to interpret the response. In addition, this disturbance makes the participant self-aware of his or her activity, of what action is required to trigger a certain response. Through experimentation, the participant can now learn to exploit this newly discovered functionality and the state of disturbance transgresses back

into a state of transparency. Since every megaphone has a distinct 'voice', participants may be curious to try out the different megaphones, drawing even more attention to their participation in the artwork.

Finally, activating more than one of the voices at once requires multiple participants. This automatically leads to a social interaction between participants that is initiated by the installation.

A third aspect of the model is the way in which the interaction design was implemented using a FSM. As already previously explained, this opens up the possibility to introduce a scenario or narrative where progression is state dependent rather than time dependent. A more in depth explanation on how this has been done, can be found in section 5.3.4.2.

5.3.3. Experience

Even though the installation is able to distinguish between different amplitude levels, it does not necessarily mean the installation conforms with all aspects of interactivity in arts as proposed in the conceptual model.

The mapping of different sounds, and thus amplitude levels, to different layers of played back sound is very straightforward and gives the public very little room to alter the initial context of the installation.

However, like in *playing_robot* I hoped to get an insight on what people thought while confronted with the installation. This can provide some insight into what people regard as responsive or interactive. To do this, Drs.

Alexander Deweppe and I devised a survey to find out how people interpret the installation.

The first part of the survey focuses on the cultural profile of the visitor, while the second part is aimed at what attracted people to the installation and how they perceived the installation. For this survey, we chose a mostly binary approach: the visitor answers either yes or no the questions. Every time they agree with the statement presented, they are questioned on a more detailed aspect of what is interactivity and how to distinguish it from responsivity.

It appears that questioning the public by means of a survey is more complicated than anticipated. The concerts held during the Lamentation week at De Bijloke had over 4000 attendees, and more than half of the visitors passed by the installation. Yet, over the course of the week only 28 of them filled out the survey. Therefor we decided to prolong the exhibition and design a new strategy. In the two weekends that followed, people were explicitly invited to either fill out the survey or to answer the same questions in an oral interview.

This eventually resulted in a total of forty surveys being completed, which represents hardly a significant percentage of the 4000 plus visitors. People, of course, were essentially there to see a concert, and were not necessarily interested in the installation. Furthermore, the fact that traditionally (classical) concerts are not combined with an exhibition of installations at De Bijloke may also have led to the weak response from the public to complete the survey.

However, of the forty visitors that did fill out the survey, 31 did perceive the installation consciously, three saw the installation but payed no further attention to it and six did not notice the installation at all. Twenty of the thirty-one participants were immediately aware that the installation responded to their presence. Thirty-eight percent of the participants said that the changing sound was the most apparent sign to conclude the installation was responsive.

Almost 25% noticed the responsiveness through the visual elements, while the remaining respondents were drawn to it by others already engaged with the installation.

When noticing a response from the installation, 85% were inclined to influence the installation even more. More than half (52%) did this by singing, talking or blowing into the microphones, whereas a quarter opted for a more subtle approach and explored the sonic space by walking through the installation. When asked for the reasons why the installation made them eager to interact, 52% said they gave in to their curiosity, while almost a quarter felt that a megaphone is meant to talk into. Another 12% just thought it would be fun.

Three quarters of the participants noticed different levels of interactivity, though only one respondent actually stated the difference in reaction between surrounding sounds and direct interaction. Others largely agreed that there were different levels of intensity but did not connect them to the way in which they moved within the installation, and approached it from the mediator's point of view.

Finally, almost 80% described the installation as being interactive, making no distinction between interactivity and responsiveness. Most concluded this by the mere fact that the installation indeed reacted to their presence, only one person refered to a two way flow of interacting and says: "because, by interacting, we activate things that again call for us to act."

5.3.4. Technical descriptions

5.3.4.1. Hardware

The megaphone used in *Lament* is a PEREL SM25N with 25W power. The five Megaphones are modified to fit the installation, fitting new more sensitive electret microphones, the circuitry design for the microphones is done by Ivan Shepers. In addition, the controls on the megaphones for volume, siren etc. are disabled. Finally, I removed the amplifier part from each megaphone as well as the need for batteries. Consequently, the signal amplification needs to be done remotely. The newly fitted microphones required Phantom Power, which was provided by a remote M-Audio ProFire 2626 audio card. This enabled me to control the volume of both the input (microphones) and output (speakers) in custom software.

5.3.4.2. Software

Each of the five megaphones is an independent cluster of two Finite State Machines (FSM). One FSM, listening to inputs from the outside world, adjusts its state according to what they capture, while, at the same time, depending on the state of the acting FSM. The acting FSM, in its turn, processes the input of the sensing FSM, and adjusts its behavior accordingly. This enables a dynamic sensing of input depending on the state the FSM is in.

The states defined for the acting FSM are:

- murmuring

- shouting

On the sensing FSM the states are:

- listening closely

- listening afar

State changes occur in the sensing FSM because it distinguishes between two amplitude ranges. On the one hand, there are the subtle differences in surrounding sounds (listening afar). On the other hand, the second amplitude range is sensed when someone speaks directly into the megaphone, resulting in a state transition to 'listening closely'. On the side of the acting FSM, this leads to a murmuring state corresponding to the listening afar state, or the shouting state which is linked to the listening closely state.

Together, the five atmospheric layers, combining five simultaneous murmuring states, form a musical backdrop. In addition, a possible maximum of five voices, when all megaphones are in shouting state, combine to a room-filling, ever-changing sound installation.

Since each of the five megaphones is an individual entity, responding to their individual input, and taken into account that within each state the external input is continuously influencing the state behavior, the possible sonic variations are endless, leading to an emergent behavior of the installation.
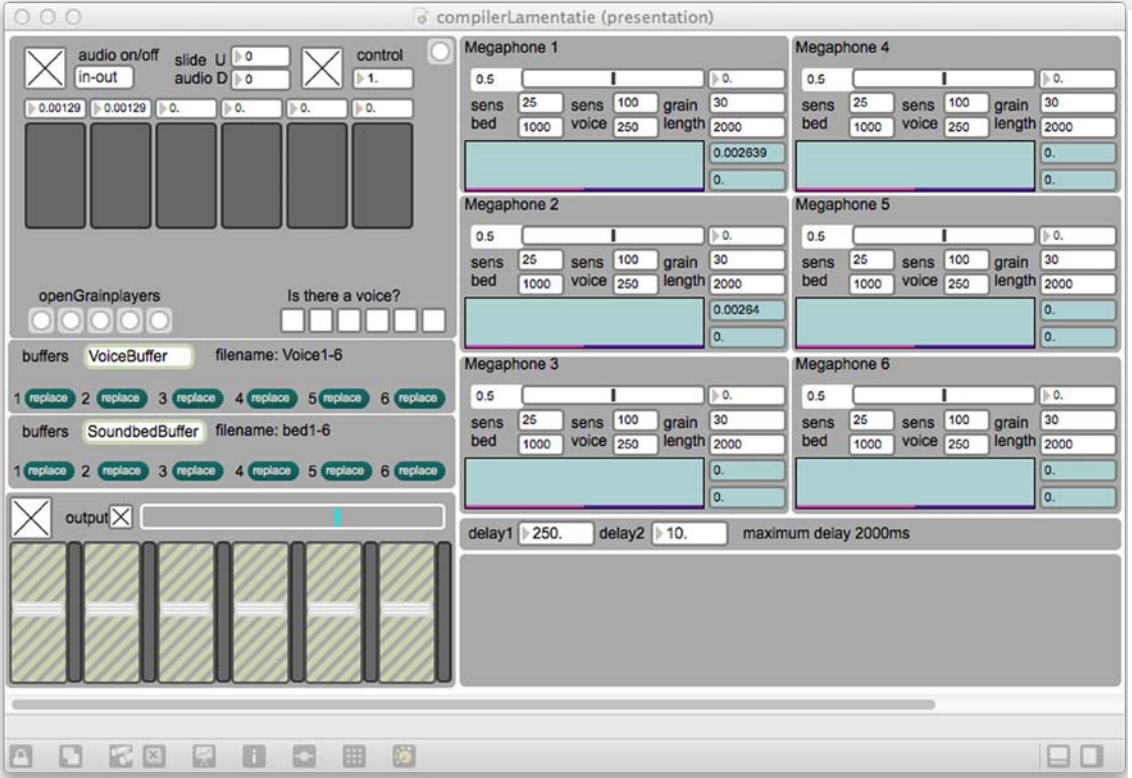
Figure 18: main GUI of Lament, enabling up to 6 voices
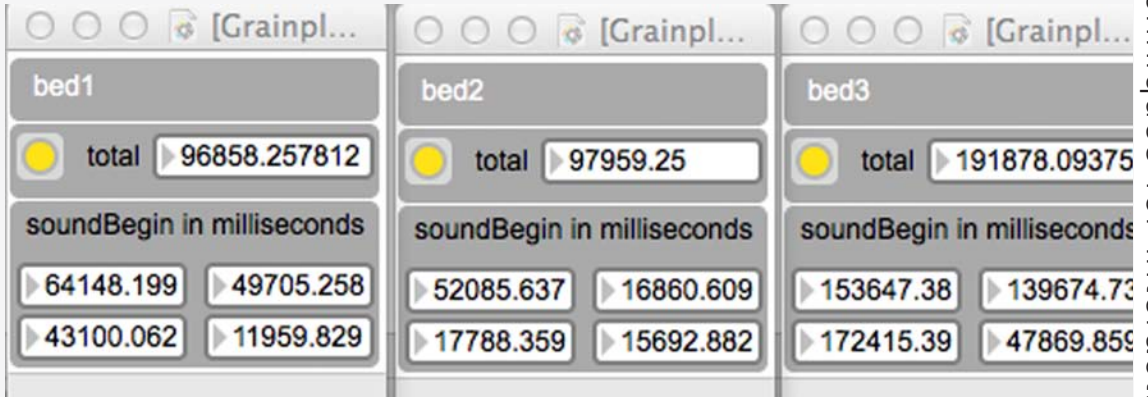
Figure 19: 3 Grain Players for Soundbed layer
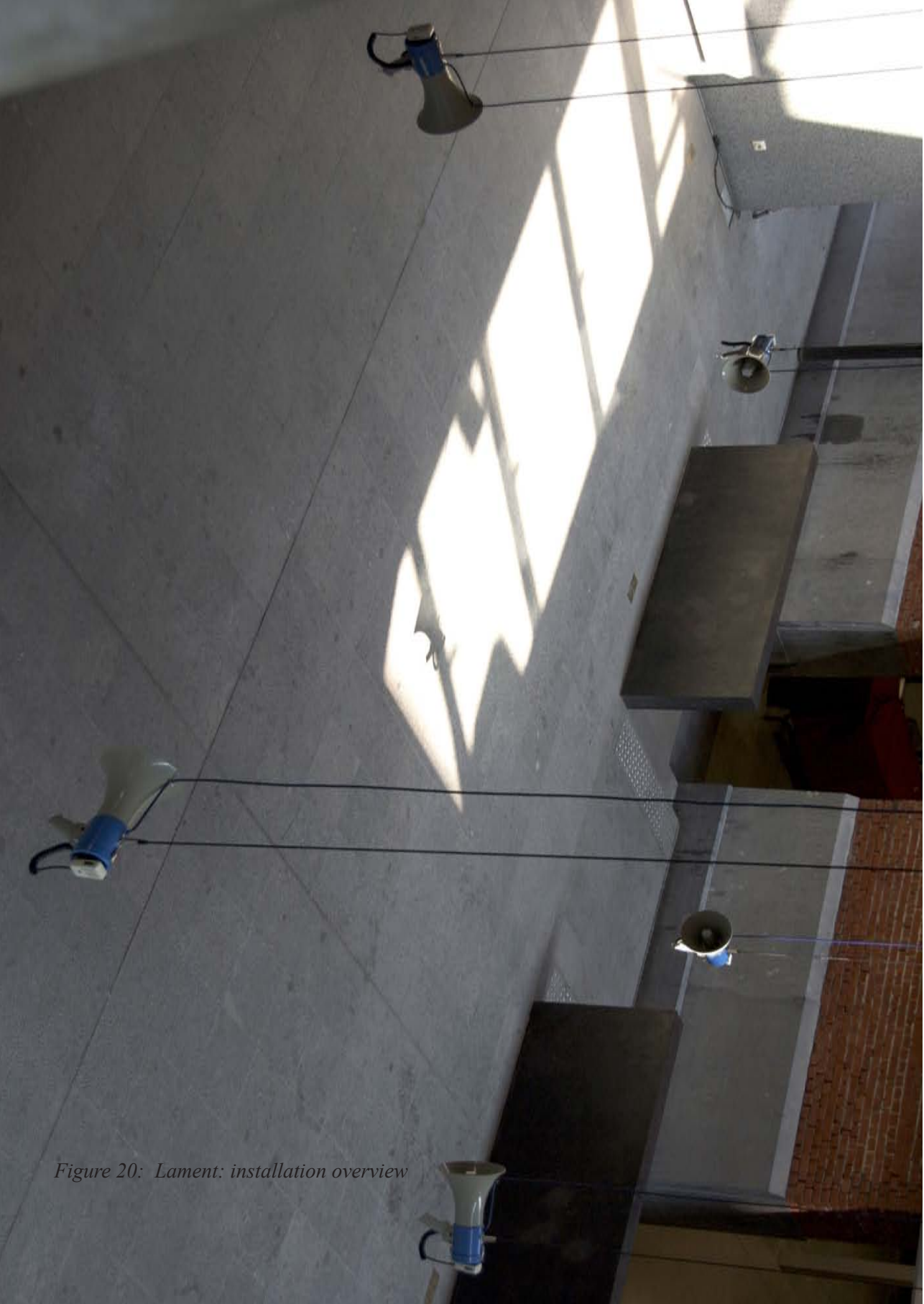
Figure 20: Lament: installation overview
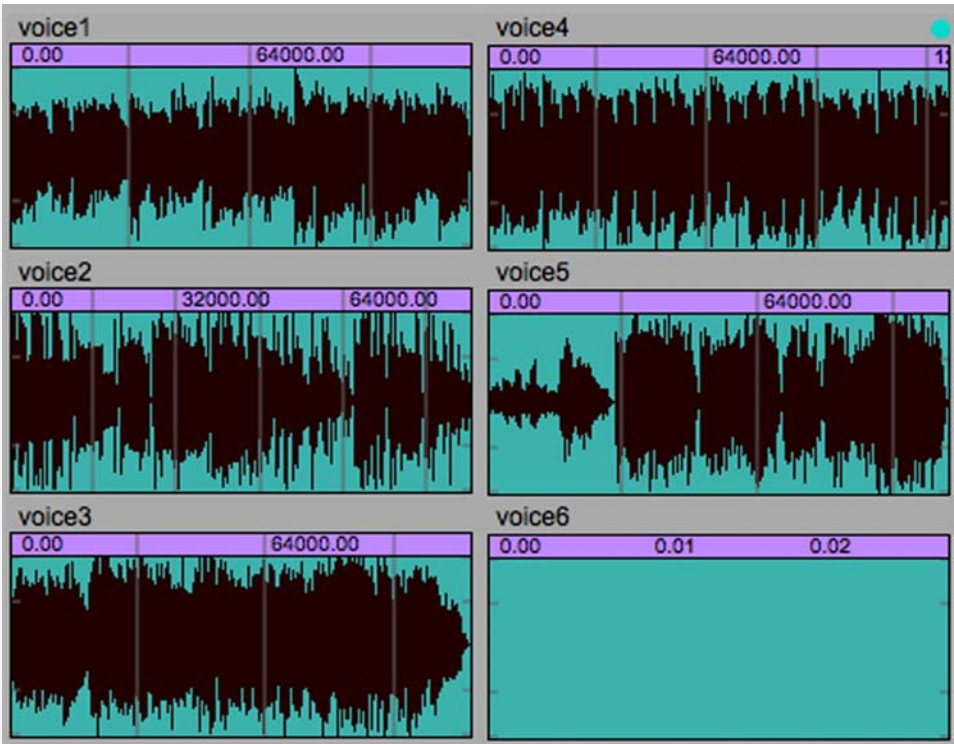
Figure 21: five different sound-samples providing a unique voice for each megaphone
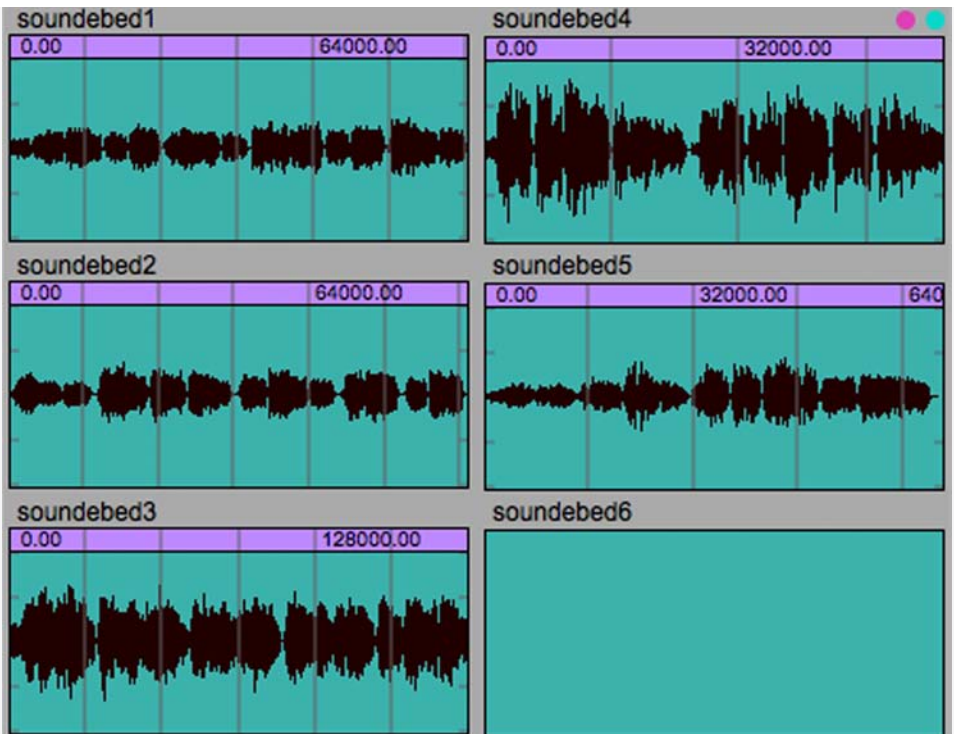
Figure 22: five different sound-samples combine into a continuous dynamic soundbed

5.4.   DIVA

The DIVA project has been developed in collaboration with Dra. Katty Kochman.

DIVA is an acronym for Dynamically Integrated Vocal Augmentation. Our aim was to develop a combined hardware and software platform to use with (operatic) signing. The system targeted an integration of technological enhancements to the expressive character of a singing performance, without it being obtrusive for the performer. Additionally, the system needed to be easily set up and have an intuitive usability. To facilitate this, we based the development on a methodology integrating narrative analysis and iterative prototyping, founded on gestural and performance analysis. We hoped to open up new possibilities that could improve the efficiency and design of vocal augmentation in theatrical contexts; increasing generalizability, dramatic integration, and facilitating a more cohesive, contextualized performance.

The system was successfully used during a live performance at the Jazz and Sounds Festival in March 2010 at 'De Bijloke Concert Hall' and the Gent Conservatory on January 16th, 2011. The system's design proved to be robust on both occasions and the set up time was less than 30 minutes allowing us to conclude that it could be transferred easily to multiple performance environments.

5.4.1.   Artistic background

DIVA was specifically designed to investigate the role of technological mediators in shaping musical interactions. Since DIVA is meant to be used for singing performances, the dynamic mapping strategies employed are

Figure 23: Katty Kochman performing with DIVA (opposite page)

achieved based on gesture-audio interaction and the physical realization of the performer's musical goals.

The artistic question that initiated the DIVA project originated from a recurring problem I had when performing electronic music. As mentioned before, there is often little correlation perceived between a musician performing a novel electronic instrument and the sound that is mediated by this controller. This may disturb the musical communication between performer and audience, making the experience for both musician and audience troublesome and less satisfying.

As a performer, I am often constrained in performance by the known standard line-up of a musical genre, i.e. a (rock) band, even though the creation process has little relation with the more traditional approach of making music with a band. While this typical performance environment provides the audience with a better understanding of what is happening on the stage and easily enhances the expressive quality of the performance and the degree to which audiences may relate to a performance, it often feels strange to me to have this distinction between producing and performing music, often involving a whole different range of instruments.

To overcome this, I am continuously searching for ways to enhance the expressive quality and relevance of my performances by trying out novel technological means. This project was undertaken in collaboration with Dra. Kochman, whose current research project includes the investigation of ecologically valid methods for the technological enhancement of operatic singing through the paradigm of embodied music cognition. Within the context of this project, she assisted in the development of a methodological model that integrates embodied narrative and cyclical prototyping, as a strategy to access implicit embodied expertise of performers. The goal of this

methodology was to create a subject-oriented performance tool that could be fully integrated in a dramatized performance.

While there is plenty of research on extended techniques for traditional instruments and the associated development of new instruments, we found very few examples of enhanced singing. Most of the examples found, explicitly used computers or more traditional music controllers such as keyboards, fader-banks, grid-like interfaces and Akai MPC-style controllers to enhance the singing. While they are used in very expressive performances, to us, this approach felt contra-intuitive. Using these types of controllers may channel the attention away from the actual singing, putting the emphasize on the playability and expressiveness of the controller, not on the actual singing. This can make it difficult for both the public and the performer to communicate musical intentions.

Instead, we focussed on the development of an unobtrusive gestural controller that would use gesture sensing techniques to enhance singing. As such, it would be possible to integrate it seamlessly in the already existing tradition of operatic singing. In addition, we set ourselves the following requirements:

- DIVA should be easily integrable in existing operatic singing settings.

- The integration of DIVA in an existing setting should have no negative consequences for the staging and dramaturgy of the piece.

- DIVA needs to be robust and the technology should be easy to set up.

- Implementing DIVA should require little expertise and should be easily adaptable to a specific performance setting.

- DIVA should make the enhancements of the voice easily controllable, while at the same time allowing the users to change any parameter or effect needed.

Operatic singing is a fully embedded and contextualized art form of the Western classical music tradition, where singers and orchestra perform a dramatic work based on both a dramatic narrative and a musical composition. Operatic performance involves a complex environment that integrates multifaceted and multimodal variables determining its success. This success depends particularly on the ability of a singer to explicitly communicate the narrative of the opera to a listening audience. In general, operatic singing is affected by many diverse aspects of vocal production, such as differences in the anatomy and physiology of human vocal tract, varied vocal techniques of sound production and voice projection, and the artistic perceptions of vocal interpretation and dramatic expressivity.

Due to the complexity of this performance environment, careful consideration is required when designing an effective mapping strategy involving the interface design of technological mediators for operatic performance.

In this study, vocal augmentation is perceived as the integration of technology and effects for the purpose of enhancing performance. Additionally, the narrative was interpreted as a sequence of constituent parts that determined the multimodality of music perception and performance. These constituent sections were expressed through the embodied narrative of the performers.

The objective of the DIVA project is to explore a comprehensive mapping strategy for the integration of the significant components of the musical narrative, integrating gestures for dramatic expressivity in augmented vocal performance contexts. Key for this, is the notion that singers already use a gestural repertoire to expressively communicate musical intentions. A firm

understanding of this gestural repertoire will certainly inspire the development process.

In order to do this, an evaluation method was selected for the integration of performer/subject experience. This selection was inspired by previous works where user experience was questioned.

The development of DIVA is done in parallel with setting up an augmented performance of an existing operatic aria, that was using the DIVA system, but should also provide insights and incentives for the translation to other performance environments. The application was designed specifically for performers and composers to facilitate the integration of technology during a staged theatrical performance. As a result, the system integrated commercially available system components and dynamic and transferrable analysis methods. The system was also continuously evaluated for generalizability and robustness. DIVA, in its current state, is still a proof of concept. The development done focussed largely on the analysis, since it proves to be key to the further design strategy. Furthermore, we came to the conclusion that even though the possibilities of technological mediation are myriad, the simple integration we made in this proof-of-concept already provided the performer with a very playable, usable and expressive tool.

5.4.2. Aspects of the conceptual model

Technical mediation affects how the emergent and complex behavior of performers are integrated in the communicative and cognitive process of musical performance (Kim et al., 2007). Therefore, the technical choices of developers impact the focus of development and the final usability of the vocal enhancement. An effectively designed vocal enhancement system should facilitate the structural coupling of the agent with its environment,

as well as stimulate a better integration of the internal cognitive process and intentions of the performing agent (Kim et al., 2007). If effectively designed, technological mediators support the existing motor and sensory processes, allowing the action perception cycle and the inner and outer cognitive processes of the performer to integrate (Leman, 2008). Therefore, it is important for the development of a technical application, to define the specific gestural skill sets tied to an effective performance. These skill sets may then be related back to the physiological parameters. Performance analysis provides a constitutive base for deconstruction of intentions of a performance and should result in better engagement with performance (i.e. action perception coupling) when performing with the technological mediation.

With DIVA, we question to which extent the narrative can provide insight into the design of a gesture mapping that supports enhanced operatic singing. We aim at developing a methodology for the creation of a gesture mapping that guarantees an effective micro integration of gesture in relation to operatic singing.

In DIVA, mapping refers to the liaison strategies between the output of the technological mediator and the performer. A crucial element of micro integration involves the mapping of one medium to another medium, such as gestural expression to audio effects.

There is no separation between musician and an instrumental mediator, when considering the physical vocal instrument of the classical singer. As no clear delineation between roles exists, creating an effective connection between a technological mediator and the sound source is particularly challenging. However, in his study of parameter mapping in electronic instrument design, Hunt (Hunt et al., 2002) demonstrated that by altering the mapping layer in a digital musical instrument and by keeping the identical interface and

sound source, the essential quality of an instrument remained unchanged with regards to the control and expressive capabilities. Within this process, the focus is on specific aspects of the vocal instrument and vocal technique of a performer. Furthermore, Hunt emphasizes the importance of the intuitive interface in terms of parameter associations for the improvement of vocal performance and vocal expressiveness (Hunt, et al., 2003).

To facilitate a concise augmentation, Wanderley suggests explicitly delineating the separate mapping layers, rather than simply focusing on the intermediate parameters themselves.

```
In order to devise strategies concerning the design
of new Digital Musical Instruments (DMI) for gestural
control  of  sound  synthesis,  it  is  essential  to
analyze the characteristics of actions produced by
expert instrumentalists during performance ....  The
importance of the study of gestures in DMI design can
be justified by the need to better understand physical
actions and reactions that take place during expert
performance (Wanderley, 2004, p. 633)
```

These intermediate parameters are based on perceptual characteristics of performance and involve multiple layers of mapping to the same control variables to enhance the transparency for the performer. This approach should produce greater generalizability and flexibility of the technological mediator. The system design should involve multi-layered mapping with microlevels of narrative integrated within the interface. This interface can provide an adequate level of flexibility that may improve the coherence of controls over different media (i.e. visual and auditory). According to Hunt (2002),

multi-level mapping models simplify the design process in terms of synthesis method and prototyping processes.

An effective mapping strategy based on real-world parameters is key in integrating a mediator in a singing performance. The analysis of such parameters is necessary for delineating separate objectives, in order to extrapolate the functionality of the instrument tied to physical constraints and to more easily reproduce interaction characteristics of the communication between performer and audience.

New media interfaces rely on the conventions of other media and the relationship between the body of the user and the interface (Manovich, 2001). Manovich argues that interface design is important as its representation not only organizes data in particular ways, but privileges particular models of perception and interaction with the human subject. These methods are hierarchical and lend preference to specific types of interaction.

The introduction of new media creates a shift in the subjectivity and the method by which the user is embodied can alter the repertoire of techniques in terms of encoded meaning and meaning representation (Hansen, 2004). Particularly in the case of music performance and perception, it is important that information does not become abstracted, disembodied and decontextualized.

In sum, it is of utmost importance to evaluate the technologies used and the consequences their use have on the performance, since it may greatly influence the mediatized. Consequently, mapping strategies need to be developed that exploit this 'coloration' of the media when needed. Additionally, in vocal augmentation, it is key to start from the performer's perspective, the technological mediator should be adjusted to his/her needs, skill sets and possibilities. Furthermore, the communication of musical intentionality is dependent on the relatability of an audience to a performer. When singing

this is enhanced by a known gestural repertoire, consequently any system for vocal augmentation should start from this known repertoire. This assures a communicative embodied relatable context for performer and audience.

The development choices in DIVA where inspired by the narrative analysis of existing staged performances of the aria *Il dolce suono* from the opera *Lucia di Lammermoor* by Gaetano Donizetti (1835). The dataset for the analysis is based on video recordings of live performances of the aria Il dolce suono. This aria has been released in several prerecorded performances. We selected five recordings, namely by Natalie Dessay (Metropolitan Opera, New York, 2007) Edita Gruberova (Concertgebouw, Amsterdam, 2007), Mariella Devia (Teatro alla Scala, Milano, 1992), Beverly Sills (BBC Profile in Music, 1971) and June Anderson (Grand Théâtre de Genève, 1983). These excerpts were selected, as they are commercially available audiovisual recordings of internationally renowned performers.

Invariant properties of the coupling between gesture and singing were extracted through analysis of five performances of the aria. This way we could design a more efficient mapping, based on actual performance data, which should result in an increased validity of movement and gestural parameters.

In addition, an iterative prototyping process, depicted in figure 10, was used to facilitate the development of DIVA. This prototyping process was inspired by Leman's action-reaction cycle (Leman, 2008). The initial stage involved the narrative analysis of musical structure and related embodied gesture. These subjective experiences can then be translated to signal processing which should result in more efficient prototype development. This method is an ongoing cyclical process. In previous studies, mappings from gesture to sound have been conceived as functional elements within stage performance. While gesture is integrated, embodied intentions may be overlooked. However, these methods emphasize organization and structure, but fail to evaluate the

intents of traditional opera performances with regards to narrative issues. Therefore, a problem remains whether narrative elements can receive a more prominent place in the gesture/audio mappings, so that the dramatic impact and character development of staged performances will be enhanced vocally.
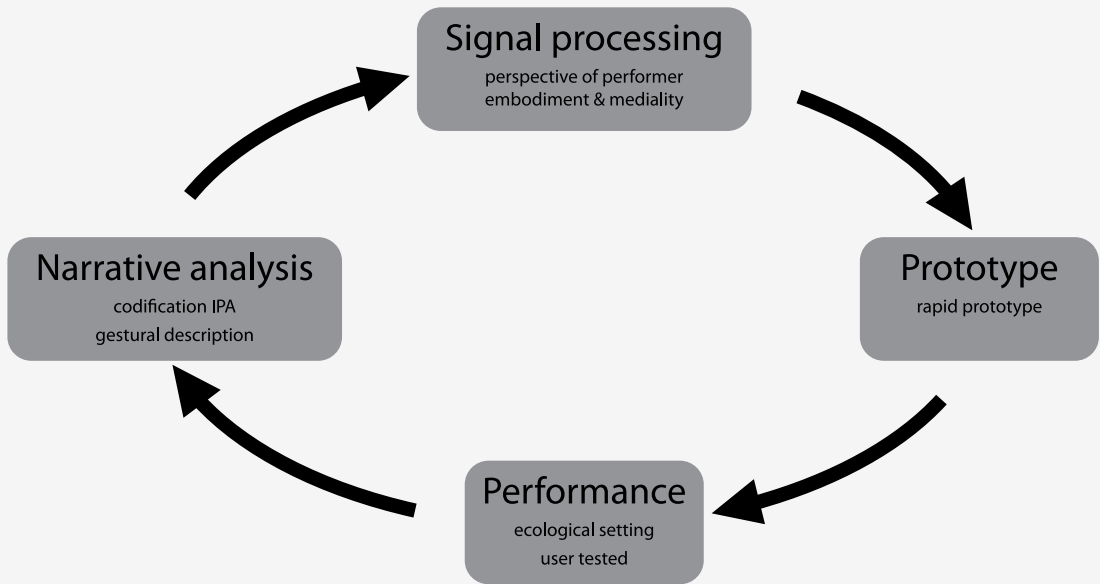
Figure 24:   Iterative prototyping process used in DIVA

To avoid the dramatic limitations imposed by nonintegrated systems of vocal augmentation, an advanced heuristic model was implemented including the design of novel control parameters that could be integrated into the existing performance and was presented in live vocal performance. One objective of the study was to improve the analysis of performing actions, which are then extended through technological mediation. To establish this, embodied intentions were directly related to the narrative of a piece.

To find the common ground in the performances, it was necessary to objectify the analysis process. We conducted the analysis by distinguishing between four primary components of the narrative, namely *staging*, *gesture*, *score* and *interpretation*. Initially, identifying the factors impacting the embodied intention of the performer is key.

The multimodal aspects of the performance environment may further influence meaning formation and mediator effectiveness. By means of an observational study, the components and directives are divided into four categories:

- *Staging features:* Include any significant transverse or cross of area on the stage to reflect where performer interaction was necessary either with the audience or other performers and level changes. Besides creating a more interesting and effective performance, these features provide information regarding range of movement and dramatic intention of the character(s).

- *Gesture features:* Are focused on gestures that express the dramatic intention or content. The gestural analysis focuses on hand and arm gestures. Facial expression, postural information, and weight changes and shifts are also coded.

- *Music (Score) features:* Are related to expressive markers on the score, as reflected by the performers. This information helped to provide the foundation for the types of effects that were later integrated into the system. Based on this information, the performance could be divided into three separate sections or themes. Each theme in the score is tied to the ideas of the three episodes. Each episode has a clear dramatic shift in score and libretto with an instrumental interlude separating these sections, which must be communicated through the embodied interaction of the performer.

- *Music (Interpretive) features:* Are helpful to code the individual interpretative differences between performers. This analysis included features such as; timbre changes, accents, changes of dynamic (alteration between louder and softer volumes), inclusion of stylistic features that are characteristic of the bel canto period in which this opera was written.

Each of these components is then thematically coded. The method chosen for this was based on the work of Davidson (2004) and her gestural categorization. This system has been successfully utilized to code classical singing performance and effectively compare singing performance.

The narrative analysis gave us a solid starting point for our development, with a clear common ground. For example, 94% of the high intensity gestures occurred in the third episode of the piece. In addition, the majority of interactive gestures (interacting physically with other performers) also occurred in this section, while the remaining interactive gesture occurred largely in the instrumental introduction of the aria. Due to the nature of the aria, many gestures expressed disassociation and separation from other performers and audience members. One could, therefore, conclude that the scaling of the effects should be adjusted to support these shifts in dramatic intentions. All performers showed signs of physical deterioration in the second episode. This observation provided important information regarding the range of action required for the system. In the majority of cases, there was a clear predominance for gestural communication using hands and arms, which was important for later system design in terms of sensor placement. In addition, we compared concert settings to fully staged performances of the aria. As could be expected, the range of action for concert versions was much smaller than in staged productions.

Performers of this piece showed a clear preference for specific gestural patterns. The majority of gestures could be classified as illustrative or display. In relation to the embodied narrative of the aria, as the intensity and frequency of gestures increases there is also a preference for illustrative gestures to communicate the narrative ideas to the audience. By not pre-defining specific gestures to control the system, we had greater artistic freedom. When integrated within the proposed cyclic process, this strategy facilitates an effective system design.

This first stage of the prototyping process assists in the pattern recognition in terms of important performance aspects. It provides a framework for identifying critical features and individual nuances of a performance. In addition, it provides information which could lead to great freedom of action and expression for the performer using the vocal augmentation system. In the initial stage of system review and appraisal, it is necessary to assure that constraints on the range of action were not caused by the system. Key gestures and interpretative features are maintained. Key dramatic shifts are identified. A methodology involving structural analysis also assists in avoiding both interpretive limitations and/or obscuring or altering musical intention. Examination of existing performances allowed for the demarcation of the system boundaries, constraints and affordances to be integrated in the system. Recognition of static and flexible elements helps identify and maintain a unique stylistic interpretation of a composition. The final mapping obtained is illustrated in Table 1:

part one	part two	part three
Hearing voices	Physical trembling	Halucination
Soft distant (reverberation) overtones (harmonizer) introduce the voice of her late husband, in harmony with the singer's voice.	A flanger and a tremelo are used to accentuate the tremors and the increase of brusque movement of the singer.	Extreme settings of a delay and inharmonic voicing, using the harmonizer, stage the singer's halucination.

Table 1: Structural analysis of musical excerpts, as linked to audio effects integration

To categorize the embodied meaning, we deconstructed the piece according to a multilayer structural coding. We made an annotation of the musical and audio features that could be tied to the intentions of the piece. These could include fermata (musical hold or pause), tempo and dynamic changes.

A second level included the annotation of those gestural features that allowed the performer to tangibly substantiate their internal representations of musical ideas. We conducted a comparative analysis between performers to come up with some general conclusions. The final level of performance analysis involved coding and interpretation. Based on previously annotated descriptors, it provided a summary of both the predominant gestural patterns, in terms of physiological strategies of performers and how these gestures are used in communication. An in-depth description of this can be found in (Kochman et al., 2012).

A final implication of the conceptual model for interactive arts is that DIVA provided an invaluable opportunity to work with an expert instrumentalist, Dra. Kochman, during the project's development. This made the consecutive iterations much more directed towards the expressive qualities of the system. The focus as such remained on the experience and performability of the system rather than on the functionality of such a mediator. In time, these insights should make it possible to broaden the scope of the DIVA system beyond operatic singing.

5.4.3.   Experience

The system allowed the singer to actively and dynamically integrate effects and multi-sensory information in the performances of the aria. Scaling facilitated the responsiveness of the system and the integration of interpretative nuance. Features, such as scaling, dynamic flexibility related to sensor placement and

a wide variety of available effects, also increase the sense of direct control over the augmented performance.

The singer could determine what types and level of subtlety to involve in system design. Direct input and cyclical reevaluation during the prototyping process reduced the limitations imposed by the system and allowed the performer to explore the communicative intentions of the piece in new ways.

The artistic approaches are extended as new performance capabilities are integrated and the musical and movement capabilities are increased. The performers gestures allow for control of the effects through dynamic mapping strategies.

Regarding the audience appreciation, we set up a small questionnaire to evaluate how effective we were in implementing the goals we set out in our application design. This questionnaire was presented to the 21 members of the audience after a performance at the Conservatory of Ghent.

Out of the audience members, 80% reported that effects were clearly perceivable. All others reported neutral, indicating some effects were more perceivable than others. 72% of audience members felt that the gestures of the singer while performing seemed natural and felt that the performance effectively communicated the narrative. 76% reported that the changes in narrative were clearly reflected. The majority also agreed that they supported the expressivity of the piece, even when they did not find effects "pleasant or enjoyable".

The results were somewhat skewed in terms of age, as the majority of audience participants were over 50. However, the younger audience members actually evaluated the performances more positively than the others, possibly because they are more familiar with music integrating effects.

5.4.4.   Technical descriptions

The DIVA prototype exists out of a hardware and a software component. The hardware used was intended to be easily expandable or altered according to the specific needs of the performance. In order to do so, we used a commercially available Analog to Digital Converter (ADC) combined with low-tech light sensors, which are not necessarily the most evident choice for gesture sensing. We did this on purpose to focus on the importance of a in-depth analysis of commonality in gestural repertoire rather than constructing an integrated hard- and software solution that would be already to specific and influential in a prototype situation. Consequently, the choice to use rather low level sensing forced us to come up with a better more substantial way to process our data.

5.4.4.1.   Hardware

The elementary electronic components were combined in an easy to use technological mediator that would fit all of the previously mentioned requirements. The prototype uses a deliberately simple design, only focusing on the movements of the performer's dominant hand.

The system was designed around a small array of three photocells, placed on a glove that was worn on the dominant hand. The sensors were positioned according to usability in the analyzed performances.

Photocells have the advantage that they are low-cost, readily obtainable sensors and can be utilized effectively in most theatrical contexts where lighting is commonly available. Furthermore, the theatrical lighting can be used as an external scale to change the range of the sensors, which can, in turn, also be combined with the performer's movements. This placement allows

gestural freedom and natural range of action based on performance parameters observed in the aria. Working with a system that is in its technological design very simple, made the importance of the underlying mapping problem more apparent, which allowed for more effective implementation. Additionally, there is no real difficulty when replacing, adding, interchanging or repositioning these sensors, since all are based on the principle of variable resistance.

gain

effects

Figure 25: Sensor Design Aspect and General Mapping. The placement of the sensors and mapping of parameters to the sensors according to an in-depth analysis.

The ADC we used in DIVA's prototype development was a Bluetooth Arduino board, allowing the wireless transmission of sensor data to the computers build-in bluetooth receiver. A disadvantage of using this rather bulky ADC is that although it is wireless, it is not wire-free. During the prototype development, it didn't pose a problem, since it was easy to conceal the ADC and the wires connected to the sensors by strapping it underneath the clothing of the performer. While this may be often the case, it is not unimaginable that this could prove to be problematic in other situations.

5.4.4.2. Software

There was no direct mapping between the sensors and a constricted gesture or movement set. Rather, the gestures that would normally occur in performance were analyzed, as described above, and the mapping for the photocells was constructed to effectively integrate into this gestural repertoire. The sensor output is easily scaled to allow for customization to the artistic work and performer, both through 'preset' settings, as well as through staging. The response time, robustness and predictability of the system remained consistent and reliable. As such, the feedback modalities possible are quite extensive, facilitating multi-modal presentation.

On the software side, we programmed specially tailored Max for Live modules, to be used as middleware between the wireless ADC and Ableton Live's own built in effects. However, DIVA is not necessarily specific to Ableton Live and the system presented could be adapted to other software programs depending on needs and competencies of the composer, performer and developer. We did want to make it easy to integrate the DIVA in existing Digital Audio Workstations (DAW). Since Ableton Live advertises itself as an ideal Live performance type DAW with the inclusion of Max for Live, facilitating the creation of speciality modules, we deemed it the best choice for our prototyping environment.

The middleware facilitated the access to the sensor data and made it possible to scale the ranges and sensibility dynamically. As such they could be used both as variable inputs or as buttons with a crude on/off functionality. In addition, the sensors could be weighed against each other, this way crude postures could be derived out from the combined sensor input. These gestures included open or closed hands and signaling whether the palm of the hand faced up or down. We considered these gestures or postures the most important, since

the majority (67%) of the gestures, related to expression of narrative, that were observed, were performed with the arms and hands. These were also the largest and most evident gestures, making them the most beneficial for our prototype.

The enhancement effects were determined according to the narrative sections:

- **Section I:** *score - Andante, bar 10, text-Il dolce suono, Effects- vocal harmonizer, and reverberation*

  In Section 1, the character enters in a state of confusion. She is clearly unaware of her surroundings or events that have recently transpired. Consequently, her separation from reality is expressed through a vocal harmonizer. The additional voices expressing that the character is detached from reality and essentially 'out of her mind'. Reverb further elucidates her separation from lucidity.

- **Section II:** *score- Allegro vivace, bar 41, text Un gelo mi serpeggia nel sen!, Effects- chorus, delay*

  In Section 2, the character begins to experience an intense physical reaction. She begins experiencing chills, trembling, and can no longer remain standing. She hallucinates her lover and calls to him to sit with her. The effects used in this section were chorus and delay emphasizing the shaky and scattered mental state of the character.

- **Section III:** *score-Larghetto, bar 85, text-Ohime! Sorge il tremendo fantasma, Effects- video projection mirroring performer, vocoder, reverb*

In Section 3, visually, a cloud was programmed, using Computer Vision and a camera filming the stage, serving as an ominous warning for future events. A vocoder, aptly named halluzione, was used to emphasize the supernatural quality of this section. This was a physical representation of the hallucinations of the character, as they become more intense and disturbing. As the distress of the character increases towards the end of the performance, the character hallucinates a phantom separating her and her lover. The phantom is visualized in the background, but mirrors the actions of the singer as a reflection of her mind; her guilt having committed murder and betraying her lover.

5.4.5. Future planning

The DIVA system was designed to address several key implementation issues for hyperinstruments, by focusing on the development of an augmented vocal performance. It is deliberately constructed with technology (hardware and software) that is readily available, easily implementable, and cost effective. The focus, therefore, was on making the most out of simple components and upholding a methodically phased development process.

To facilitate this, DIVA proposed an integrated development methodology for technologically mediated singing performances. It included a critical discussion of the issues affecting the usability and interaction with technology in contemporary vocal performance. Through thoughtful reassessment during progressive stages of the iterative process, we addressed this normative gap

based on the values and conclusions of the methodological model, concretely demonstrating the dynamic interaction between action and reflection.

With DIVA, we designed and implemented a system to provide concrete solutions to the developmental problems they wished to address. Each of the organized performances was situated in a specific context and background, leading to the necessity of the participants' and developers' reflections on consequential meanings inherent in the vocal performance.

The interplay between a technological development, from the field of HCI, and meaning creation, as part of performance art, proved to be central and was used as an intertwined design strategy for gaining access to experiential knowledge, knowledge construction, and sensory experience.

The use of technology inherently imposes certain constraints, which influences how individuals perform and interact with the technology and audiences. We based our choices on the embodied cognition paradigm, taking the human motor constraints as a key guideline in the development, while refining them through a detailed performance analysis.

Currently, we are working together with a composer and a singer to further the development of DIVA in 2012. By including the composer and an additional singer in the development process, we hope to gain new insights into the limitations and potential of our system and development process. This would, additionally, enable us to bring DIVA to the next level, with a more advanced integration in a performative context supporting a composition especially integrating vocal augmentation.
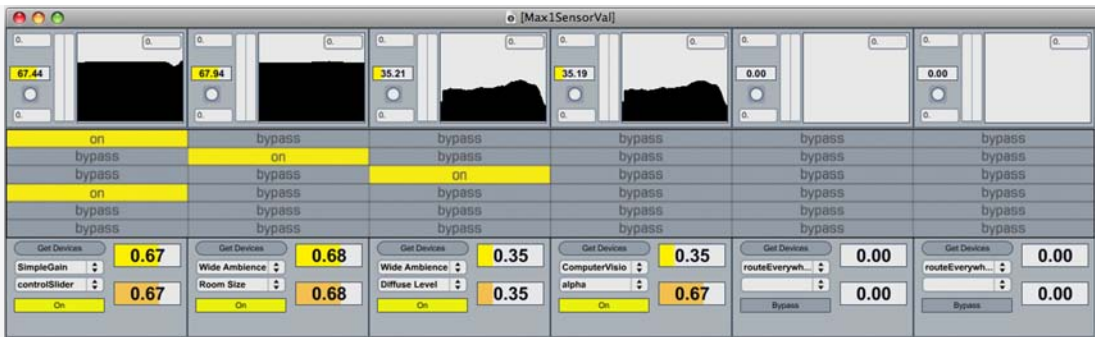
Figure 26:   Sensor Data Overview and Routing

Figure 27:   effects chain for Part 1: added reverb and added voices using a harmonizer, using build-in fx of Ableton Live

Figure 28:   effects chain for Part 2: added modulation using a flanger and tremelo, using build-in fx of Ableton Live

Figure 29:   effects chain for Part 3: extreme modulation using pitchshifter and delay, using build-in fx of Ableton Live
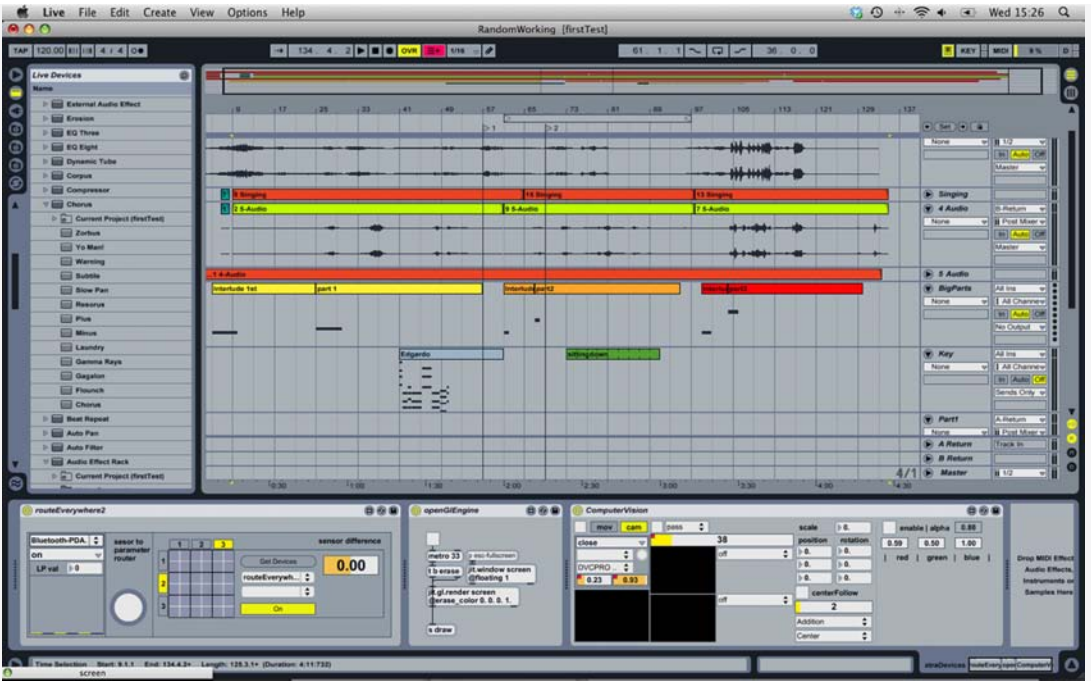
Figure 30:   Global overview of DIVA in Ableton Live.

Top: Backingtracks with Midi-cues to announce the three distinct parts Bottom Left: Sensor input module Bottom Middle and Right: Computer Vision patches and OpenGL enabling video analysis and output
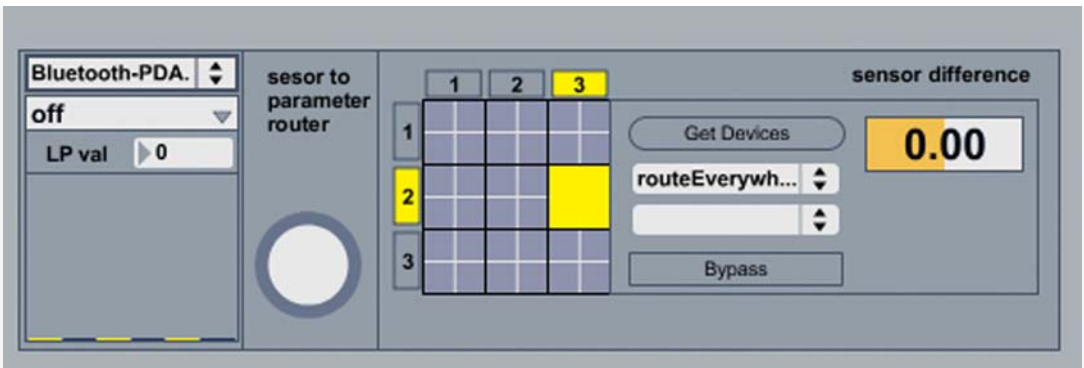
Figure 31:   detail of Sensor input module

Figure 32   SoundField exhibited at ArtBots 2010

5.5.   SoundField

SoundField is a project set up in collaboration with drs. Alexander Deweppe and drs. Nuno Diniz. Together, we aspired to create a test bed for different modes of interaction, usability (and interface) evaluation and use-case development. Consequently, providing a methodological framework that would be applicable for our independent research topics including the usability of novel applications for the cultural-creative sector, interactive sonification in auditory display and interaction modalities for new media arts.

In my particular case, *SoundField* provided the possibility to fully implement the proposed conceptual model for interactive arts whilst developing an artwork. The long-term project made it possible to implement the results of the parallel usability studies of A. Deweppe, undertaken for *SoundField*, in the design strategy. N. Diniz contributed in a similar fashion, by providing a flexible java-framework for multi-modal interaction with an initial application domain of interactive sonification within auditory display. His prior research (Diniz et al., 2010, Diniz et al., 2011) was invaluable for the applied mapping strategies of gestures to sound in *SoundField* where N. Diniz' research in multi-variable sonification using electro acoustic composition techniques was inspirational, alongside the virtual object mediation The user-centered development strategy of the framework, undertaken in our collaborative project, is particularly suited for integration in the iterative, participatory prototyping context for interactive art, which I already refered to in my conceptual model for interactive art in section 4.5.

SoundField is an immersive augmented reality environment where a variable number of participants interact with any number of virtual objects, mediatized by various artistic media. It presents a virtual space in which sound and visuals can be created, influenced, manipulated or explored. The virtual

space corresponds to a physical installation room in which the participant's movement are tracked by means of a 10-16 infrared-camera set up. During the development process, the specifications of the sound system for positioning the sound has evolved from a stereo into a quadraphonic and finally into an octophonic speaker system with a flexible vector based amplitude panning (vbap) controlled sound positioning system. The cameras constantly track the position of the participants, enabling the user to experience corporeal control over the sonic and visual environment and creating a means for exploring new modes of creative sound and music interaction. The subjects moving through the room affect the projected images and the produced sound.

5.5.1.   Artistic background

SoundField is an art work in progress, a research place for interaction. It is developed to investigate the relations that emerge between the installation (with its own personality) and the public and how this relation can serve as an invitation for social interaction. This social interaction is the key element for the development of the art work. Many of the early use cases were specifically targeted at it, encouraging participants to work together, rather than focusing on the use of technology.

Artistically, in *SoundField* I wish to provide a space for participants engaged with aural and visual elements by using dynamic and intuitive mapping strategies for gestural feature extraction and easy-to-use technology. Consequently, my artistic input for the installation is limited to contextualizing the overall experience and guiding the actions of the participants. To efficiently do so, a thorough user-inspired development process is needed. The cross-

pollination of the research topics of Deweppe, Diniz and myself resulted into the collaborative development of *SoundField.*

dot - line - surface (- volume): structural dimensions
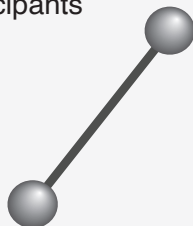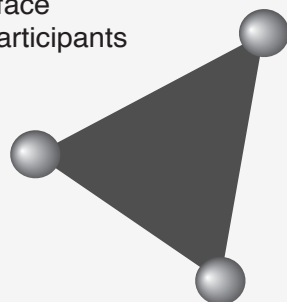
Figure 33:   increasing dimensionality according to number of participants

The initial artistic idea was to provide users with a comprehensible parallel increase in dimensionality at the embodied, aural, visual and social level. This would ensure a gradual increase in complexity at aural, visual and embodied levels, that can be easily overcome by a participant while interacting. In order to do so, *SoundField* implements a gradual increase of complexity from a possible interconnectivity between additional points; one point is a dot, two points can be connected to form a line and three connected points enclose a surface as depicted in Figure 33. This process could potentially be extended to include a volume with the addition of a fourth point. In the initial stages, we limited ourselves to the inclusion of surfaces, since the orthogonal projection used is not ideal to display easily defined volumes. Unlike the triangle shaped surface which is the simplest polygon in Euclidean space.

A single person engaging with the installation is provided with a single sound, represented by a single visual dot or small sphere in the virtual world. He or she can manipulate this sound by moving it within the auditory space,

which is symbolized by the visual representation of the dot following the participant's movement. As such, there is only one level of interaction available to the user, which limits the interaction but enhances the action-reaction coupling between participant and installation. However, this simple interaction modality enables the user to affect the sound in a very expressive way, since both the participant's position and velocity of movement is taken into account with regards to the manipulation of the sound. A hypothetical mapping from action to sound is presented in Figure 34.

X-axis: Overtone Range
        OSC wavetable pattern
Y-axis: Base frequency

Z-axis: Frequency Drift

oscillation ~ velocity
creating variance in frequen
drift

oscillation ~ velocity
creating variance in
overtone range
creating variance in

oscillation ~ velocity
creating variance
vin global pitch
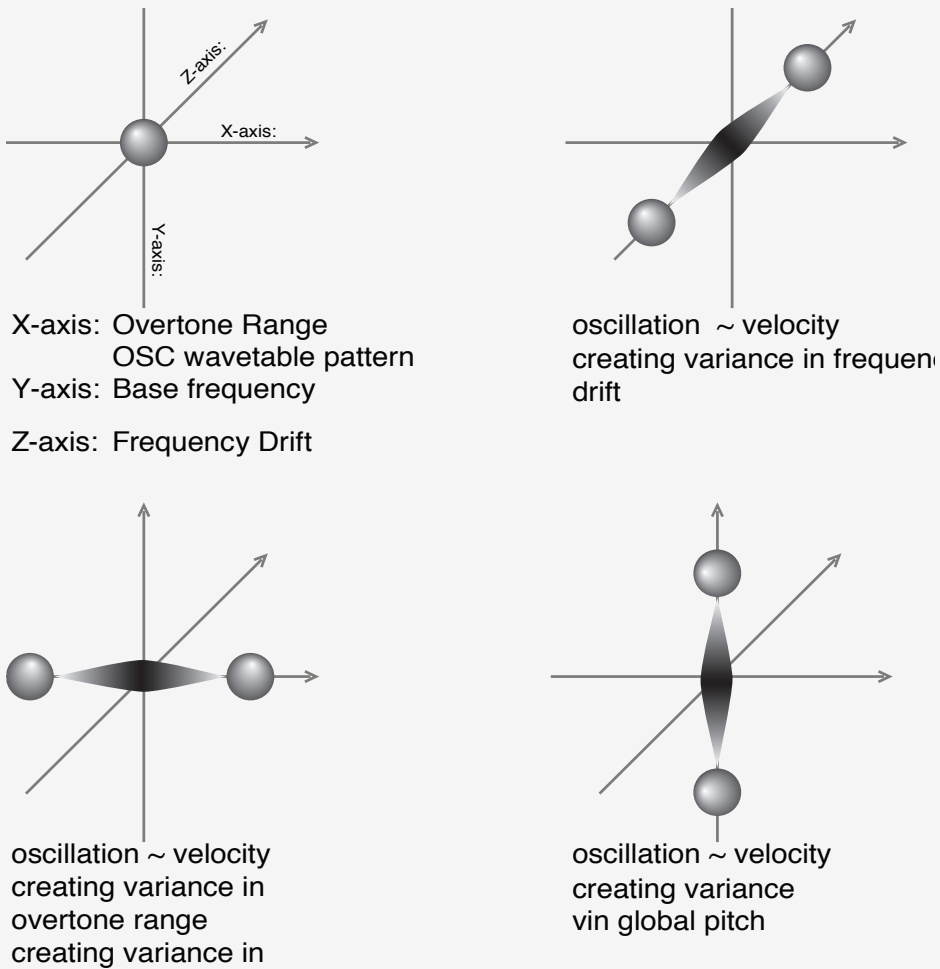
Figure 34:   a hypothetical mapping of sound to spatial and velocity of movement parameters

The practical implementation of this low level in the installation is done using spheres. They are attributed a limited number of properties. During the development process, they could either have be static or dynamic. The sphere-objects sonic properties respond to their repositioning in Euclidian space. The fixed sphere-objects response either to the proximity of other objects or to the collision between different objects.

Two persons engaging with the installations are each provided with their own sphere, containing the same mapping scheme. A second participant, therefore, already partially learns the installation's response to the first participant's actions by observing his or her behavior. Consequently, this second participant's understanding of the installation's functionality can already be understood as the result of an imitation process initiated by social embodiment.

While both participants can manipulate the installation independently, the introduction of a second dimensional level invites them to explore the installation by cooperating with one another. Initially, the two participants may be inclined to explore the installation's response to their individual movements. This is further emphasized by the spatial distribution of the sound, which adjusts to the participant position in the installation room. While the combined soundscape of the participant is ever present, the individual sound components, controlled by each participant, are easily recognized. This entrusts each participant with a strong connection to the sound-sphere and a thorough understanding of the action-perception coupling. Finally, this individual explorative stage is further validated by the fact that people tend not to invade each other's personal space.

In *SoundField,* we consider the different spaces surrounding the participant as subjective body-centered spaces. These can be discriminated as:

• the pericutaneous space: which is the space directly surrounding the body

• the peri-personal space: which is the area that immediately surrounds a person and is within reach of the subject.

• the extra-personal space: the space out of the reach of the participant.

Individual exploration occurs primarily when the participants are unhindered in their peri-personal and pericutaneous space. Both participants, as a consequence, are beyond each other's reach.

The connection between participants signaling the emergence of the second dimensional level requires an intimate (spatial) relationship between the two participants. The line connecting both participants will only be created when one participant enters the pericutaneous space of the other. When this happens, a second type of sound is instantiated. Two participants working together control the line-sound.

A different mapping strategy is applied to relate the participants' combined movement to the line-sound. The spatial positioning is similar to that of the sphere-sound. The pitch depends on how far the line is stretched, which resembles the action of tuning a string of a traditional instrument.

As long as the two participants are within each other's reach, the connection between them is maintained. Or to relate it to the paradigm of subjective body-centered space, the connection between the two is severed when they leave each

other's peri-personal space. By entering the undisturbed extra-personal space, they return to their individual explorative stages. At first, the instantiation of the second level may occur by accident, and the social interaction between the two participants may be unintentional. The transitions between the two dimensions will, however, alert the participants to a brute change in the installation's response. This will bring about a state of disturbance for the participants, making the functionality of the installation less transparent. When they continue their exploration, this added functionality will be learned too. The attention of the participants will, by experimenting, be directed to the collaborative actions that brought about this change. As such, they will divert the attention away from the (technological) functionality of the installation. Consequently, the state of disturbance of the medium (or installation) shall have effectively introduced a new social embodied interaction level.

In practice, this was implemented by string-elements, usually formed between two (static or dynamic) spheres. The line's dependency of the connecting sphere-objects makes the properties of string-behaviors slightly more complex.

A third person, observing the interplay between the two participants present, unlocks an additional dimensional level when entering the installation. Similar to the aforementioned process in the second dimension, this person may have learned the installation's first and second level functionality through observation and imitation. The third person is, again, presented with a sphere-sound, bearing an identical response as the other sphere-sounds, that he or she can modulate by moving through the space.

Each pair of participants can collaboratively access the second dimensional line-level, creating connections as described above. Considering that people have (cultural) reservations when their peri-personal and pericutaneous space is invaded, the exploration of the line-dimension by the third participant

will be mostly inspired by observing the other participants interacting from a distance, since he or she will seldom engage directly in the interaction. This perceived social interaction may entice the third party to connect to the others, making the interaction more dynamic.

When three participants enter each other's pericutaneous space, the three spheric virtual sound-objects, representing the participant's in the virtual world, are interconnected and a virtual surface object is instantiated. This surface object is sonified by a percussive sound, analogous with a membrane of traditional percussive instruments. The action-reaction coupling that lies at the basis of the line-object's parameter mapping to sound is transposed to the surface-object, resulting in the pitch of said object being related to the size of the surface area. By repositioning themselves, the participants enlarge the surface area and, consequently, lower the pitch. When the surface is stretched beyond the participants reach, signaling leaving one another's peri-personal space, the surface dissolves.

Practically, this is implemented using the plane-elements, constructed in between (minimally) three spheres. Their behavior is similar to that of a string; they are activated by collision and the total surface area determines its pitch.

On a side note, we imagined situations where participants function within the installation with more than one person at a time, without the aforementioned strong reservations concerning peri-personal and pericutaneous space. During the development process, which was based on static use-cases, this was certainly the case. A more task driven usability study was undertaken, needed in order to further develop our software, hardware and interaction

design. We have only recently included the dynamic changing levels in our design, inspired by the results of our lengthy development.

The participants can be acquaintances, having already established relationships that transend the aforementioned reservations. Since *SoundField*'s main intent is to facilitate social interaction, this may not be an issue. On one hand, it may affect the gradual increase of complexity over the different dimensions. On the other hand, people already accustomed to each other tend to communicate better, enabling them to explore the different stages by simply talking to each other.

The dynamic between the three levels and multiple participants makes for an expressive embodied social interaction experience. For the whole duration of *SoundField*'s development*,* this multi-dimensional approach with an increasing complexity over the different levels has served as the recurring theme with regards to the installation's functionality.

SoundField relates social interaction to the spatial use and interactive sound design in a dynamic body-centered approach. The subjective body-centered spaces act as affordances for the participant's proprioception. This self-awareness relates to the instantiation of the different interaction levels. The cultural reservations of participants are additionally used to divert the participants' attention away from the projected visual cues towards the embodied cues they receive from each other's behavior. For example, in one of the early use-cases with contemporary dancers, we noticed that it became easier for participants to situate the position of the virtual line-object, connecting two participants, when solely focussing on each other's physical position. Their interaction evolved from an interaction with technology,

requiring them to interpret the different projections, to an embodied social interaction.

This structuring of interaction possibilities and functionality according to a social embodied dynamic requires that participants are unhindered when interacting. Consequently, the development of the artistic concept needed to be fused with a thorough study of the usability of the technology used in *SoundField*. The results of which guided the decisions made in the final stages of development.

Currently, *SoundField* is still presented as an unfinished black box artistic installation based on a flexible, multi-modal enabled java-framework. It continues to function as a test bed for different modes of sonic, visual an social interaction, usability (and interface) evaluation and use-case development. In addition, it is also being presented as an art installation. Therefore, the setup is, both in terms of content and interaction, in essence open-ended. A large part of the continuous research is directed towards improving the ergonomics, elaborating the interaction modalities and finding new approaches for interactive multi-variable sonification.

5.5.2.   Aspects of the conceptual model

This section will primarily address the approach we adapted for the development of *SoundField*. In the section described above, a functional artistic idea is presented. During the development process, we focussed, however, on facilitating a large number of usability tests and the set up of a methodology that endowed a participatory design and iterative development of a multi-modal software framework. Only after this development, resulting in specific guidelines on how people wish to interact with technology in an immersive augmented installation, the artistic content is implemented to

situate and contextualize the prefatory functional artistic idea addressed in section 5.5.1.

5.5.2.1.　　User-centered development and evaluation

To facilitate the participatory and iterative design, A. Deweppe developed a customized set of design guidelines, usability heuristics, complexity indexes and evaluation parameters, resulting in a practical and efficient evaluation procedure (Deweppe et al., 2012). Offering a realistic alternative for task-based usability and efficiency more commonly used in HCI, A. Deweppe's methodological approach adapted the standardized HCI heuristics for gesture-based interfaces to facilitate the evaluation of an open-ended interaction and quality of experience measurement.

The development was made possible by working in close collaboration with the educative centre Destelheide in Dworp, Belgium. At this centre, we were given the chance to set up the installation and to continuously work with groups of creative people over the course of four months.

Prior to setting up the installation in October 2010, we presented a first demo during the yearly summer school held in July 2010. This summer school brings together a group of people of different ages and with broad artistic interests. This provided a well suited test audience.

The demo consisted of a screen-based demonstrator of what was to become the immersive installation. It simply presented the participants with the dimensional functionality described above, and allowed the participants only to take control of the system using a computer mouse. We deliberately left out most parts of the story, referring solely to the correlation between number of participants and number of sound-objects, being dot, line and surface.

After a short explanation of the basic functionality of the system and an explorative stage, the participants were divided into small focus groups based on their individual artistic practices. During half-open interview sessions, they were asked to think out loud about the possible applications they could imagine in their artistic domain.

At the beginning of October 2010, a technically fully developed version of the previous demonstrator was tested using a heuristic evaluation. We resolved some of the previously reported issues and presented the new demonstrator again at Destelheide. We followed the same approach of combining demonstrations with explorations and focus group sessions polling their experience. This was done in collaboration with the instructors of WISPER, a cultural organization providing workshops and courses on different artistic media.

Out of both sessions, first with the rudimentary and continuing with the more advanced demonstrator, several ideas emerged that further inspired our development. Many of the ideas the participants presented eventually got crystallized into specific use cases, catering for specific art forms or media, that proved to be key in the development of *SoundField*.

Throughout the whole duration of the project, the participatory design and iterative development process was conducted by following five consecutive steps where interactive sessions were varied with evaluation and implementation sessions (Deweppe, 2012). To ensure the methodological approach over the course of the project, the same procedure was applied throughout all iterations. It also enabled the developers to incorporate their own experiences in each of the consecutive use cases.

5.5.2.2. Scenarios

The functionality of the installation was addressed according to the different levels describe in section 5.5.1, resulting in the basic levels of interaction being constructed around three types of virtual objects with adaptable properties, namely dot, line and surface.

Setting up scenarios allowed for rapid implementation of behavior-sets into *SoundField*. In total, there were five of these scenarios, discussed in full detail by A. Deweppe (2012). They were based on the user-expectations discussed during the focus group sessions:

1.   Sphere:

    a.   most basic interaction.
    b.   basic operation of positioning sphere objects.
    c.   interact to calculate proximity or detect collision.
    d.   applied to all use cases.

2.   Necklace:

    a.   basic interaction.
    b.   two dynamic objects.
    c.   interact with sphere objects to affect line object.

3.   Fence:

    a.   more complex interaction.

    b.   creation or presence of a number of static objects, strings or planes in the interaction space.

    c.   interaction with the object present by means of a sphere object.

4.   Umbrella:

    a.   complex interaction.

    b.   a large number of static or dynamic objects are connected to a central static object.

    c.   interaction dependent on proximity to central object.

5.   Tug of War:

    a.   variation on Umbrella.

    b.   a large number of static or dynamic objects are connected to a central mobile object.

    c.   interaction dependent on proximity to central object and/or collision between objects.

To facilitate the different artistic practices, functionality and esthetics, we combined behaviors into adaptable and joinable scenarios. It allowed us to incorporate these user-informed adaptations effectively and efficiently in the different use case.

Throughout the duration of the project, all use cases were developed in a similar fashion. After a demonstration and an explorative session, group discussion on interaction-strategies, sonification and visualization were

organized. Following the group discussions, the possible implementation of these ideas was structured according to the scenarios, resulting in the specific use case. The actual implementation of their ideas, was again presented to the participants. An interactive session and/or an artistic performance followed and was concluded with a standardized evaluation questionnaire.

5.5.2.3.   Use cases

Throughout the development, the different use cases have been divided by A. Deweppe into six main categories according to their dominant application type. These categories are demonstration, sound manipulation, sonification, choreography, theatrical and movie manipulation use cases. During the development process there was no dynamic increase in levels of complexity according to the dot-line-surface principle. In use cases with strings and/or planes, participants had access to these levels despite their proximity to each other.

The demonstration use cases were used to illustrate the basic elements and features of the system, to explain the different dimensional levels and to exemplify possibilities (and limitations) of the system. They were presented to all users of the platform.

It contained two demonstrators, SoundObjects and SoundFlock. SoundObjects facilitated five users, who were attributed the control over five virtual objects with an abstract sonic and visual representation. In addition, they could activate higher level objects that were formed in between the sphere-objects when collaborating. The relation between low and higher level objects is illustrated in Figure 35.
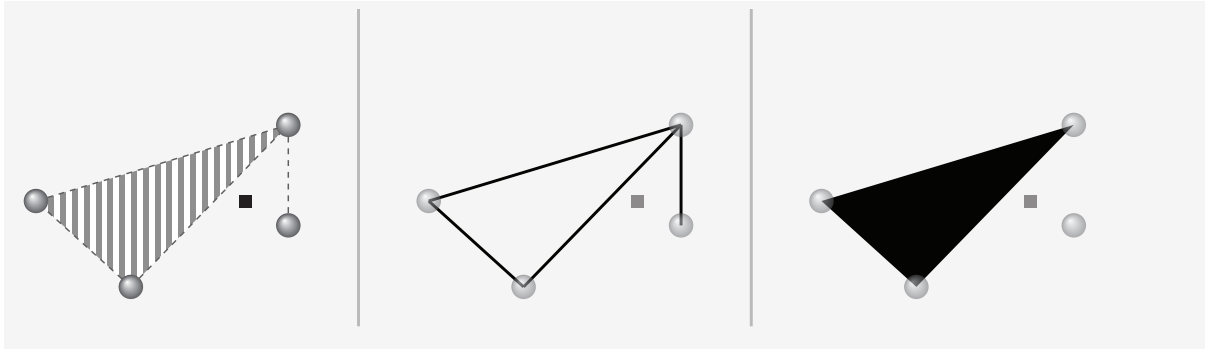
Figure 35: SoundObjects: 1 activation object and 4 spheres, controlled by users, with 4 connecting lines (b) and 1 resulting surface (c)

SoundFlock was meant for a single user, with a large number of virtual objects following the participants movements. This is used to demonstrate that the virtual objects don't necessarily need to behave in a one to one relation with the participants in the real world. The flock of objects was programmed to closely chase the participant by following a set of rules of a Boids-algorithm. This algorithm makes instances of objects behave similar to a flock of birds, adjusting to their neighbors' behavior. The movement of the flock, trailing on the participant's movement, provided the sonic and visual outcome, resulting in an interactive communication between the participant and the system.

Many of the use cases aimed at realtime multi-leveled manipulation of sound parameters. Throughout each consecutive iteration, the mapping of movement to sound parameters becomes increasingly complex. This is needed to find an ultimate balance between the complexity of the multi-level interaction and its usability. Over the course of the project, there was a total of three SoundSculpture iterations with variable mapping strategies and complexity. This allowed five participants to collaborate. In addition, there was a use case SoundScapes, in which less musical sounds were used, in contrast to SoundScapes. In this use case, the participants recorded their own sounds after they had seen a demonstration of the *SoundField* platform, in which we exemplified how sound could be stretched and changed. We integrated their

recordings into the installation in a similar way as in the SoundSculpture use cases. These ambient sounds, allowed for a more free spatial interaction, making the participants 'movements less constrained by their efforts to make things sound 'right' (i.e. more in tune) in SoundSculpture.
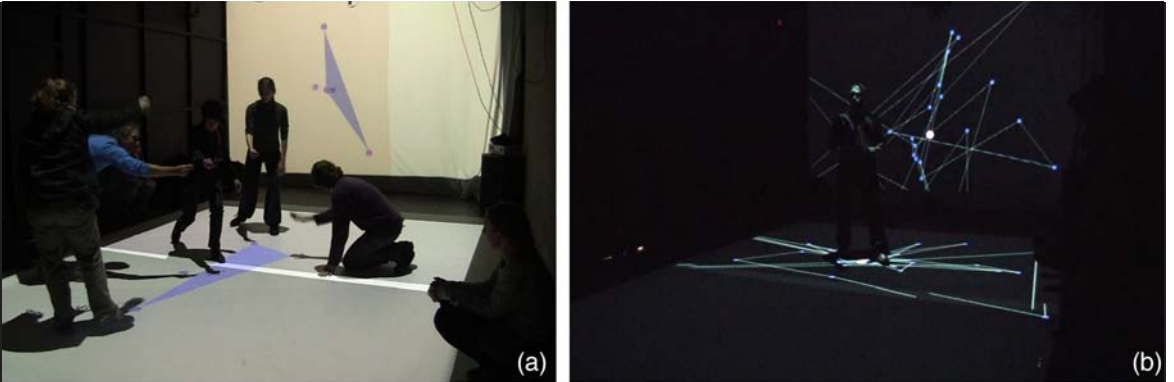
Figure 37: Participant(s) in SoundField: SoundObject (a)
and SoundFlock (b) use case.

The SoundTrails use cases continued along the same line, but more emphasis was put on the visuals by including a continuous three-dimensional trail of the participants' movements, resembling a drawing in 3D space.
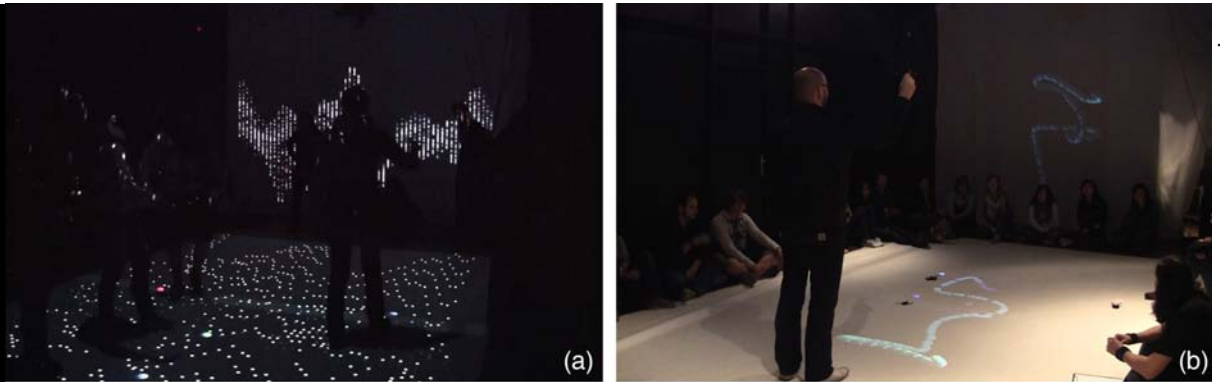
Figure 36: Participant(s) in SoundField in SoundSculpture (a)
and SoundTrails (b) use case.

Unlike the sound manipulation use cases in which there was a more or less arbitrary coupling between sounds and sound manipulation parameters, SoundPath had a clear goal to investigate how a user can access multi-variable data through interactive sonification. SoundPath was clearly an outlier in our development, introducing a whole new set of possibilities inspired by electro acoustic composition techniques. The specifics of which are discussed in detail in "An embodied music cognition approach to multilevel interactive sonification" (Diniz et al., 2011). It did inspire participants to come up with several new ideas and application types, which eventually led to SoundTracks, a use case in which elements of SoundPath and SoundTrails were combined. SoundTracks allowed for the two participants to collaborate. One participant would start a choreography, generating sound according to his or her movements and leaving a visual trail of data-objects for the other to explore. This second participant would than not only be able to interact with the first participant in real time, he or she would also have access to the first participant's 'movement history' that he or she could interact with. To ensure that it would not become to complex, the 'movement history' only represented the last twenty data-objects containing the participants movement.

The theatrical SoundScene was created to serve a theatrical context. Depending on the performance, the participants would trigger and reshape the four sounds that were latent in the environment. These sounds could be either ambient sound effects or parts of a narrated pre recorded monologue.

SoundTales was a second case used in a theatrical setting, accompanying a dramatic narrative improvisation workshop. In SoundTales, concrete background noises and sound effects were incorporated in the system. Each of them had a distinguishable sonic identity (e.g. a city, a forest, the beach, biking, doing dishes, etc.) The sounds were distributed throughout the room, providing a spontaneous setting that would be able to inspire and support the narrative in a number of improvised scenes. The actors proximity to the sound-

station would trigger the sounds. By moving more or less close to the stations, a dynamic mix of up to four different scenes was created. The narrative was, in the case of SoundTales, used in two distinct ways. On one hand, actors moved freely through the room mixing up the different sonic identities, the narrator would then tell a story according to the sounds he or she heard. On the other hand, the narrator could initiate a story requiring a certain sonic backdrop. The narrative would then instruct the actors to trigger that specific sonic identity. As the story continued, the narrator could introduce different independent settings into the narrative or combine any of the available sonic identities. Often this resulted over the course of the workshop in hybrid forms where an exciting dynamic between narrator environment and actors came into play.

In SoundStage, the environment served as a stage for a performance, combining live video feeds and 'musique concrete'. It accompanied a performance art workshop. The live video feed provided input for the visualization. The visualization was manipulated and distorted by a second performer's movements. Live sound, generated by using and rattling different utensils and materials on a soundboard equipped with contact-microphones, would be manipulated by yet another performer. While this resulted in an unearthly, impressive performance it remained an outlier for the development process by the inclusion of external instruments in the performance.

SoundDance provided a responsive environment for dance-improvisation. Five participants controlled the abstract sound manipulation, and additional sounds were triggered using the collision of strings fixed between free moving sphere-objects, according to the ideas laid out in section 5.5.1. As previously noted, this ensured that people would not only interact with the installation,

but that they would engage, in time, in a social interaction with each other. By means of their choreography, they created an embodied ambient soundscapes.

The SoundMove(i)es use cases are three iterations of a use case facilitating an embodied spatial manipulation of movie clips for three different video-workshops, tutored by a single person. These movie clips, made by the participants, were focussed primarily on texture and use of color, stressing less on the importance of a linear narrative structure or on dialogue. While they resulted in small excerpts that did tell a story or set a mood, they were perfectly suitable to be played in a loop or to be combined with other fragments. The underlying idea was that the position of the participants controlled the changes in the sonic and visual playback. The interaction with the installation was targeted at blending and manipulating four simultaneously projected movies. Over the different iterations the mapping changed in favor of controllability, often limiting the range of possible mappings of movement to effect.

Each of the previously mentioned use cases and application types inspired our work process in different ways. Some use cases focussed more on the sonic properties of the installation while others were clearly more visually inspired. By addressing the sonic and the visual components independently, working with a large group of participants and expert users, we were able to pinpoint the most pertinent issues at hand and extract the features that were most important for users to facilitate a communicative relation. A commonality in all the use cases is the importance of the social interaction, which enabled users to get a better understanding of the installation's response. Over the course of the project, this dimension of social interaction proved to be invaluable to establish a satisfactory relation with the sonic and visual information mediated by means of this immersive, technology-savvy environment.

Little artistic input was deliberately provided by us, making it possible for us to come up with different implementations and applications. While we did

remain true to our artistic idea, stressing on the basic dimensional functionality paradigm in all use cases, we believe that the lack of artistic contextualization resulted in a more versatile collection of use cases and possible applications than we could have come up with. The whole point of the development of *SoundField* was to not influence the participants' experience too much when they interacted. Evidently, we did determine how the participants' ideas would be implemented, using the dimensional approach of dot, line, surface, in *SoundField*. Apart from this requisite of the installation's functionality, to which the participants needed to adhere to, our artistic input remained limited. The only exception was the SoundPath and SoundTracks, where the sonification was inspired by electro acoustic composition techniques.

5.5.3. Experience

In the following section, a summary of the general tendencies that were the result of our intensive evaluation process will be discussed. A detailed description of all the individual aspects of the evaluation will not be discussed this thesis, but is described in full by A. Deweppe (2012). The detailed evaluation process, undertaken by A. Deweppe, included evaluations before and after the main interactive sessions. In addition, Deweppe reported on the complexity of each use case, addressing the implemented features, behaviors and implications of the social factors. The results of this evaluation has continuously influenced the development of the software, hardware and middleware and has inspired us to create better interactive use cases. The key results that are most important with regards to interactive arts are:

- The entertainment value, rather than the aesthetic qualities of the individual elements and the implemented mapping strategy, is primordial to perceive an experience as worthwhile.

- Sounds and visuals should be complementary. This is imperative to establish a beneficial relationship between the participants' gestures and the installation's response.

- Participants reported that they mostly relate to the visual cues, even though most use cases focussed more on the sonic qualities.

- As the number of controllable sonic parameters increase, it becomes harder for participants to accurately control and discern the sound elements.

- The quality of social interaction is linked to how suitable participants consider a use case to be for communication.

- Both in number of action possibilities and participants there appears to be a maximum of what is feasible. The ideal number of participants, involved with a similar basic task, appears to be between three and five. A large group of participants interacting at the same time, greatly limited the sense of control, making it hard to distinguish between different sound objects.

- In general, the participants easily understood how their actions related to the virtual objects, attesting to the easy perceivable action-perception couplings laid out in the dot-line-surface idea.

The results of the evaluation provide valued incentives for a wide range of versatile future implementations. The complementary nature of the responses and actions is key. In addition, the focus should primarily remain on the actions of participants engaged in the creation of meaning. A specific narrative can be

introduced, rather than (fully) implemented by the sonic and visual elements of the installation when the embodied nature of the communication is kept in mind.

5.5.4.　　　Technical descriptions

In this section, a short overview is given of the extensive technical development that took place over the course of the *SoundField* project. A general scheme, outlining the different components can be seen in Figure 38. First, a general outline of the hardware is presented. Afterwards, the software is discussed. It addresses the implementation the interaction modalities, the visual and sonic representations and the structuring the installation's elements' behaviors.
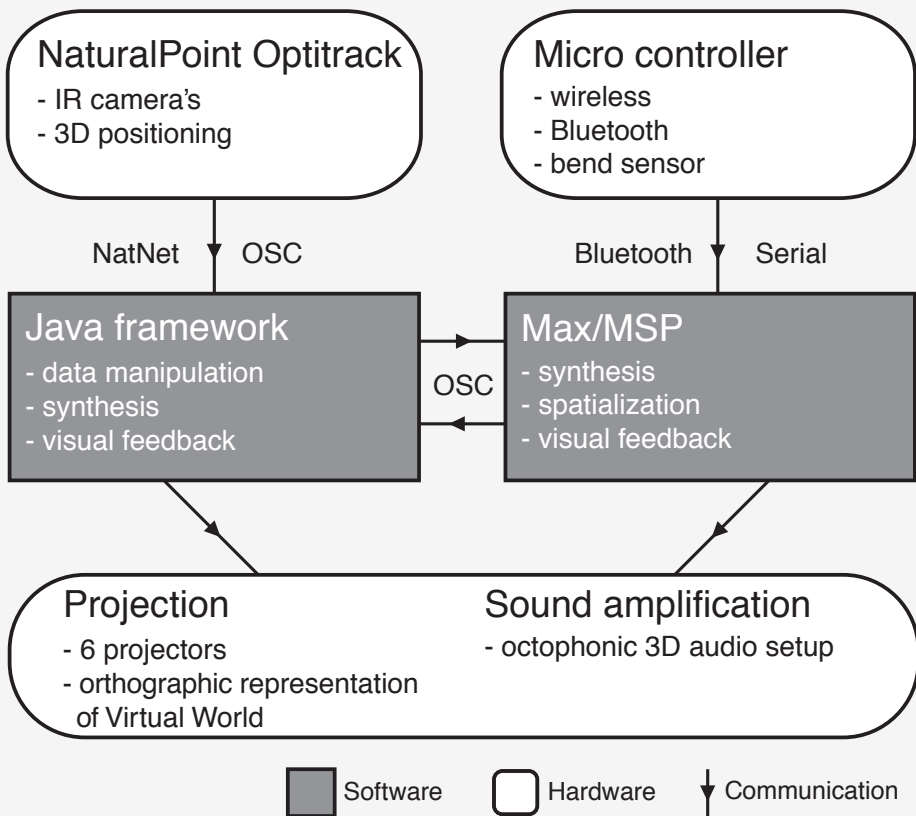
Figure 38:　schematic overview of SoundField

5.5.4.1.   Hardware

The immersive environment has been altered favoring a more easy and flexible set-up. During the development process, the installation was build inside a constructed black box. Two projectors, suspended on the ceiling provided a five by four meter ground projection. Two additional projectors on two opposite walls accommodated the side projections. In its current form, *SoundField* is assembled with a custom truss setup spanning seven by five meters. It supports a total of six projectors allowing for a projected area of six by four meters. The camera system used to track participants is a commercial optical motion capture system called OptiTrack from Naturalpoint. A total amount of sixteen cameras is used to provide an optimal tracking space. At the moment there are eight active monitors present in the installation to facilitate an vbap-driven spatialization of the sound. They are connected to a 26 channel external audio card.
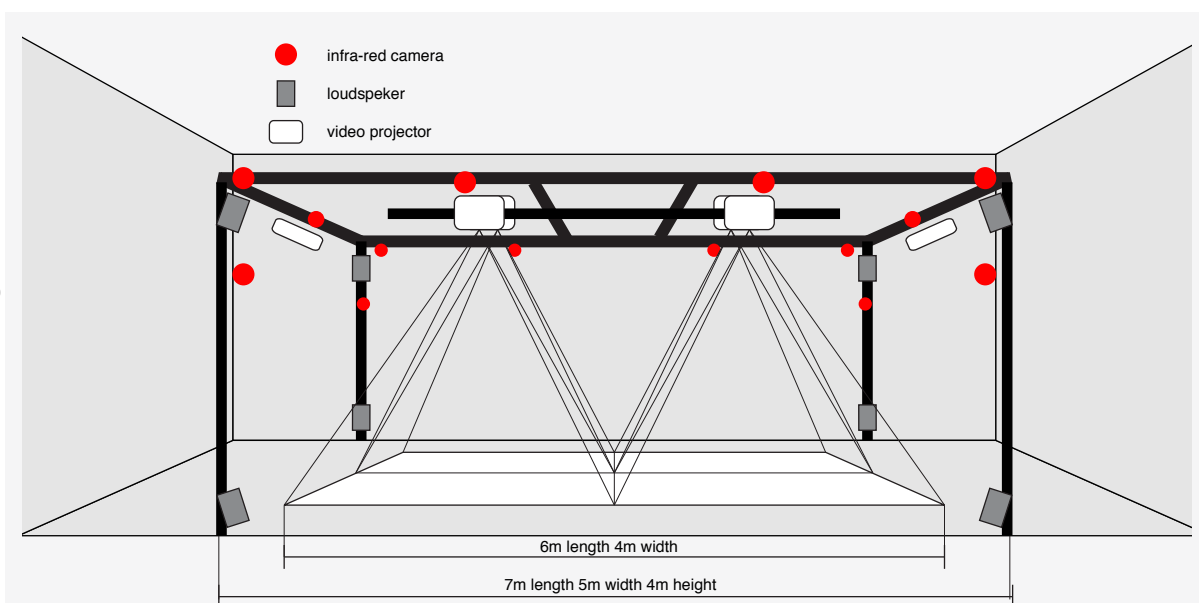
Figure 39: technical drawing of SoundField set-up

The system could hypothetically be expanded to allow for a larger interaction space by increasing the size of the black box used. In addition, a more immersive experience could be facilitated by additional projections on the two opposing unused walls. Finally, increasing the amount of speakers can help provide an even more fine-grained positioning of individual sound. The software and middleware used in SoundField already takes this into account, using a modular structure.

A last category of the hardware is the incorporation of wireless Analog to Digital Converters (ADC's) providing for additional sensors to be used in the installation. During the development process, a wireless I-CubeX Wi-microSystem was used, to which a single bend-sensor was attached. This sensor was integrated into a glove providing the participant to have (more or less) unobtrusive and intuitive control over the interface. For this, a gesture similar to grabbing and releasing a ball was used. In the last showing of *SoundField,* this was replaced by a set of Wii-Motes by Nintendo, given to each of the five participants. While these did not have the same intuitive mapping of the grabbing gesture, they were far more robust and the time the participants needed to exchange the Wii-Motes between them and connect rigid bodies to themselves, was reduced to a minimum. In the future, we hope to build a custom robust solution that combines the two, taking into account the specific advantages of each interface.

5.5.4.2.   Software

The software used during the development of SoundField can be divided into three main categories. A first category consists out of all middleware used to connect the input and output of the system to the computational processes that provide the inner logic of the system. These include:

- *sound distribution:* using vector based amplitude panning to spatialize the sounds in 3D. Early use cases used the stereo field, which over time led to a quadrophonic and finally an octophonic implementation.

- *visual projection:* using multiple projectors for the ground plane and two additional projectors for the side projections.

- *movement capturing*: using a multi-camera optical tracking system in conjunction with a customized data-parser to make the movement data available to other software programs, designed by N. Diniz.

- *movement sensing:* using commercially available software to gain access to the connected wireless ADC's.

A second category is the underlying multi-modal Java-framework, developed by N. Diniz, facilitating the different behaviors and the structuring of and connections between the different cores (sonic, visual, etc.) needed for the installation. It also provides build-in visualization using Java-3D and a sound-engine using SuperCollider (McCarthy, 1996).

A third category builds upon this framework and is specifically targeted at expediting the prototyping, using custom patches made in Max/MSP. This may include both the creation of visual and sonic mappings and allow for new experimental behaviors to be set up.

Connections between the different categories are established through Open Sound Control (OSC), "a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology" (Wright, 2002).

Middleware

The sound distribution in SoundField is done using a set of max objects made by Ville Pulkki (1997). These objects allow for a very flexible use of different speaker set-ups, both in 2D as in 3D. To facilitate this in 3D, each speaker's position is defined by an azimuth and elevation position in relation to the center of the installation room. A 2D setup requires only for the azimuth to be provided. The [vbap]-object allows for a positioning of a sound using position expressed by its azimuth and elevation. It further uses the build in [matrix~]-object used for the actual distribution, based on the [vbap]-object's output. An additional parameter controls the spread of a sound, making it possible to fine tune the position of each sound. This combination results in a versatile solution to distribute sound over any number of sound channels.

The distribution of sound was implemented into distinct manners over the course of the project. During the development process, the sound distribution was implemented in Ableton Live, by means of MaxForLive patches, using an independent module for each sound-element, sending the distributed audio. A series of receiving modules loaded into individual auxiliary channels provided the eventual output. This complex structure was needed because Ableton Live currently does not natively support surround set-ups. Consequently a work-around needed to be devised. While this work-around suited the development process where a maximum of four speakers was used, it did not lend itself for a modular in depth structuring, allowing an undetermined number of audio channels to be implemented on the spot.
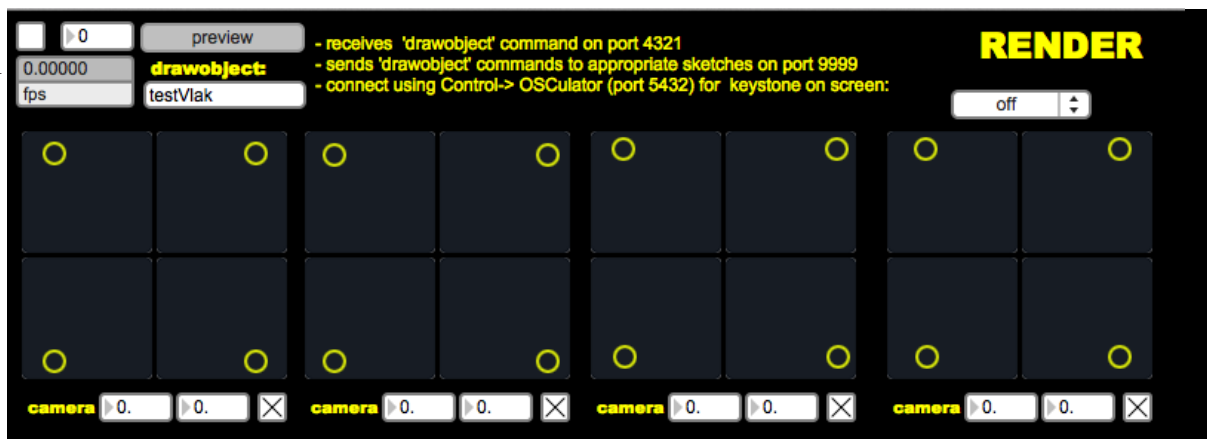
Figure 40:   GUI to control the four projectors keystone and adjust the individual viewports to be combined in a single floor projection

Consequently, the second implementation used a structuring that was fully contained within Max/MSP, without depending on Ableton Live, to make sure it was easily expandable. This set-up also consisted out of a central receiving patch that took care of the actual digital to analog conversion, and was directly connected to the actual sound channels. This was a more flexible implementation since it did not depend on Ableton Live's auxiliary channels.

To facilitating the projections on the floor, a solution for combining several projectors into one projection plane was needed. In addition, it needed to allow for a flexible adaptation to any possible configuration and type of projectors. Therefore, the software included an independent keystone for each of the projectors to facilitate a flexible and easy set-up. Currently, this software module is being rewritten, since the last version of Max/MSP provides an easier way of implementation than the one that I used. To visualize the virtual 3D-world, an orthogonal projection was chosen, each of the virtual cameras filming the scene was aligned to provide an almost seamless composed image on both the floor and the walls.

To capture the participants movement, NaturalPoint's Arena software was used. This software, in conjunction with the NaturalPoint infrared-cameras, allows us to track infrared markers attached to the participants. To make sure the Arena software can identify each participant, each of them is given a small device with a specific constellation of (minimum) three infrared-reflective markers. While Arena provides a network connection to many commercial applications, using various network protocols, it provided no out of the box solution to communicate with Max/Msp or the custom Java-framework. To solve this, N. Diniz developed a program, parsing data between the NatNet protocol and the more general OSC-protocol that was used throughout the project. This ensured that the data was simultaneously available for all applications used.

The last piece of middleware provides access to the data sent by the Wii-motes, which connect to the computer using bluetooth. Consequently, an application to reformat the data coming from the Wii-motes is needed. For this OSCulator, a stable and easy-to-use application, was used. The parsed data is then collected from the network in Max/MSP with a custom OSC-parsing module.

Java-Framework

The underlying framework allowing for the creation of behaviors, collision detection and general interconnectivity of independent modules was made by N. Diniz (2011). This framework serves as the central hub, gathering all the OSC data from the input components and is used to manage an update the data related to the virtual objects in the scene. The framework also includes behaviors for monitoring the virtual objects' parameters. This informs a collision-detection-engine and subsequently relates the relevant data to the individual visual and sonic components. A full description of the framework can be found in "A Java framework for multimodal interface prototyping" (Diniz et al., 2012).

Rapid Prototyping

While the Java-framework already provides a visual core (Java-3D) and a sonic core (SuperCollider), most of the prototyping development and actual audiovisual content was done in Max/MSP and Jitter. To enable this close integration, the framework allows for an independent instantiation of the different cores. Consequently, the representations can be implemented into several other software environments. However, the fundamental difference in programming paradigm between the framework and Max/MSP did require a cautious well planed connection between the two. For example, Java allows for an easy instantiation of a variable number of objects. This object oriented approach is not used in Max/MSP, resulting in a requirement of setting a pre-determined maximum for the audiovisual representation of the virtual elements.

Inspired by the modular approach of the framework, I structured the software in a similar way: several individual modules for both the visual and the sonic representation of each type of elements were constructed. These

Figure 41: screen grab of flower trailing on participants' movements.

(opposite page)

interchangeable modules allowed for different action-reaction couplings, addressing different parameters or whole new types of sound-synthesis to be used. In conjunction with the custom middleware, this presented me with a versatile solution with limitless potential, without having to translate it into a programming language I am not accustomed to.

The combination of a programming environment allowing rapid prototyping of different audiovisual representations in conjunction with a well-developed, modular, multi-modal framework makes it possible to continue developing the visual and sonic identity of SoundField to facilitate a better (social) interaction. Until now, we limited our own artistic input with regards to the installation. Instead, we chose to focus on mediating the social interaction between participants in a clear and functional manner.
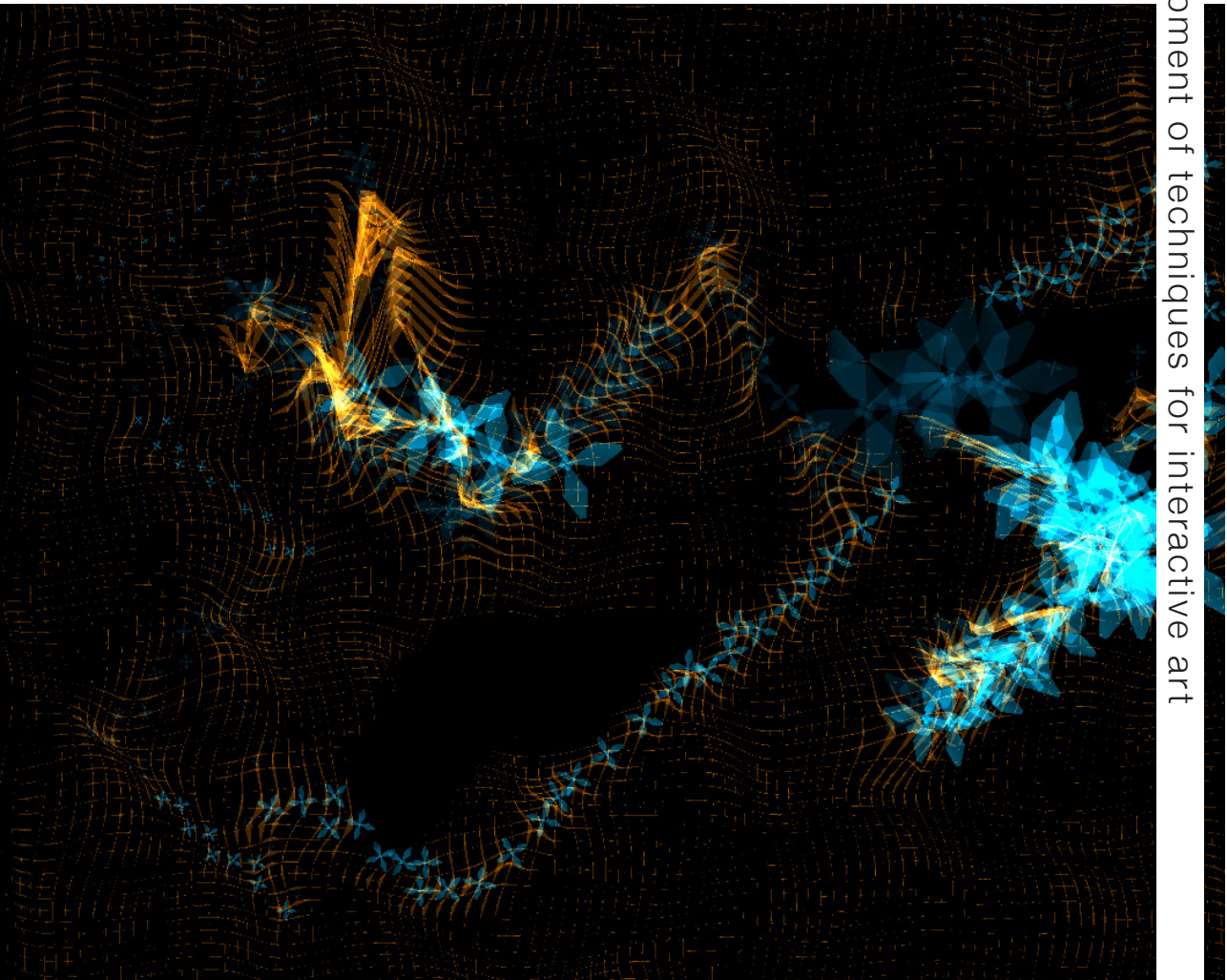
5.5.5.   Current work and future planning

After the development process, there were two showings, in which the *SoundField* was explicitly intended as artistic installations. In these two showings, I included a mapping from movement to sound and visuals to contextualize the participant's actions. While the context of these mappings is certainly an artistic choice, the inspiration for these mappings is a direct result of the thorough and methodological development and evaluation process.

The first showing was done during the IPEM open day in May 2011. I focussed primarily on the visual content in this iteration of SoundField to guide the participants, as the analysis proved that participants connected more often with visual cues. The different sounds were divided into two main categories, a first layer formed a sonic backdrop that was complementary to and supportive of the visual metaphor, a second layer grouped the sound generated by social interaction.
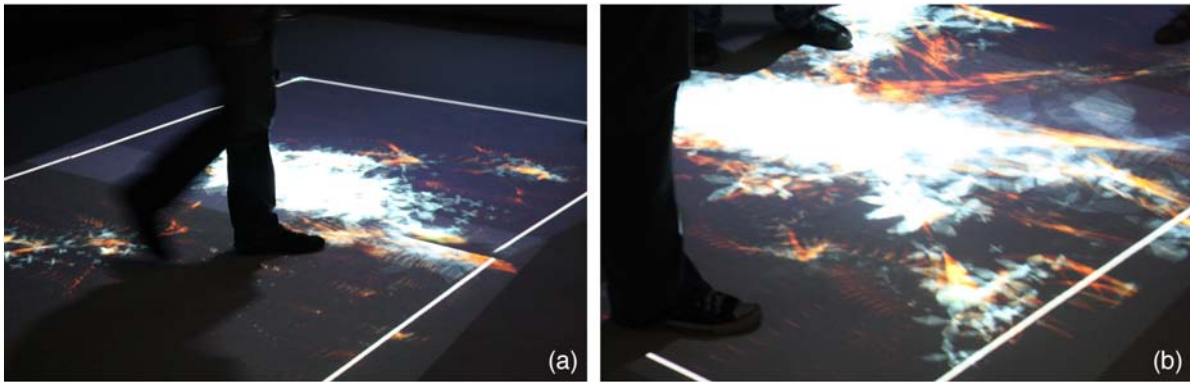
Figure 42: a participant leaving a trail of flowers (a), a participant overviewing the visual representation of a previous interaction (b)

These sound represented the additional dot and line level. It was also the first time that a dynamic increase from dot to line was implemented.

The visual identity of the installation metaphorically represented a meadow in which participants could roam free. The velocity of their movements was visualized by a trail of energy on which small flowers bloomed. This metaphor contextualized the participants' movement. The installation's use of fragile flower shapes hoped to encourage the visitors to thread lightly.

low cut-off frequency

high cut-off frequency
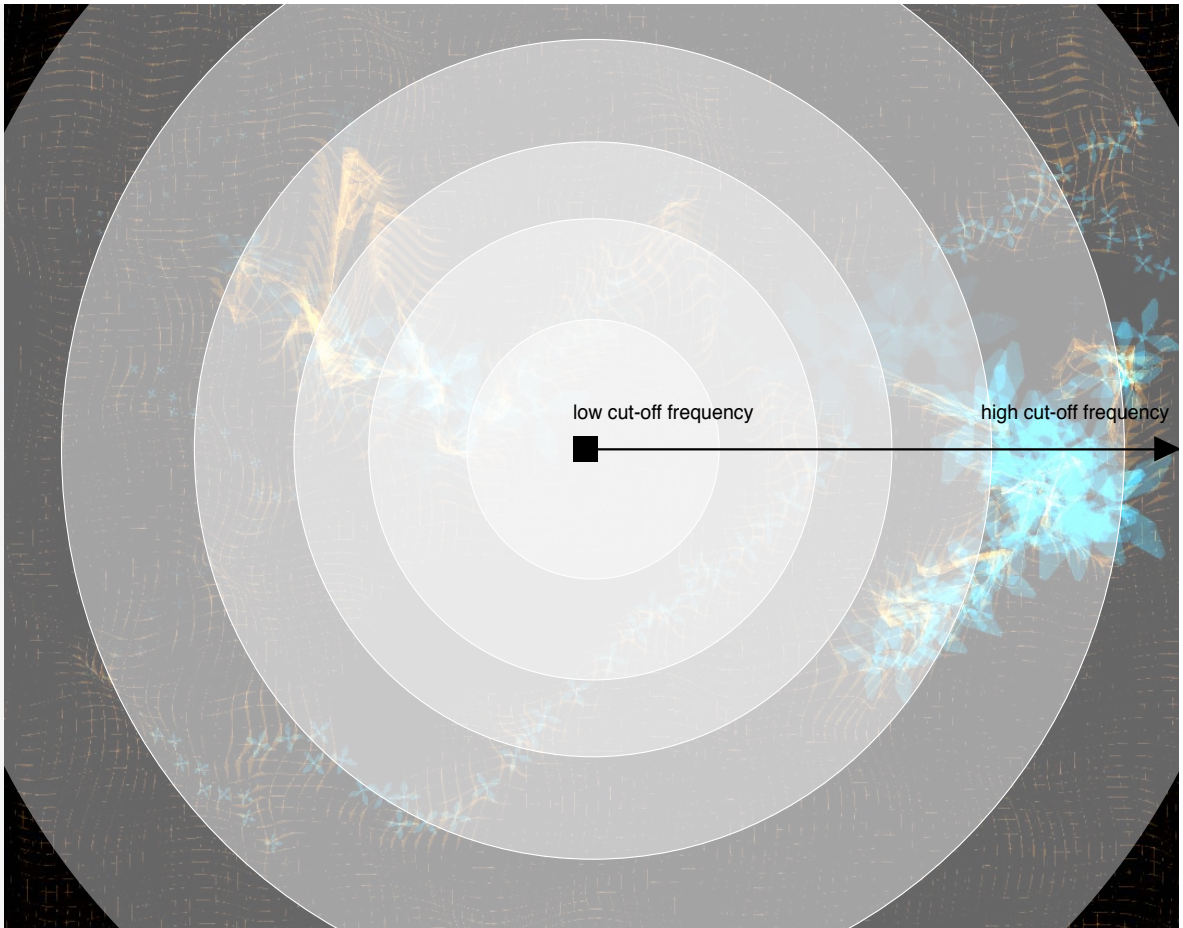
Figure 43: the flowers created at the centre of the installation will have considerably less high frequency content in their sound than those near the edges of the room

Visually, this was represented by a grid-like plane, that would deform when participants walked over it. On a participants trail, small flowers would grow when a set velocity threshold was breached. Gentle movements would grow small flowers, while fast, more active movements would grow bigger flowers. The flowers would wither over time and the disruptions in the plane would disappear, leaving no trace of previous interactions.

Sonically, the aforementioned first category, creating a basic atmosphere for the installation, was complementary to the visuals. Each growing flower was attributed a similar sound, based on the combination of two main components. The combined sound of all flowers created a dynamic sonic backdrop for the installation. Movements near the edges of the installation where presented by more harsh sounds than those triggered when moving in the middle of the installation space. As such, the overall sound palette of the installation provided a sonically calm centre where participants were directed to. It would also encourage participants to work together, while generating different sounds by accessing higher levels of interaction.

The first of the two components of the flower-sound was a small sample of a breaking twig, heard at the moment the flower was created, symbolizing the initial stage of growth. Each of these sounds was slightly different, making it (1) easier to discern between the different sounds (or flowers growing) and (2) making the combined sound of all flowers more dynamic and interesting to listen to.

The second component was a resonant filtered noise synthesis, that responded to the flower's position in the field and to the participant's velocity of movement at the moment of creation. With each flower having a different centre frequency depending on their position, flowers created at the edges of the installation space contained a lot of high frequency content, while flowers situated in the centre generated a more low frequency content.

To be more precise, the distance to a fixed point in the centre was calculated. This distance would then determine the centre cut-off frequency of a resonant bandpass filter. The participant moving through the room would excite and deform a grid of points according to his or her velocity. Each point in the participant's trajectory would move along with the participant, changing its position accordingly. The higher the participant's velocity of movement, the more a point would be inclined to follow a participant's movement and the less resilient the point would be to hold its original position. The distance between the original position and the affected position controlled the amplitude of the noise synthesis. Over time, this elastic grid would restore itself to its original form and all points would resume their original position, ensuring that all amplitudes returned to zero, silencing the installation.

The combined sound was spatialized according to its position on the lower array of four of the eight speakers in the installation room.

The second category was visually not represented in the virtual world. This to make the exploration and discovery of those higher levels more challenging for the participants. This category was implemented using the line-paradigm, where two people close to each other would connect. This dynamically appearing and dissolving connection between two participants was sonically represented by a sound, again composed by combining two individual elements. The first element was a synthesized sound that had a clearly defined plucked feel to it. This was instantiated the moment the string came into existence and would only play once. The second element would continue to sound after the initial creation sound. Therefore, it required a sound that could be repeated indefinitely. The tuning of the combined sound is dependent on the length of the string. Thus, two connected participants can dynamically change the tuning of the sound by collaborating. Each string's sound spatial position follows the interaction.

Figure 44: participants helping and guiding each other in SoundField

The interplay between the different levels of sound creation and manipulation, and the visual identity directing the participants' movements helped create a dynamic explorative immersive environment in which the audience was encouraged to act.

However, in evaluating this installation, it became apparent that people almost solely focussed on the visual character of the installation. While this was certainly to be foreseen, it also meant that they would focus less on what they could explore by working together, discovering this often by accident. The metaphor of the fragile flowers softened the participants' actions, eventhough there were people who would test the limits of an installation quite actively, trying to evoke a very exuberant and even violent response from the installation. However, they soon stopped testing this, sometimes claiming the installation broke down, saying that this was probably not its intended functionality.

A second artistic showing of SoundField was done at ArtBots Gent, the Robot Talent Show in October 2011 during which we were invited as a special guest. We adopted a different approach than we did during the previous showing in order to facilitate the social interaction and collaboration between participants. We focussed on the multi-leveled and collaborative manipulation of sound rather than on introducing a partial narrative through visuals.

A more continuous mode of interaction was required here because participants could enter and leave the installation at any time. To facilitate this, six low level sphere-objects were implemented that were constantly present in the virtual world, regardless of how many participants were present. However, the dynamic spheres would not necessarily connect to the participants. Instead, participants could decide whether or not they would 'grab' a sphere. When they did, they could move the sphere through the room, changing the quality of the sound. In this iteration, only the dynamically interchangeable

Figure 45: SoundField at artbots

Figure 46: cSoundField at artbots

Figure 47:   colliding (yellow) and non-colliding (red) strings

string-level was implemented. Two spheres, positioned close to each other, would connect generating a string. In addition, a participant could choose to detach him or herself from the sphere he or she was connected to, and leave the combination of the spheres and string be. He or she would than be able to move to a different sphere to instantiate another string. As such one participant could play at different levels without needing others. However, often participants explicitly collaborated with each other, which they preferred over sculpting on their own.

The participants were represented in the virtual world as small particles, following there every move. This was mainly done to overcome technical difficulties of the camera's losing track of the infrared markers used to track participants. Often this was caused by the (additional) audience standing in the way of any of the cameras. When a participant's representation in the virtual world was not following her or his actual movement, she or he would know to slightly change position to make tracking possible again. The spheres were visually represented by spots of a blue light with a very bright centre. When spheres would come closer to each other, they would blend into very bright white blobs of light, much like two-dimensional metaballs. Strings that did not collide, are represented by thick red lines, while the color of colliding strings changes into a bright yellow. An example of this can be found in Figure 47.

However dynamic and futuristic the visuals might have looked, they were mainly used to relate participants' actions. As such, they had a more illustrative function, representing the virtual counterpart of the participants and allowing more access to the virtual objects than during the previous showing where they introduced a partial narrative.

Figure 48: representation of participants, by means of particles, sphere-elements and strings. Spheres close to each other form metaball-type blobs)

In contrast, the sonic quality of the installation was developed to simultaneously allow for the easy discernible access to the low level sphere-elements and an expressive embodied experience. To do this, each of the spheres was attributed a rather complex sonic identity. The spheres not only responded to their position in 3D-space, affecting different sound-parameters on the X, Y and Z axis, they would also relate the participants velocity of movement, modulating each of the parameters on the individual or combined axes. This would cause a sphere that is 'thrown away' to vary the amount of effect on the modulation parameter. For example, the X-axis (length) is attributed the control over the pitch of the sound. If you move your hand controlling the sphere near the center of the installation room, the sound of the sphere would have a low pitch. When moving to the corners of the room the sound would become high-pitched. If you would quickly move your arm along the same X-axis and release the sphere at maximum velocity, you would create a frequency modulation (FM) at (a set) maximum modulation amount. Releasing the sphere with a lower velocity would affect the FM to a lesser extend. Simply releasing the sphere when holding still, would have no effect on the FM. This was done on all axes, with an amplitude modulation (AM) on the Y-axis (height) and a bit-crushing effect on the Z-axis.

The sound design started with creating a sound that would be 'static' in origin, one that would be easy to blend with other similar sounds into an atmospheric composed soundscape. It also needed to be able to be very expressive encouraging participants to sculpt the individual component sounds of the soundscape. Resulting in a contradiction between moving and non-moving sound. Most interesting and expressive sounds change over time, either because of the specific materials used in a (traditional) instrument or by using modulation sources (often mimicking traditional instruments) in synthesized sounds. Creating a static, non-moving sound, therefore, proved to be a challenge. By entrusting the participants the control over those manipulations that are normally dependent on time, I hoped to create an environment that

was particularly suitable for accessing a fine-grained control over the sound manipulating parameters. The combination of the six sphere-elements, positioned arbitrary in the virtual space constructed a soundscape responding to the last known activity of participants. When a participant would connect to one of the spheres, the timbre of it would change. In practice the synthesis would mix an equally tuned sine and saw oscillator. When the sphere-element was not connected to a participant, the sine oscillator would be heard. Due to its absence of additional harmonics, this kind of sound blends nicely into the background. When a participant is connected to a sphere, the sine oscillator would change into a saw oscillator, creating a sound rich in harmonics. This sound is easily distinguished from the others, facilitating the participant to (mentally) connect to it. When the participant disconnects from the sound it blends back into the soundscape in a matter of ten seconds. As already present during the previous showing and many of the use-cases, the position of the sound is spatialized over an octophonic speaker array using a vector based amplitude panning.

The sphere elements allow for a very expressive exploration of the different action-perception couplings. Quite some time is needed, before a participant discovers the full array of possible manipulations in the sphere elements. After the exploratory session, a participants could, hypothetically, have a very controlled interaction with a single sphere. Fine-tuning the ranges of the amount of modulation of the individual parameters in a more discrete (musical) way, could even facilitate the use of SoundField as an embodied musical environment.

The string elements are less complex in sound design than the sphere-elements. They adhere to the same rules as during the previous showing with one exception. The exception being that the string elements have no sustaining sound component. This means that they will stop producing sound if they are not re-triggered. Triggering the string elements is caused by a participant

colliding with them. This makes it possible for a participant to set up any constellation of sphere and string elements and trigger the strings elements independently of accessing the sphere elements. It also enables several participants, connected to sphere-elements, to set up constellations around another participant who can then trigger the string elements. This provides for a very engaging experience where collaboration is hugely encouraged.

Each of the previous showings had its merits and were generally well received by the public. To some, the interaction using virtual objects feels strange, others seem to get to grips with it quite fast. Especially during the second showing, it became evident that the functionality was not clear for everybody. What was remarkable is that children seem to have less constraints and get more easily involved with the installation. They didn't seem to have any reservations about the technology used and were much more inclined to explore more than the mere functionality of the installation. The technology used could greatly be improved. The tracking of the participants requires them to wear only a few markers in order to identify them. However embodied we want the experience to be, the actions of the participants are still directed towards the position of the markers on their body. During the first showing, the head was key. During the second showing, a hand-held devise was used to be able to connect and to disconnect from the spheres. The markers were placed on a bracelet, attached to the controller. The controller used to facilitate the connection to the sphere was a wii-mote. This provided a robust wireless solution, needed for the exhibition. The fact that children may be more familiar with this specific controller, will certainly explain (part of) their already established intuitive relation with the installation. Surely, more suited controllers can be designed. Specifically, the metaphorical grabbing and releasing of a sphere, may well benefit from a gesture mimicking this, unlike the pushing of a button on the wii-mote which is used now. This would result in the use of an affordance that could explain how one connects to and disconnects from a sphere. One of the most important things that happened during the showing of *SoundField*

occured when a couple of children, playing in the installation, came up to us to give us very clear directions on how to operate the installation, clearly thinking that we, the developers, had difficulties in comprehending how it worked.

Apart from the technical difficulties which have clear implications for the participants, the artist and the developers, the relation between increased levels of complexity, using the dot-line-surface paradigm, and the collaborative nature of the interaction is well established and is almost self-explanatory. The further development of *SoundField* will certainly focus on improving many of the technical issues. It will, however, not devert from its initial intent; namely to facilitate a social interaction between people that work and create something together in an immersive environment. This reflects a fully embodied approach to interaction.

6. Discussion

In this doctoral thesis, I have presented a novel framework for interactive arts, that, when applied, could help an audience to experience interactive art in a more profound and engaging manner. A key component of the framework is the communicative intention of interactive art, which is a direct consequence of the two way flow of *things influencing each other* implied when addressing interactivity.

Starting from art as communication, it was necessary to reevaluate the role of the audience and, consequently, the artist. In this thesis, I have argued that, in interactive art, the audience (partially) creates the meaning of an art work by participating. Often, it can be argued that the audience in fact co-creates the art work itself. Doing so, the audience ultimately fulfills the idea of a spectator making the picture which Duchamp introduced and the Avant-Garde embraced when activating the viewer. As such, the incorporation of new media, specifically computational interactivity, into art has led to a new discipline where the Avant-Garde ideals can flourish.

At the same time, interactive art provides an ecological setting for explorative research in HCI and related fields. The synergy between art and design, typical in interactive art installations, has the potential to be mutually beneficial; interactive artists can certainly take some pointers from designers concerned with interface design, while designer may be inspired by the way artists communicate ideas using the specifics of carefully constructed technological mediators.

All of the above, evidently, leads to questioning the role of the artist. Throughout the thesis, I have argued that the role of an interactive artist differs from that of a fine-art artist. An interactive artist should pursue a more objective understanding of audience behavior than a fine-art artist, in order to be able to shape and steer participants' actions to support his (subjective) concept. Only then can participants create a meaning, by participating in a

prescribed manner, that is in line with the artist's intent. This accord between artist and audience is necessary for establishing an effective communication, which, in turn, can only be mediated by an art object with a great usability, both for artists and the audience.

In the proposed framework, interactive artists combine concepts and techniques from both the arts and HCI (e.g. embodiment, affordances, mediality, iconography) to guide participants' actions. To effectively map participants actions to audiovisual content, I have argued that an interactive artist's main concern is knowing the full repertoire of actions an audience can perform in the interactive environment he or she has created. For this, a methodological approach should be undertaken, in which the action-perception and action-reaction couplings are studied in detail. The results of which can help at making participants' actions prescribed, allowing for a close and intimate relation between art object audience and artist. Evidentially, the methodology used to study the usability of a novel interface, undertaken in HCI, needs to be adjusted to fit the goals of artists more.

Throughout the practical implementations discussed in the thesis, I have explored different possibilities and methodologies to incorporate usability studies in the development process of interactive art installations with varying success. Ultimately, I believe that the participatory design paradigm, applied during the development of SoundField, holds the greatest potential to enhance an interactive art experience by incorporating a methodological approach that unites artistic and HCI research.

6.1.   Conceptual and technological interactivity

In chapter 3, I have made the distinction between two main viewpoints on interaction in art. Either interaction is perceived as social interaction, often not depending on the use of technology. This is most common in fine-arts and is an attribute borrowed from the Avant-Garde. Or it is seen as working with an experimental (sensing) technology that enhances a medium, which is the common view in new media art. Because of new media's fascination with technology, it is often associated with HCI rather than with fine-arts. Admittedly, this is presented as a very polarized conclusion and there are examples that surpass this one-dimensional application of interaction. However, in my experience there are only a few examples of this and the clear division between new media art and fine-art may be a direct cause of this.

However, when both stances are merged together, they provide a foundation that has great potential to initiate the creation of interactive art installations that facilitate an enriched interactive experience for the audience. Consequently, in this thesis, I have advocated the use of interactivity in art only when an artist's concept requires the use of it incorporating the technology necessary to reach his or her goal.

6.2. Communication is key to interactive art

In this thesis, I have, on the one hand, concentrated on the communicative aspect of interactivity that originates from the Avant-Garde idea of activated viewer, which has become a key element in contemporary installation and participatory art.

On the other hand, the HCI research field, where intuitiveness and usability stand out as two key concepts, has provided a range of practical guidelines to ensure a close connection between a technological interface and its users.

However, what seemed to be lacking in these guidelines for their applicability in art, is the notion of the participatory role of an audience in creating meaning. HCI is fundamentally concerned with task driven research to establish whether or not a novel technological interface is suited for the specific application. Unlike in art, HCI researchers are seldom searching for new ways of creating meaning or support a narrative. Interactivity is primarily regarded to facilitate an effective use of technology. This is often seen as irreconcilable with art, in which the communicative relationship between artist, audience and art object, acting as the mediator, is key.

Nevertheless, interactive artists can adopt one of the many methodologies used in HCI that can improve their art practice and the effectiveness of their communication with the audience. In this thesis, I have elaborated on those that are most commonly applied to art, attempting to strengthen the link between HCI and artistic research.

6.3. Embodied cognition as a bridge between worlds

A concept, that can further reconcile the two aforementioned fields, is needed. It is my belief that, with regards to interactive art, constraining oneself to either of these two points of view greatly diminishes the overall potential of an interactive art experience. Moreover, simply combining the two aforementioned fields does very little to improve the interactive art experience. Often leaving interactive art installations in the limbo between both application fields.

Throughout my thesis, I have tried to link HCI and artistic research; attributing the audience with a key role in the creation of art installations and guiding the participants' actions by applying techniques, concepts and methodologies inspired by HCI research.

To do this, I relied heavily on the embodied cognition paradigm introduced by Leman. As a researcher, musician and sound artist I found that this paradigm, based on the articulation and expression of meaning through embodiment, has the potential to link both disciplines in a concise and mutually beneficial manner.

For example, the conceptual insights provided by the development of technological mediators for musical expression together with the long tradition of instrument building, have played an imperative role in defining the conceptual framework for interactive arts discussed in this thesis. Relating gestures to expressive (musical) content, asks for a fully embodied premise in which technology functions as a natural extension of the human body. At the same time, instruments are key examples of both cultural artifacts and technological interfaces that are designed over many iterations to facilitate

the musical communication between performer(s) and audience. As such, they brilliantly (re)unite art and technology and serve as an inspiration for interactive installations. Consequently, the framework for interactive arts, presented in this thesis, combines elements from systematic musicology, art science and HCI to enhance the interactive experience for both artists and audience in art.

6.4. Corporeal articulations as communication

The key communicative element of interactive art, in the presented framework, can be explained by the use of corporeal articulations. Consequently, a thorough understanding of these corporeal articulations is imperative to provide a setting in which experience is unhindered by the use of technology. How this can be done, is discussed in detail in section 5.5, where the target audience is included in the development process from the start. Working together with a large group of participants from early on in the development process of *SoundField,* has led to a better understanding of how technology can be used to mediate corporeal articulations in an unobtrusive manner. The absence of my artistic input, except for the functional constraints of the dimensional structure (dot-line-surface), has helped participants to explore the limits of the installation to its fullest. The results of the usability studies and the iterative participatory design, have certainly guided the further development of *SoundField* into an art installation, allowing me to make informed decisions that, hopefully, allow the (future) audience to have a more engaging interactive art experience.

6.5.   Understanding action-reaction couplings

When dealing with interactive art, an audience should be able to understand the action-reaction couplings used in interactive art. One aspect to facilitate this, is taking into account the gestural repertoire participants use when dealing with a specific art installation.

The other aspect deals with the causality between action and reaction. With regards to interactive art, however, this causality between action and reaction does not equal transparency, which is often aspired in HCI interfaces. As argued in section 4.3.3, artists deliberately use transitional states of transparency and opacity to guide an audience. In doing so, the artist contextualizes the actions of the audience members, making their actions prescribed. This aids at their exploration and creation of the embodied narrative. The audience is introduced to different aspects of the installation, making the experience challenging and worth while. To ensure that this will happen at the pace of the audience, interactive artists can use state dependent transitions, rather than time dependent transitions, to further develope the embodied narrative.

Important for this process, is the concept of transparency and disturbance applied to interactive art. For an artist, the transitional state of disturbance can be used to direct an audience to specific elements of the installation over time, making them more visual than others. When the audience understands the causal relation between action and perception, this state of disturbance becomes a transparent state, allowing for other elements of the installation to be brought to the attention of the participant. These skills, that are acquired during participation, challenge the audience to explore an installation further. The efficiency of this system is dependent on how the technological mediator either aids or hinders the audience's exploration. On one hand, affordances

can effectively be used to guide participants, ensuring a fluid exploration. On the other hand, affordances are closely connected with expectations. An artist who does not take these expectations into account, will eventually make the action-reaction and action-perception couplings hard to understand, making the communicative aspects of the experience indecipherable for the audience.

7. Conclusion

With regards to the feasibility of a profound practical implementation of interactivity in my art works, my research may have provided me with more questions than answers. Nevertheless, I feel that the conclusions of my research can contribute to the current debate on interactive art, unifying to some extent the different approaches on interactivity.

The assumption that communication is key in art, is not new. Although an artist's conceptual intent may have lost a great deal of legibility in contemporary fine-art. In new media art, and specifically interactive art, this also holds true. Often, an audience merely accesses a functional level of an installation, when trying to understand how a certain technology mediates their actions into the audiovisual content provided.

In this thesis, I have tried to answer questions on interactive art that have preoccupied my artistic practice for over a decade. I believe that, during my research, I've been able to further define the outlines I once set. I hope that my work can help at providing an audience with a more engaging and challenging art experience and that interactive artists and their art benefit from this newly defined relationship between artist, audience and art object.

8. Publications

This chapter is a collection of all relevant papers published during the course of my doctoral research. I have included them to give a complete overview of my research activities. The issues most relevant to this doctoral thesis are addressed in chapter five.

Each paper is reformatted to fit the style of the thesis, the references have been moved to the end of the thesis.

8.1. The Heart as an Ocean: exploring meaningful interaction with biofeedback

Authors. Pieter Coussement, Nuno Diniz, Dr. Michiel Demey and Prof. Dr. Marc Leman

Abstract. This paper discusses the need to redefine the concept of 'interaction' within the context of interactive (audio) installations. This discussion is based on the realization of 'The Heart as an Ocean', a media piece that explores the relationship between auditory senses and biometric feedback.

8.1.1. Interactivity in the context of arts

'The Heart as an Ocean' is a new media piece (designed by the first author) that is based on the artistic use of the participant's auditory senses and biometric feedback. In a broader context, 'The heart as an Ocean' also functions as an experimental setting in which new forms of interactivity are explored , more particularly in the context of media installations and new technologies. The media piece explores the fundamentals of meaningful interaction by looking

to what extend the physiology of the body can be both sensor and actuator in an art context. The installation was first exhibited at Gallery Jan Colle in Ghent, Belgium (Coussement: 2007) in February 2007.

Figure 49: Gallery Jan Colle, Belgium.

8.1.2.   Problem definition

Within the arts, interactive media installations become more and more prominent, although interactive media installations are seldom part of the permanent collection of museums. Interactive media installations have been mostly exhibited at special festivals like the Ars Electronica festival in Austria or SIGGRAPH in the U.S. Recently some private organizations, started to build

collections of media installations (in Belgium, see the Verbeke Foundation (Verbeke, 2008). Although they are oriented towards a more general public rather than a public of specialists, it still requires a specialized exhibition environment and some advanced maintainability of the installations.

8.1.3. Interface and usability

The usability and user interaction are among the most defining factors when developing interactive media installations for art. When dealing with usability it is important to take into account that technical complexity of both the user- interface and the sensory data mapping which mainly influences the experience. On the one hand the complexity can be due to the fact that the user interface is too complex or on the other hand that reactions of the system having little to none of an obvious correlation with the public's interaction. Until now this resulted into a way of thinking about 'interactivity', usability and interface design as a subtle equilibrium between the need of easy-to-use interfaces and a certain amount of complexity. This should result in an exciting experience where people are challenged to explore and play with the installation. Although this may be sufficient to explore some technical issues surrounding new media installations it seems not sufficient enough to explore a more conceptualized meaningful interaction.

8.1.3.1. Meaningful interaction

In the design of 'The Heart as an Ocean', art has been conceived as a way to communicate between artist and public, but also to communicate on a broader social level among the public itself. Art communicates ideas through sense and the artistic experience is a result of the effectiveness of this communication. It involves a conversation between artist and art piece, and between art piece and

public. Within an ideal interaction this relation is symbiotic both in concept as in realization. There is a need to differentiate between responsiveness and interaction even though both may have its distinct use in digital arts and entertainment.

The responsiveness of interactive art can be situated between a range of 100% responsive and 100% autonomous. From that perspective, hyperinstruments (Machover, 2012) for example, are 100% responsive since they always respond in the same manner to the same stimuli. However in using hyperinstruments in interactive installations, the public is often confronted with a learning curve during which technical possibilities and functions of the device have to be explored and learned. Of course this may be fun and exciting in itself. Yet, in the end this focus on the instrument may result in a rather limited experience of interaction, since the interaction does not necessarily imply a goal-direction. Therefore no effect of non-mediation or implicit conceptual meaning can be developed. As a result, the artist may have the feeling that the public is not able to transcend beyond the barrier of the technological mediator, and the public may have the feeling that it never experienced the artist's intentions.

The question is whether it is possible to cope with this problem of technological mediation and learning curves. Are there ways to overcome the inherent limitations of hyperinstruments?

8.1.4.   Basic concept

In 'The Heart as an Ocean', the goal was to get a natural flow of communication without the restrictions of having a too technical interface that could obtrude the intended interaction. The interaction had to work like an affordance. No

sophisticated explanations should be necessary to interact, and user feedback should be based on a very strong homogeneity in 'experiencing'.

8.1.4.1.   In depth concept

The media piece was designed in such a way that the state of mind of any person who interacts with the installation could be sensed. This way it would be possible to influence that person's physiology through sound in such a way that the outcome would be similar for every participant.

To achieve this goal, a synthesized ocean wave was created, that imitated the breaking of a wave on an imaginary shore. The intensity, level, duration and amplitude of the wave are all derived from the heart rate of the person who interacts with the installation. The way in which the musical parameters relate to heart rate is as follows: an agitated person, with a strong and fast heart rate, would generate strong loud and fast waves. A calm person, with a weak and slow heart rate, would generate slow and gentle waves. Since a new wave is generated at every heartbeat the auditory illusion of a sea breaking on a shore is created. This effect is emphasized by a spatial movement of each wave in a setup with eight speakers. Each wave starts its cycle randomly at one position and moves through the auditory space using the other speakers. The sound of the sea was initially chosen because of its soothing effect. Secondly, water has played an important role in the spiritual, psychological and physical ablution throughout history. Moreover, the sound of the sea has all frequency bands in it and therefore, it can be conceived as a sort of a white noise signal spread out in space. Because of this, it largely numbers out all other surrounding sounds resulting in a very personal auditory space. Michael Wenger, Dean of Buddhist Studies at the San Francisco Zen Centre, speaks about this:

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Moving water is 'white noise', in which you can hear
many things. Each individual may hear a different
song in the water. Just listening to the sound--
not tying it to anything, just letting sound wash
over you--is a way of letting go of your ideas and
directly experiencing things as they are.
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8.1.5.   Technical realization

When the installation was first presented there were some difficulties related to the use of the heart rate sensor, which had to be taken into consideration while programming the software. During a recent upgrade of the project, the heart rate sensor has been replaced with a wireless sensor. This gives better results and leads to a less obtrusive interaction.

8.1.5.1.   Hardware

'The Heart as an Ocean' consisted of seven satellite speakers, one subwoofers and a heart rate sensor hooked up to an Arduino board[1] connected to a Mac Book. The seven satellite speakers were spread across a wall spanning eight meters. The subwoofer was discretely placed in the room. An M-Audio Firewire audiophile was used in conjunction with the computer line output to create an aggregated device providing eight line level outputs. An extra nineteen-inch screen showed the software GUI. The speakers were hidden in order to emphasize the atmosphere of the exhibition space, giving more room to the audio.

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1   Arduino is an open-source electronics prototyping platform http://www.arduino.cc/

[enter Name here]

[name]   [record]

The Heart as an Ocean
Pieter Coussement
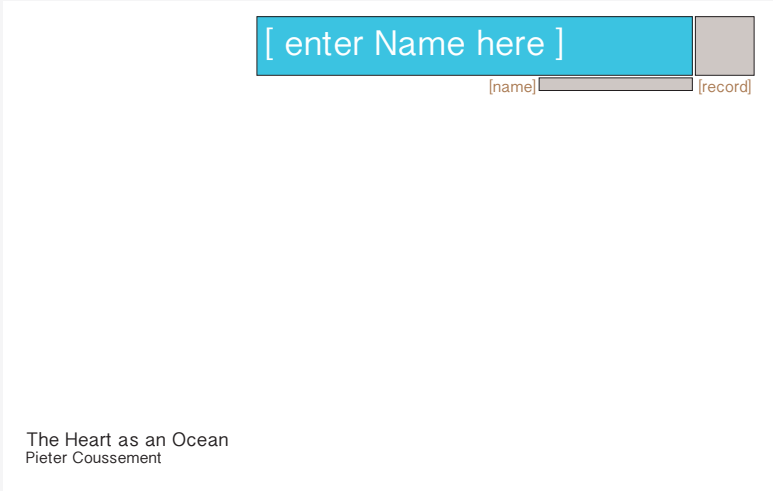
Figure 50: GUI enabling a named recording

8.1.5.2.   Software

The software is developed using Cycling 74's MAX/MSP. On the top level there is a GUI running, which enables a real-time HD recording of the interaction. This can be rendered to a DVD and is offered as a multiple.

Beneath the GUI level there are several patches working together to capture and calculate the heart rate from the sensor, create the waves, take care of the spatial position of the wave and render the recording.

8.1.6.   Action-reaction cycle.

In order to get a meaningful interaction, a feedback loop was installed, based on an action-reaction cycle model for ecological interaction (Leman, 2007). The cycle consists out of 4 stages, called: Play, Listen, Judge and Change. Play is the stage in which sound is generated. Listen involves the perception of sound, while Judge involves its evaluation. In the final stage the action is changed to modify the resulting sound. Within interactive art, both the Judge and Change stages are often left unexplored, resulting either in responsive art intended as responsive art or responsive art intended as interactive art. Both have little to do with what I call meaningful interaction. Within the states Judge and Change lies the essence of meaningful interaction because they rely on the activity of the participant, even if this activity is unconsciously stimulated.

In the case of 'The Heart as an Ocean', the Judge and Change stages are implemented in a rather direct way. Judge is calculated as the relationship between speed and amplitude of previous waves and the heart rate. Change is calculated as the amount of energy the installation will implement in the next wave. To complete the cycle, the installation will first Listen to the heart rate and only then start to Play.

Even though the mapping is rather obvious, the results were impressive. People interacting with the installation all made similar comments. The participants found the interacting to have a soothing effect. Most of the participants identified with the sound. They liked to listen to themselves. Some of them fantasized what kind of beach (either sandy or rocky etc.) they were on through analyzing the sound. Most of them wanted to walk in the

exhibition space instead of sitting down, what has led me to change the sensor into a wireless sensor for future exhibitions.

8.1.7.   Problems to solve / Problems solved.

Concerning the installation, some changes have further improved the basis for interacting. Originally, the heart rate sensor used a three point measuring technique with the consequence that the public had to sit down in front of the installation. In addition, there was also a lot of noise in the sensor data that had to be filtered out. More accurate commercial heart rate sensors were at that time too expensive or too hard to implement. As a result, not every heartbeat came across and sometimes, although largely filtered out, noise was interpreted as a heartbeat. By using new commercial wireless heart rate sensors, these problems have now been fixed. Although a speaker setup spanning eight meter is enough to have a distinct spatial impression, a lot of extra reverb effects were added to ameliorate the experience. Having a bigger exhibition space with more speakers and more generated waves is preferred.

8.1.8.   Discussion

The reaction of the public corresponded with the intended design of this project. And after some time, depending on the subjects, the effects of the installation on the public's physiology were quite similar. This leads to some points of interest in extending our research of interactive art. First of all, there is indeed the need to further (re)define interaction within interactive arts. The idea that the installation needs to mediate intelligently between the artist's concept and what the public conceives is of great importance. Secondly, if you choose to implement interactivity, it should be a necessity from the point of view of the affordance of the installation, which engages the user in an

interaction that is originally intended, rather than in an interaction about the technological mediator. Finally, it can be stated that interactive and responsive art are essentially different from each other. The main difference is that interactive art subscribes an action-reaction cycle model in which feedback has an effect on the conditions for interaction.

8.1.9. References

The references have been included in the list of references at the end of the thesis.

8.2. Coming From the Heart: heart rate synchronization through sound

Authors. Pieter Coussement, Dr. Michiel Demey, Prof. Dr. Marc Leman

Abstract. This paper encompasses recent art works of the first author, where the use of biometrics, more precise EKG, was explored in the context of interactive installation art. The paper also introduces a series of ongoing experiments, in which the effects of audio stimuli on heart rate is studied. These experiments aim to study if and how the human body copes with attuning to rhythmic stimuli. The used stimuli are derived from peoples heart rate, creating a feedback loop to be used in artistic interactive work.

Keywords. Interaction, biometric, embodiment, heart rate, sound, art

8.2.1. Theoretical background

8.2.1.1. New media vs the mapping problem

Art has consistently dealt with mapping problems, although in traditional art they are more related to senses as to sensors. Meaning within an art piece can be regarded as being embedded in the combination of a given sociocultural context, the artist's concept and the public's interpretation. How meaning is constructed is a much debated topic in formal and new media art. However in new media art the discussion becomes even more complex when the incorporation of sensor technology and participation of the public is included as valued parameters in the construction of meaning. In sum it can even be argued that the mapping problem (or more appropriate, how artists handle

this) is one of the main topics of new media art. Dealing with the creative or artistic way in which meaning is communicated through form or sound might well be the essence of 'creating art'.

In interactive art, this mapping problem becomes increasingly complex, seeing that the public is invited to become an equal partner in the construction of meaning. This role is far more than merely fulfilling a role as an interpreter of (artistically) implied meaning. Media theorist Andy Cameron addressed the public's role in interactive media in his presentation 'Dissimulations, The illusion of interactivity' (1998), he states that "Interactivity is the ability to intervene in a meaningful way within the representation itself not to read it differently." [sic].

Furthermore, in his book 'The Language of New Media' (2001) Lev Manovich differentiates between 'open interactivity' and 'closed interactivity', the latter referring to a fixed branching structure where the choices of the user define the path they follow. This is to a great extend what Cameron refers to as 'to read it [the representation] differently'. In contrast, open interactivity refers to the use of artificial intelligence, artificial life and neural networks coded into software. At the same time, Manovich warns about using the term 'interactive media' when addressing the post- modern shift towards a physical interaction between the user and a media object. He states that this occurs "...at the expense of psychological interaction."

Therefore, the development of sensor technology and implementation of this technology in interactive art works should be guided away from the object (or interface) towards the experience. Focus should be on humanizing the objects rather than objectifying humans. As a result the author presents a strategy towards 'natural' mapping which can guide future research.

8.2.1.2.   Interactivity in music and sound art

Within music research, interactivity is a well established concept. The process of interactivity is a cyclic process, described as an action-reaction cycle (Figure 51) in Marc Leman's book 'Embodied Music Cognition and Mediation Technology'.(2008)
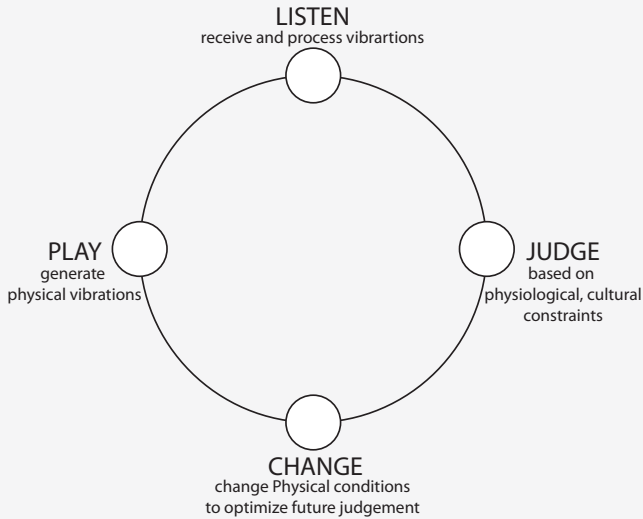
Figure 51: action-reaction cycle

Interaction is made apparent by using the metaphor of how an instrument is built. While playing the instrument, the resulting sound is processed by the human auditory system. A perception is build up in the mind and judged, by undertaking an action the instrument can be changed. This results in a change of the conditions of the instrument and as a consequence this changes the sound produced by the instrument when it is played.

Leman extends this idea in his model of musical communication, with the purpose of communicating musical intentionality between listener and performer. This is realized through corporeal articulations, transformed through the use of a mediator. This mediation technology can ideally be

perceived as an extension of the body, capable of interpreting the intent of the performer and distinguishing between various sets of actions. This implies that the mediation technology should be considered no longer merely as an object to which the performer needs to focus his energy, but as an agent, that is on its own capable of interpreting this energy.

8.2.1.3. Interactivity in new media art

In new media art, which can include multi sensory aspects and is not only sound-related, the action-reaction cycle or model for musical communication may be less apparent. In his introduction on multimedia environments, Leman proposes to "create an autonomous virtual social agent that is able to communicate..." [sic], such agents should be able to deal with capabilities of both synthesis and analysis. In order to do so, it is necessary to have a mapping strategy that is deduced from objective measurements, ideally cross-referenced with an analysis of subjective experience. This mapping strategy should also have a more universal nature than a mapping available to the public based solely on the artist's decisions.

8.2.1.4. Interactivity and biometrics

The availability of a large range of bio sensors at a reasonable cost is fairly new for artists and it is imperative that new mapping strategies are researched. The choice for using a heart rate sensor is very much related to the belief that change in heart rate is an involuntary corporeal function, and thus it should behave on a more subliminal level than responses induced by cognition.

Rethinking Interactive Arts - a viewpoint based on social embodiment

8.2.2.   Artistic background

The experiments are founded on two existing art-installations of the first author, the first being "LiebesLektion", an (unintentional) responsive work dating from 2003. While the second is an interactive sound-installation called "the Heart as an Ocean"(Coussement, 2008) (Figure 52).

Figure 52: the Heart as an Ocean, exhibited at the new media festival PLUTO, 2009

For "LiebesLektion" a specially designed contact microphone was used to record the heart rate of two lovers while embracing each other. Every recording made, showed that after approximately 15 minutes the heart rate and phase of the two persons grew very close to each other. Whether or not this was due

to the fact that they were physically touching was not investigated further. However, when exhibiting the piece, the public's response to "LiebesLektion" was striking. Everyone but one who stayed near the installation left the exhibition space relaxed. The one exception being a man with a pacemaker implanted.

These findings led the first author to the second installation "The Heart as an Ocean" in which the heart rate of a participant is transformed into a sounding ocean, thus binding the heart rate and rhythm more subtly to sound. Here also, people had a feeling of getting more relaxed while interacting with the installation. The goal of 'The Heart as an Ocean', is to generate a natural flow of communication, and the installation was developed to be easily comprehensible as a more complex technical interface could obtrude the intended interaction. The interaction functions more as an affordance (Gibson, 1977). Where objects refer to just those action possibilities which are readily perceivable by a participant. On that account sophisticated explanations should be unnecessary to begin interaction, and user feedback should be based on a strong homogeneity in 'experiencing'.

The experience would originate out of a reflection of the state of mind of the person interacting with the installation. For this reflection, a synthesized ocean wave is created every third heartbeat. The total of consecutive waves imitates the sound of an ocean breaking on an imaginary shore. The intensity, level, duration and amplitude of each wave are all derived from the heart rate, detected by a Suunto comfort belt, of the person interacting with the installation. Musical parameters are altered in direct relation to heart rate: an agitated person, with a strong and fast heart rate, would generate strong loud and fast waves; a calm person, with a slow heart rate, would generate slow and gentle waves.

Rethinking Interactive Arts - a viewpoint based on social embodiment
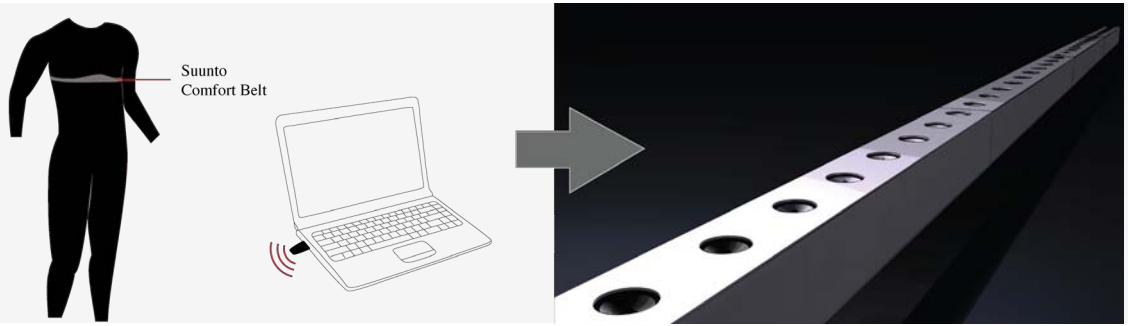
Figure 53: the Heart as an Ocean, diagram

The effect of a sea breaking on a shore is emphasized by the spatial movement of each wave in a setup with twenty speakers. Each wave starts its cycle randomly at one position and moves through the auditory space using the other speakers. The sound of the sea was initially chosen because of its soothing effect. Water has also played an important role in the spiritual, psychological and physical ablution throughout history. Moreover, the sound of the sea contains all frequency bands and therefore, can be conceived as a type of a white noise signal in space. As a result, surrounding sounds are numbered out, resulting in a very personal auditory space. Throughout the first five to ten minutes the mean heart rate is calculated and delta times between heart beats are compared (to detect if people where straining to affect the installation more by, for example, running). After which the software gently lowers the presented heartbeat and makes a prediction on when the following beat will occur. When the trend of the following heartbeats is as predicted this process is repeated, further lowering the tempo. If not the installation adapts to the participants heart rate again.

The installation imposes a different rhythm upon the participant in an attempt to lower that participants heartbeat, relaxing him/her without causing any strain on the body.

8.2.3.   Previous research

Previous research studies in music therapy (Knight et al., 2001) report on the impact of 'sedative' music on anxiety. Wendy E.J. Knight et al. executed a lab experiment with eighty-nine participants, in which the goal was to see whether 'sedative music' prevents stress-induced increases in subjective anxiety, systolic blood pressure and heart rate. The piece selected for the experiment was Pachelbel's Canon in D major. Previous studies reported that the piece induced relaxation in many participants. The results of this study suggests that music indeed largely prevents increase of subjective anxiety and heart rate. In fact, in most cases there seemed to be a slight reduction in stress levels. However, whether or not music is classified as being 'sedative' or 'stimulating' has been argued to be an oversimplification (Hodges, 1980). Furthermore, Repp and Penel (2003) found evidence that synchronization of movement with auditory rhythms is more common than synchronization with purely visual rhythms. Synchronization can be conceived of as a type of sensorimotor mechanism and is, in principle, possible without paying to much attention to the physical stimulation.

The aim of the experiments described in this paper is to investigate if this synchronization is also reflected in heart rate, and investigate if evidence can be found of the soothing effects of sound with non-musical stimuli. The experiments forgo the term music, due to its cultural references, and investigate to what extent sound can induce or effectuate a connections with biological responses. These experiments investigate the physiological responses to sound stimuli and are targeted towards implementation in artistic projects.

8.2.4. Experimental setup

Relaxing music is, in general, characterized by slow tempo, repetitive rhythmic patterns and gentle contours. Based on this categorization, we opted to concentrate on the element of repetition in conjunction with slow tempo, and designed a synthetic heartbeat from a sine wave oscillator with both amplitude as frequency modulation.

The stimulus is produced as follows. The ADSR envelope shaping the frequency, set at 102.4 Hz, has a sharp attack and a sustain of half of the attack value. Thus keeping the tail of the presented sound at 51.2Hz. The amplitude modulation has an identical attack but has a more gradual decreasing tail. Combining two sounds results in the easily recognizable sound of a heartbeat (Figure 54).

Figure 54:   example of synthesised heart beat

The experiment consists out of 3 consecutive stages of five minutes each. In the course of the first stage, the test subject is listening to the synthesized heart beat, synchronized to his or her own heart rate. Throughout this first stage, the average heart rate of the participant is calculated. In the second stage, twenty beats per minute are deducted from this average over a period of one and a half minutes, after which the heart rate presented normalizes to a slow pulsating rhythm. During the third stage the rhythm increases until it it is synchronized with the heart rate of the test subject.

An I-cubeX wi-microSystem, from the company infusionsystems, is used for sending the data to the computer. Both a BioEmo and a BioBeat are connected to the ADC in order to measure GSR (BioEmo) and the full EKG (BioBeat). The heart rate is derived from the EKG signal, after which it is sent to a pulse train to trigger the audio-synthesis. The BPM that is detected is simultaneously recorded with the EKG and GSR values for further analysis. All the data recording and the sound synthesis is handled by a MAX/MSP patch. After the experiment each subject is asked to comment on their experience in a short interview.

8.2.5. Results

The study took place in a quiet room where the 10 subjects were tested individually. The task at hand for them is to sit back in a comfortable sofa and relax while concentrating on the sound. hey were told that they would be listening to their heartbeat and that this stimulus would change it's rhythm twice.

8.2.5.1. Subjective data

Each of the participants was asked to respond to the following questions:

- Could you identify the heartbeat you heard as being a part of you?

- Did you feel like you had to change anything during the experiment to cope with what you heard?

- Could you clearly differentiate between the consecutive stages?

- Could you describe how and what you felt throughout the different stages of the experiment?

All participants except for one reported that the presented stimulus sounded natural. In the first stage of the experiment, they identified with the sound and though it to be a part of them. The people who identified with the sound also reported that the rhythm was mesmerizing, only one of them reported the experience thus far as being stress inducing. She elaborated on this by explaining that this was because she was very concentrated and overwhelmed by what she heard and was not used to 'sitting still'.

On the second question, there was a wide variety of answers, with reference to the first two stages of the experiment. Most noticeable was the answer of the participant who could not identify with the sound, he reported feeling compelled to adapt his breathing to what he heard to make the experience more tolerable. There were another three subjects that noticed change in how they were breathing, and reported there breathing slowed down in the transition from the first to the second stage of the experiment. The other six didn't notice any immediate change in behavior.

All of the participants outlined the three stages of the experiment without difficulty. In the second stage all participants but one felt detached from the sound, reporting no identification what so ever, describing the sound as 'just something in the back' or 'noise'. One described the second stage of the experiment as being 'exterior' as opposed to an 'interior' feeling in the first and third stage.

The transition from the first to the second stage felt strange for some (30%), with people thinking things like 'what is wrong with me', or 'what are they doing to me'. The transition from the second to the third stage was more worrying to our participants, with 70% of them reporting an apparent reaction.

Four participants started breathing faster to 'calm their heart' while the other three simply reported being stressed. During the third stage, all the subjects that felt initially identified with the sound, felt the same level of identification.

Most of them found the whole experience calming, although none of them could say with certainty if it was the stimulus or the mere fact that they had a 20 minute break in a comfortable sofa.

8.2.5.2.   Objective data

When analyzing GSR and EKG no conclusive results were found. Although, with a few of the subjects, it seemed that when the heart rate dropped there was a tendency to follow no significance was found, and the results remain inconclusive. The average heart rate did not change according to the setup during the experiment. There was hardly any activity measurable in the GSR signal, which leads us to believe there was no significant raise of stress levels.

8.2.6.   Discussion

To our knowledge, there are not that many art projects concerned with biometric sensing and biofeedback. The most well known in art history are perhaps the compositions of Alvin Lucier and David Rosenboom. In his Music for Solo Perfomer (Lucier, 1965), for example, Alvin Lucier uses EEG electrodes to detect alpha waves to actuate percussive devices like kettle drums and snare drums, among others. However, it was David Rosenboom that has been the most articulate on the role of systematic change in biofeedback music. His own brainwave analysis software, used "for creating self-organizing musical forms" being just one example. In "On being Invisible", which he composed in 1976-1977, the software learns the cognitive processes mapped to his

listening over time, thus truly envisioning the concept of creating a feedback loop. He describes "On being Invisible" as "a self-organizing, dynamical system, rather than a fixed musical composition" (Rosenboom, 2000) A more recent example is Atau Tanaka's BioMuse instrument (Tanaka,1995), which he plays solo or in Sensorband, an ensemble formed by Edwin van der Heide, Zbigniew Karkowski and Atau Tanaka. The BioMuse is a system that tracks neural signals (EMG), translating electrical signals from the body into digital data and via software to sound.

Our prognosis is, that there will be an increasing amount of projects dealing with biometrics, seeing that biosensors become more commercially available. They have already been widely used to interpret the effects of sound (and vision) in both medicine and psychology. Concerning systematic musicology, and to be more precise our research group, the use of biometric for monitoring is still in its early stages. Using biometrics as a means of creating the aforementioned feedback loop is even more in its infancy. The aim of this paper and the discussed research is to create a framework where the physical influences of sound on the human body are explored and documented, in conjunction with qualitative results. This to increase our knowledge about how we encode what into sound, and if it will affect us humans universally.

The results of this paper are to no extend conclusive and a larger study need to be done. However the sense of identification with a sounding heartbeat and the lack thereof when listening to a very disassociated heartbeat is a trend we would like to explore further. The feeling our participants had of getting more relaxed when concentrating on the rhythmic pattern of their own heart as opposed to the second transitional stage in which they reported discomfort leads us to believe there is some room to explore this further.

In conclusion we acknowledge that the setup of our experiment could be approved upon. Having people exposed to music only on headphones might be a much to limited experience, seeing that we l are responsive to low frequency vibrations with the whole of our bodies and not only with our, specialist, ears. The setup also commenced with people being at rest. There is no clear manner for them to actually direct their actions into getting relaxed, for instance sitting down when being upright or even lying down. The effects should be further quantified in order to make a more firm statement, that is not only of concern in a lab context but is at the same time pointed towards implementations into artistic projects.

8.2.7. Acknowledgments

I would like to thank my promoter Marc Leman for his insightful ideas and remarks. The further development of this installation and surrounding research is made possible by the EmcoMetecca project at IPEM. I would like to express my gratitude to Nuno Diniz, who wrote the Java program, connecting the heart rate sensor to my software, and Ivan Schepers for many hours of testing and rethinking the electronics of the installation.

8.2.8. References

The references have been included in the list of references at the end of the thesis.

Rethinking Interactive Arts - a viewpoint based on social embodiment

8.3. "playing robot": An Interactive Sound Installation in Human-Robot Interaction Design for New Media Art

Authors. Benjamin Buch, Pieter Coussement, Lüder Schmidt

Abstract. In this study artistic human-robot interaction design is introduced as a means for scientific research and artistic investigations. It serves as a methodology for situated cognition integrating empirical methodology and computational modeling, and is exemplified by the installation playing robot. Its artistic purpose is to aid to create and explore robots as a new medium for art and entertainment. We discuss the use of finite state machines to organize robots' behavioral reactions to sensor data, and give a brief outlook on structured observation as a potential method for data collection.

Keywords. Human-Robot Interaction, Embodiment, Finite State Automata, New Media Art, Dynamic Mapping, Structured Observation

8.3.1. Introduction

Playing robot was presented at the ESCOM 2009 conference as an outcome of a students' work from the International Summer School in Systematic, Comparative and Cognitive Musicology (ISSSCCM-09), which both took place in Jyväskylä/Finland. The installation served as an environment for an observational study in human-robot interaction and as a first step in (artistic) human-robot interaction ((A)HRI) design. (A)HRI design is being developed as an integrated research methodology combining empirical-experimental research strategies with computational modeling in investigations on situated cognition and as an application of embodied cognitive science to human-

computer and human-robot interaction in art and entertainment. For the sake of brevity, we use "situated cognition" as an umbrella term for embedded, embodied, and extended approaches to the mind/brain in cognitive science (Robbine et al., 2009). In such a situated approach robots and concepts from robotics are indispensable scientific tools to study empirically the "musical mind/brain", interactivity and systems interacting with their social and natural environment as well as the logic of the underlying biological mechanisms. Concerning art and entertainment we agree with Bar-Cohen and Hanson's (Robbins et al., 2009, p. 112) analysis that "Bio-robotics and AI-driven computer animation promise to transform the face of entertainment and art in ways no previous art medium has" and that...

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. . . artistic explorations effect change in the
mindscape and in our cultural information landscape.
They (i.e. explorations using robots) can forever
change our expectations of what robots are and should
be, and what humans are and what we may be in the
future. (Bar et al.: 2009, p. 114) cf. also the
contributions in (Lischka et.al, 2007)
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To cope with the challenges sketched above we introduce (A)HRI design for the scientific as well as artistic use of robots in New Media Art. The scientific approach uses the metaphor of (A)HRI design to guide experimental design. (A)HRI design is thought of as an extension of observation, experiment, measurement, and modeling to real world situations. Its goal is to establish a methodological foundation for the idea that New Media Art is a testbed for scientific research (Seifert, 2008, Seifert et al., 2008). The artistic purpose of (A)HRI design is to explore the creation of interactive art and entertainment with robots as a completely new medium. playing robot is the first installation we developed to exemplify these ideas.

8.3.2. playing-robot Installation

8.3.2.1. Description of playing robot

Playing robot is an interactive installation which utilizes embodied agents (robots) equipped with sensory and motor devices and computational sound processing to enable interaction with the visitors. It is the first interactive union of a Lego Mindstorms NXT[2] robot, a Khepera III[3] and humans.

For playing robot, the Lego Mindstorms NXT construction system was used to build a turtle-like robot (Benedettelli, 2008, Ch. 6). The Turtle utilizes one control unit based on a 32-bit microprocessor and three servo motors: Two motors actuate the four legs for slow, "crawling" movement; the third one animates the head which consists of a NXT ultrasonic proximity sensor.

The Khepera III robot used in this installation is a small (diameter ca. 13 cm) mobile robot running an embedded Linux operating system on an ARM processor. It is driven by two motors and equipped with ultrasonic and infrared proximity sensors placed horizontally around its body.

The installation takes place in an area of approximately two meters in diameter with no other objects than the robots in it.

When the installation starts, the Khepera III is driving in a circle of approximately 1.5 m in diameter while the Turtle is located a short distance away, facing in the direction of the Khepera III. The Turtle is sitting still, with random leg movements of short duration from time to time. A children's song

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2   http://mindstorms.lego.com/en–us/default.aspx
3   http://www.k–team.com/

is played as an artistically inspired choice to contextualize the robots' playful behavior.

Approaching Khepera III: When a visitor approaches the scene and comes close to the Khepera III, the infrared proximity sensors of the Khepera III are affected. If the distance to the Khepera III falls below approximately 20 cm, both robots change their movements: The Khepera III traces backwards the same circular path, and the Turtle begins to move its legs back and forth rapidly. Those movements produce whizzing sounds due to motor activity. Additionally, the children's song is processed by granular synthesis, resulting in a very noisy sound.

If the visitor keeps a short distance to the Khepera III, following it on its backward course, both robots again change their movement patterns: The Khepera III starts to move back and forth slowly and the Turtle moves forward, slowly approaching the scene. The children's song is again processed by granular synthesis, but this time to produce a purring sound.

If the visitor does not stay close to the Khepera III, the robots fall back into their initial behavior after a certain time. The sound changes back to the original song.

Approaching the Turtle: When a visitor approaches the proximity sensor constituting the Turtle's head to within a range of 20 cm, it starts to move back and forth randomly for 5 seconds. This head movement neither affects the Khepera III nor the sound that is played.

8.3.2.2.   Technical setup

A technical goal of the installation was to have the two robots communicate, one notifying the other if it changed its behavior due to interaction; sensor data derived from human interaction with one robot should also be accessible to the other one.

As the Lego Mindstorms NXT's communication is based on bluetooth whereas the Khepera III communicates via wireless LAN, a direct connection could not be established. Instead, both robots were remotely controlled from a set of computers.

The robots' sensor data was sent to the computers for processing which was integrated with sound generation and the production of motor control commands in Max/MSP. OSC was used as a general protocol for the communication among different applications running on the computers.

As OSC is not natively implemented in the Lego NXT software package, we relied on the Java-based LegOSC[4] for communicating with the Lego NXT. LegOSC works as an OSC gateway and allows any software implementing the OSC protocol to exchange data with the Lego NXT using the built-in bluetooth connectivity.

While the Khepera III is capable of wireless LAN communication, there exists no interface to the OSC protocol. A custom interface[5] was used which enables UDP-based access to the low-level read and write commands of the internal Khepera III control using a PureData patch.

Due to performance reasons, robot control and sound generation were distributed among three computers. The first one was running PureDate and

4   by J. Cardoso, http://diablu.jorgecardoso.eu/
5   written by T. Grewenig and R. Becker

communicated with the Khepera III. The second one was running Max/MSP, did the processing of the data and communicated with the Lego Mindstorms NXT via bluetooth. The third computer was running Max/MSP to process the sound.

8.3.2.3. Art as science

A traditional scientific approach to human-computer and human-robot interaction aims at the evaluation of systems with respect to clearly defined problems to be solved and according performance criteria to be met such as accuracy of task completion and time required (Norman et al., 2008). In the context of interactive artistic installations, however, such well-defined criteria will be difficult to formulate. Instead, reference is made to general notions of interaction and to the quality of observed / experienced interactions e.g. in terms of emotional affection or the time resp. intensity of involvement (cf. Rye et al., 2005).

To go beyond informal descriptions and to allow for scientific investigation of behavior in interactive artistic contexts, artistic human-robot interaction needs to develop a methodology that does justice to the openness of interactions and yet provides for rigorous analysis. As one possible approach we consider the adoption of structured observation (Bakeman, 1997). In order to initiate the development of a coding scheme that is appropriate for the observation of behavior in the context of New Media Art informal observations and video recordings were collected during the playing robot installation.

Within artistic contexts, finite state machines have been recognized as a powerful means to generate complex and interesting interactive behavior (Trogemann et al., 2005, Rye et al., 2005). In particular, one concern in the design of playing robot was to avoid stereotypical system responses in favor

of a dynamical mapping of visitors' behavior to robots' reactions and sound changes, which was based on the state of the system. The intention was to keep the visitors within the interaction process.

Moreover, the idea of finite state machine is discussed in the context of modeling (human) behavior within cognitive science (Burks, 1972-1973). Because of this possible merger between artistic practice and modeling approaches and because of difficulties arising in the interpretation of playing robot in this context, the main focus in the following discussion will be on notions related to finite state machines and their extensions.

8.3.3. Finite State Machines

8.3.3.1. States and behavior

The general idea behind finite automata and finite state machines is that the behavior of a system, e.g. a machine or an animal, is described as a function of its current (internal) state and its current input.

Notions of state that have inspired the design and implementation of the present installation originate in a variety of contexts and are within these applied at different levels. In classical descriptions of physical systems (cf. Messiah, 1958, p. 3) state is conceived of as the information that is necessary to determine the further temporal evolution of the system under given circumstances. It is captured by variables whose values in the course of time are given by the solution of a set of first order differential equations taking into account environmental conditions. Ideally, these differential equations will be formal expressions of physical laws, so that the description in terms of state variables will not only yield accurate predictions of future states but also

provide a kind of explanation of observed sequences of state values (Hempel, 1965).

In the formal context of automata theory the explanatory ideal is typically dropped. Descriptions of computing systems refer to state as an internal or (machine)-configuration (Chomsky, 1963, Turing, 1936) which can change according to certain rules given a specific input and together with the input determines the machine's further operation. Thereby (abstract) sequences of states are separated from their physical realizations and time as parameter is replaced by serial order.

Reference to internal configurations is omitted in an approach advanced e.g. by Minsky (1967): Taking state to be determined by previously encountered conditions and determining future operation of the machine together with external conditions, a definition of state is offered as equivalence class of sequences of previous conditions ("histories") giving rise to identical sequences of future operations for all possible future sequences of external conditions.

A related perspective is taken e.g. in the field of behavior-based robotics (cf. Murphy, 2000, Chapter 5.1). Observable sequences of operations (behaviors) of the systems to be designed are assumed to stand in a one-one relation with internal configurations of the systems, and therefore are taken as unique indicators of system state. In consequence, state and behavior are not treated separately. Instead, states are labeled by the associated behaviors.

In all of these cases, state is employed within a description of a system operating in a certain environment, and it is assumed that a distinction can be drawn between system and environment. Minimally, reference will be made to the possible states of the system, the relevant environmental conditions

interpreted as inputs to the system, and system operation via the combined effects of state and input on future states of the system.

The uses of state and related system descriptions range from detailed accounts of physical processes incorporating explanatory aspirations to heuristic tools for the structured description of a situation in the process of system design. These positions are connected by the common reference to formal properties which are investigated in automata theory. Whereas scientifically oriented applications will probably exhibit an inclination towards the former position, in the case of artistic installation design emphasis will be on the aspect of structured description. It is one of the ultimate goals of the approach presented here to integrate scientific and artistic ideas in a coherent and rigorous manner.

The tasks for interaction design faced in the context of the installation presented included decomposition of the situation in terms of the formal elements of the system description (inputs, states, behaviors, outputs; identification of system and environment) and development of satisfactory input – state/output/ behavior mappings.

More theoretical considerations will address the adequate choice of formalism and the applicability of formal automata/system theoretic results as well as the interpretation of the chosen formalization with respect to the relevant scientific background.

8.3.3.2. FSM: Formal definitions

Generally, two variants of finite state machines are discussed: FSMs which do not produce any output, called *acceptors*, and FSMs with output called *transducers*. If the new state of a FSM is uniquely determined by the current

state and input, it is called *deterministic*. In the following, we will restrict ourselves to deterministic transducers.

Formally, a finite state *transducer* can be described as a 6-tuple (cf. Hopcroft et al., 1979, pp. 42, 43) M = (Q, Σ, O, δ, λ, *qo*) consisting of a finite set of states Q, a finite set of inputs Σ, and a state transition function δ : Q x Σ → Q. The output function " can be defined in two variants:

1) λ : Q → O associating output only with the current state of the FSM; in this case the FSM is called a Moore machine.

2) λ : Q x Σ → O associating output with both a state and an input encountered while the machine is in this state; a FSM conforming to this definition is called a Mealy machine.

Finally, an initial state *qo* needs to be specified.

8.3.3.3.   Playing robot as Finite State Machine

In the case of playing robot state was used to refer to combinations of concurrently running processes (cf. Section Technical setup) which were taken to realize the behavioral patterns described above. Moreover, these states were labeled as playful (P), anxious (A) and trustful (T) in accordance with the artistic scenario alluded to in Section 'Description of playing robot'.

The only inputs to the system *as a whole* were the readings of the infrared sensors of the Khepera III robot. These were differentiated by the conditions of at least one value exceeding 300 indicating an object in the vicinity, referred to as near (n), or all values being less than 300, in the following referred to as far (f). As the conditions for changing the behavior/state of the system also

involved the time span during which a sensor reading n did or did not occur, a timing device needed to be included, which was (re-)started every time the condition n was encountered and expired after a period of 15 seconds.

In terms of finite state machines, the situation may be described as follows: The set Q of states contains the three elements represented by the labels P, A, and T , i.e. Q = {P, A, T }; the initial state q0 of the system is P.

The set of inputs Σ needed to achieve state changes will contain the conditions n and f as well as a condition indicating that the timer has expired, referred to as timeout (t); in consequence, the timer will have to be considered as external to the finite state machine. In symbolic form we have: Σ = {n, f, t}.

Starting resp. re-starting the timer can be captured by allowing the finite state machine upon (re-)entering the states A and T to produce an output start timer, represented by the symbol ◙. Thus, a set of outputs containing this one element will be included: O = {◙}.

Because the output according to this scheme is associated with state transitions and thus with combinations of states and inputs, the finite state machine realized here will best be understood as resembling a Mealy-type FSM.

Although it provided inspiration and guidance in setting up playing robot, the formalism of finite state machines may not be the optimal choice for the purpose of installation/ interaction design: As illustrated by the description of the timer above and the missing integration of the Turtle's head movements into this scheme, the formalism does not lend itself naturally to the treatment of concurrently running processes influencing each other within a single coherent system description. Moreover, the processes underlying the different behaviors of the system are indiscriminately lumped together under one label, although in the process of implementation they were treated rather

independently. Possibly a more satisfactory framework can be provided by an extension of the FSM approach such as that introduced by Harel (e.g. Harel, 1987) under the name of statecharts. These allow e.g. for hierarchical grouping of states as well as simultaneously being in different ("orthogonal") states, and offer the explicit inclusion of temporal conditions.

8.3.4.   Conclusion

Concerning the artistic goal to structure and organize interactive behavior of installations, finite automata appeared to be a good starting point. The FSM we used, however, lacked the features of hierarchical structure and concurrency, which are deemed to be important to achieve interactive or reactive behavior in New Media Art. Therefore, as a next step the exploration of Harel's state-charts (1987) – designed to incorporate these features – may be promising. Moreover, from the development of the installation playing robot arose the necessity to clarify the interpretation of the concept "state" and its relation to the observable behavior of a system.

In the playing robot installation, part of the visitors apparently became involved beyond the point of merely understanding system behavior, exhibiting what may tentatively be called playful interaction. The structure of installation behavior appears to be reflected in visitors' behavioral patterns, although for a more rigorous comparison the tools still need to be adapted. In developing a coding scheme for structured observation which may serve this purpose, hints may be drawn from the observation that some aspects of behavioral patterns implemented in the robots were also displayed by the visitors, such as backing away from each other and avoiding close contact or gently approaching one another. Moreover – and in contrast to previous attempts at observational studies of human-robot interaction, e.g. (Michalowski et.al, 2007) – it should be taken into account, that visitors' behavior was not only directed at the

robots, but also included co visitors. Ultimately, an interpretation of these behavioral patterns in a broader ethological context appears desirable.

Three observations of general interest concern the initialization of the human-robot interaction process, the functional role of the robots' appearance, and the importance of sound for contextualizing the situation. The human-robot interaction should be initiated by the robots or more generally by the designed system. This might be achieved by the physical appearance in connection with meaningful movements. An appearance or behavior vestigially being animated may serve to elicit empathy in humans. Anamorphic structure of a robot in connection with some "provoking" (sound) activity directed towards the visitors of an installation seems useful to attract their attention, interest, and to stimulate interaction. In playing robot the robots' identity and the context of the installation were adapted to the robots' physique and not optimal for human-robot interaction: the robots should not be too tiny and if necessary this should be compensated by artistic means. Sounds may serve as a tool to contextualize meaningfully a situation or the state of the system in order to facilitate "communication" with humans.

In the near future, (A)HRI design in connection with neuro-, social and evolutionary robotics will become indispensable for testing and developing concepts in research on the social human mind/brain and its underlying mechanisms as well as for interactive artistic and entertainment applications.

8.3.5.　Acknowledgements

We would like to thank Erika Donald (McGill University, Montreal) and Jan Richter (Universität Hamburg) as co-workers, Mikko Leimu (University of Jyväskylä) for technical support, and the organizers of ESCOM 2009 for giving us the opportunity to present the installation.

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8.3.7.　References

The references have been included in the list of references at the end of the thesis.

8.4. Dynamic Mapping Strategies for Interactive Art Installations: an Embodied Combined HCI HRI HHI Approach

Authors. Pieter Coussement, Dr. Michiel Demey and Prof. Dr. Marc Leman

Abstract. This paper proposes a theoretical framework for dealing with the paradigm of interactivity in new media art, and how the broad use of the term in different research fields can lead to some misunderstandings. The paper addresses a conceptual view on how we can implement interaction in new media art from an embodied approach that unites views from HCI, HRI and HHI. The focus is on an intuitive mapping of a multitude of sensor data and to extend upon this using the paradigm of (1) finite state machines (FSM) to address dynamic mapping strategies, (2) mediality to address aisthesis and (3) embodiment to address valid mapping strategies originated from natural body movements. The theory put forward is illustrated by a case study.

Keywords. Art, Artificial Intelligence, Finite state machines, Fuzzy systems, Interactive systems.

8.4.1. Introduction

When developing interactive installations we have to be aware of some of the paradigms surrounding interactivity. Addressing interactivity can be done from many different research fields, all posing very different research questions, ranging from psychology to computer science.

8.4.1.1.   Social interaction

As humans, we like to think that interaction is a given, and to some extent this is true; all of us interact with each other on an almost continuous basis, whether we are sitting next to one an other on a bench, are having lunch together or are talking to each other. Apart from our Human Human Interaction (HHI), we spend a great deal of time 'interacting' with the world around us in various ways through a multitude of interfaces. These forms of interaction are subject to various research fields that proof to be even more intriguing.

8.4.1.2.   Computer science

In computer science interaction is by far one of the most fashionable words to date, and is associated with research fields as Human Computer Interaction (HCI), Human Robotic Interaction (HRI), among others. How we perceive interaction is very much dependent on our willingness to conceive something as interactive, the context of our interaction and the partner at hand when interacting. Furthermore, 'being interactive' is a quality that is often stowed upon an object in a very dubious matter. In such a way that it is often a quality that is perceived by the user, not one that is inherent to the object. Of course, since we are designing the object, there is nothing to stop us to make our objects to be responding via sonic, visual or tactile cues.

In this article, I address interactivity from the perspective of a new media artist, and discuss its application in the context of interactive art installations. The theoretical framework starts from an embodied music cognition theory paradigm and extends into new media art. As such it answers questions on how interactivity should (or could) be perceived in art and may lead to a new

way of addressing the concept in HCI, especially in regards to the uprise of physical computing and novel computer interfaces.

8.4.2. How to read the map

Art has consistently dealt with mapping problems, although in traditional art they are more related to senses as to sensors. The meaning within an art piece can be regarded as being embedded in the combination of a given sociocultural context, the artist's concept and the public's interpretation. How we perceive a piece of art is so to speak embedded in how we interact with our environment and how the individual elements are defined within the piece and the way we interact with them.

How meaning is constructed is a much debated topic in formal and new media art. However, in new media art the discussion becomes even more complex when the incorporation of sensors and actuators through the use of technology is included. Including technology enables participation of the public in a valued manner. The degree of participation and the choices for incorporating certain technology become prized parameters in the construction of meaning. In sum it can even be argued that the mapping problem (or more appropriate, how artists handle this) is one of the main topics of new media art. Dealing with the creative or artistic way in which meaning is communicated through form or sound might well be the essence of 'creating art'.

In interactive art, this mapping problem becomes increasingly complex, when the public is invited to become an equal partner in the construction of meaning. This implies far more than merely fulfilling a role as an interpreter of (artistically) implied meaning. Media theorist Andy Cameron addressed the public's role in interactive media in his presentation 'Dissimulations, The illusion of interactivity' (1998), he states that *"Interactivity is the ability to*

intervene in a meaningful way within the representation itself, not to read it differently." [sic]. Lev Manovich subscribes the same idea, in his book 'The Language of New Media' (2001), when differentiating between *'open interactivity'* and *'closed interactivity'*. A segregation that is certainly imperative in the context of new media art. However, it is not my intention to give a classification of new media art in which participation of the public is wanted, but to refine the definition of 'interactive', making it a more evened out term in research and praxis. Manovich states that the proposition of hyperlinking, one of the key elements of interactive media, *"objectifies the process of association"* (2001, p. 61) and questions what to make of this *"desire to externalize the mind"*. There is indeed a danger when following a pre-programmed path, while browsing through a webpage with a fixed branching structure. The choices of the user define the path they follow, and the system they navigate leaves little room +to wonder, as it imposes associations upon the user. This is, of course, to a great extend what Cameron refers to as 'to read it [the representation] differently' [sic]. In contrast, open interactivity can refer to the use of artificial intelligence, artificial life, neural networks and finite state machines, coded into software, leaving room for a more subtle way of interacting with, interpreting and experiencing a work of art. To conclude, he warns about using the term 'interactive media' when addressing the post- modern shift towards a physical interaction between the user and a media object, and states that this occurs *"...at the expense of psychological interaction"*. I concur with Manovich, although I perceive it as a temporary problem, at least in interactive art. One that can be solved by upholding a fully embodied standard in creating art.

8.4.3.   Interactivity in music and sound art

Within music research, interactivity is a well established concept, since it used to comfortably reside within psychology. However, in recent years the

development of new technology has been prying at this comfortable position. In the past a musical instrument has been seen as a natural extension of the body, enabling the performer to surpass the limitations of the body and give way to new corporeal possibilities. When developing new (digital) instruments, this natural extension is not always a given. While classical instruments are very much modeled around the body, new (digital) instruments are often derived from or build upon existing HCI interfaces. Interfaces that are often more inspired by technological advances in the research field, than an intuitive usability. Whether these instruments are more screen-based or tangible, they usually do require more mental processing to make sense of how the interplay of different media works, both for the performer as the public. This interdisciplinary nature is part of every day life and naturally takes hold of music as well. Although this might complicate the discussion on interactivity in regards to music research, by upholding an embodied approach to (musical) interaction, we pave the way to safeguard the psychological interaction, which is of utmost importance when we are confronted with art.

The embodied view of the process of interactivity is of a cyclic nature. Marc Leman describes it as an action-reaction cycle in his book 'Embodied Music Cognition and Mediation Technology' (Leman, 2007).

Interaction is made apparent by using the metaphor of how an instrument is built. While playing the instrument, the resulting sound is processed by the human auditory system. A perception is build up in the mind and judged, by undertaking an action the instrument can be changed. This results in a change of the conditions of the instrument and as a consequence this changes the sound produced by the instrument when it is played.

Leman extends this idea in his model of musical communication, with the purpose of communicating musical intentionality between listener and performer. This is realized through corporeal articulations, transformed

through the use of a mediator. The mediation technology should ideally evolve afresh as an extension of the body. This time it should be capable of interpreting the intent of the performer and distinguishing between various sets of actions, by implementing behavior in software. This implies that the mediation technology should be considered no longer merely as an object to which the performer needs to focus his energy, but as an agent, that is on its own capable of interpreting this energy.

8.4.4.   Interactivity in new media arts

In new media art, which can include multi sensory aspects and is not only sound-related, the action-reaction cycle or model for musical communication may be less apparent. In his introduction on multimedia environments, Leman proposes to *"create an autonomous virtual social agent that is able to communicate..."* [sic], such agents should be able to deal with capabilities of both synthesis and analysis. In order to do so, it is necessary to have a mapping strategy that is deduced from objective measurements, ideally cross-referenced with an analysis of subjective experience. This mapping strategy should also have a more universal nature than a mapping available to the public based solely on the artist's decisions.

8.4.5.   Affordance

Marcel Duchamp exhibiting '*Fountain'* in 1917 is probably one of the most well established examples to date of the use of an everyday objects outside its known context. When coining the term 'Ready-Made', he described it as an object where we have no emotional relationship with, nor a certain opinion about, readymades are an exercise avoiding inurement. Todays technological possibilities make it possible to surpass the level of known things and artists

devoutly spend their lives visualizing their fantasies through art. Still they deal with conventions and constraints, whether they are sociocultural or coming from art history, as an important aspect of their creation process and how the public will perceive the work.

Although Marcel Duchamp predates the theory of affordances by a few decades, '*Fountain*', and any other readymade, is strongly related to it. Affordance is a term the perceptual psychologist James J. Gibson introduced in his 1977 article 'The *Theory of Affordances*' (Gibson, 1977). Gibson meant by affordance '*an action possibility available in the environment to an individual, independent of the individual's ability to perceive this possibility*' (McGrenere et al., 2000). Donald Norman introduced the term to the HCI community in his book *'The Psychology of Everyday Things'*, and differentiates from Gibson's theory:

> *...the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords ('is for') support and, therefore, affords sitting. A chair can also be carried.'* (Norman, 1988, p.9)

The big difference between both theories is that Gibson addresses affordance from the point of view of perception, while Norman refers primarily to the fundamental properties of an object. A logical distinction, if we take their independent goals into account. Gibson was primarily interested in how we perceive the environment, while Norman's interest lies in manipulating or designing the environment. Taking both approaches into account is of vital importance for the suggested mapping strategy.

8.4.5.1. How affordance is used to evoke behavior

In POET (The Psychology of Everyday Things) Norman states that *'understanding how to operate a novel device has three major dimensions: conceptual models, constraints and affordances.'* , emphasizing the role of past experience and culture. In regards to design in HCI, Norman makes a distinction between 'real affordances' and 'perceived affordances', although design is about both, he states that *'the perceived affordances are what determine usability'* (Norman, 1988, p.123).

Gaver (Gaver, 1991) sees affordance as *'properties of the world that are compatible with and relevant for people's interactions'* and addresses the common examples as *'perceptible affordances'*. Designing easily-used systems is making affordances perceptible. To Gaver, the concept of affordances implies that:

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the physical attributes of the thing to be acted
upon are compatible with those of the actor, that
information about those attributes is available in
a form compatible with a perceptual system, and
(implicitly) that these attributes and the action
they make possible are relevant to a culture and a
perceiver.
```

All of the theories imply action-reaction possibilities, whether invoked by culture, memory or functional design. A well designed object will lead to the user acting upon it, this is certainly true for utilities but is equally true for interactive art installations.

8.4.5.2. How affordance is used in art

Within interactive art installations great care is taken in designing the installation itself. Installations can be minimal in design or visually exuberant, small or huge, but they all in one way or another expect the user to experience them fully. The designs that gush a myriad of new technological features are often technically esthetic but their function is awkward. On the other hand, designs based on users' current articulated needs and tasks surpass the potential nested within new technology. This leads to designers introducing terms like 'intuitive gestures' when '*pinching'* photos on their iPod Touch (apple), or *'throwing a frisbee'* to share selected content and catching the data *'like catching a ball'*[6]. Finding new ways of interfacing with novel devices is both exiting and (to some) frightening, and advertising this include a marketing campaign focused on how natural everything appears to be, comparing it to fun games we remember from early childhood. Finding the right balance between new technology and a natural way of interfacing, is therefore imperative, and doing so leads to truly experiencing a work of art or a certain interface. Gaver gives a similar notion in reference to affordances when stating that *'Affordances are not passively perceived, but explored... Exploration of afforded actions leads to discovery of the system, rather than knowledge of the system metaphor leading to expectations of its affordances'*. Whether or not we are designing a computer interface, a new music instrument or a fully multi modal artistic environment, we should keep in mind that exploration of a new yet (strangely) familiar world is key for an intimate artistic experience.

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6   Hoccer: retrieved from www.hoccer.com/video.html

8.4.6.   Aisthesis and mediality

Gibson, Norman and Gaver neglect affordances in the context of social interaction. Both Marc Leman and Lev Manovich, as do I, believe that social interaction is of great importance. Especially in new media art, with its remarkable exploratory ways of 'interfacing'. Hence, the question arises to what extent the actions of others guide our interaction? On a different scale we can ask ourselves if the way we perceive things is not largely influenced by the technology we have been using up until now. According to Jager et al.

> `computerhuman interfaces (CHIs) serve as media, not only in the sense of technical apparatus but also in terms of performing inter-medial translations which act as a condition for the emergence of meaning and/ or experience` (2008)

Creating such interfaces, therefore, requires artistic and technological mediation strategies. She introduces the term '*mediality*' to deal with the question of how CHIs mediate 'meaning' and shape the experience. In Media theory, a medium becomes 'transparent' so that the 'mediatised' comes to the foreground, as such a medium is characterized as being a sterile empty vessel. When dealing with new media art, however, the interface retains its material presence and stays, for a part, opaque. Even though, often, the artist would like to support the illusion of non-mediation in his work, creating a sense of being there, a feeling of presence.

This seems to be a contradiction, while in fact it is not, if you would take social interaction into account. The goal of the artist is to communicate intentionality, as introduced by Marc Leman referring to 'musical intentionality' or Manovich when stressing the importance of psychological interaction. On the public's

side, one of the goals is to pick up on the artist's intentions and distillate a meaning. In return the artist wants to know how his art is perceived by the public, which renders into a cyclic process, key when addressing 'interaction'.

The invitation to act that is embedded in affordance theory might be elaborated within social interaction as an 'invitation to enact'. This whole process is made possible by different strategies, of which mirroring behavior is the most crucial. The experiments of Meltzoff (2002) on imitation behavior in new born human babies have started a silent revolution in thinking about early childhood. Based on these experiments, imitation is believed to be a basic form of corporeal articulation; which is goal-directed and based on purposeful action (Meltzoff et al., 1998). Imitation can also be seen as part of a learning process, including a decomposition of the observed sensory action into constituent components, encoded in motor components. Which is followed by a reconstruction of the action pattern from the motor components. This decomposition is guided by an interpretation of the motor pattern as a goal-directed behavior. The main characteristic of corporeal imitation, in regards of imitation of moving sonic forms is, according to Marc Leman, body movement, and is based on a mirroring process which, in turn, is based on both multi-sensory information-processing and the sensing of movement (kinesthesia) (Leman, 2007, Ch.5 p. 110). In the same chapter Leman mentions 'Embodied Attuning' (p.115), which implies corporeal music in accord with music. Attuning brings the human body into accordance with a particular feature of music, a way of navigating with or inside the music.

All of which leads to empathy, the ability to share another person's feelings or emotions as if they were one's own (see, e.g., Berthoz and Jorland, 2004). This assumes participation, identification and understanding. Recent results (e.g., Carr et al., 2003) suggest that the motor system may access the emotional system with different degrees of engagement, offering a view of how behavioral resonance to affect emotion could be accessed. Embedding

emotional intention in a (virtual) agent through the use of a (virtual) motor system is an approach that is a common practice in responsive environments (e.g. Hylozoic Soil, Philip Beesley, 2009) and/or interactive art.

In artificial environments, where the artist is only represented by his interactive artwork, the cyclic process, previously mentioned, needs to be implemented within the action reaction possibilities, and even action perception possibilities, of the artwork, which suggest agency. According to Jager and Kim *'an interface ... is defined as a part of the machine through which it "communicates" with its environment.'* and 'An interface mediates sensory and motor processes of interacting entities.' (2008). In interactive installations this would suggest that the interacting entities are both of an organic and inorganic nature. Because of the nature of interaction this would mean that both entities are, to some extent, sentient. Although this term is avoided in AI research (mainly because of the possible ethical dilemmas) the definition of sentient, being 'able to perceive or feel things' does attribute to what I believe an interactive art piece should be. Moreover, when we spend so much time and attention to creating anthropomorphic actions, it is a logical step to add the same level on the sensing side. To confirm with AI research, it might be better to imply the installation to seeming sentient. Doing this implies a mapping strategy that is scalable and dynamic.

8.4.7.   Dynamic Mapping Strategy (DMS)

The development of sensor technology and implementation of this technology in interactive art works, through mapping strategies, should be guided away from the object (or interface) towards the experience. Focus should be on humanizing the objects rather than objectifying humans. Creating interactive artworks, therefore, require a sensitive and variable mapping strategy, where multi-sensory information-processing is valued alongside the installation

being aware of its relation to the environment and its own kinesthetic qualities, requiring agency. This should be done with unobtrusive sensor-technology to allow a sense of presence or flow.

The strategy I propose for monitoring behavior can also be used to introduce behavior to artificial entities. It enables us to mimic, or mirror, behavior. This behavior is deducted from objective observations and verified with subjective experiences.

8.4.7.1.   How we can implement DMS using FSM

The website of the National Institute for Standards and Technology states:

a Finite State Machine (FSM) is a model of computation consisting of a set of states, a start state, an input alphabet, and a transition function that maps input symbols and current states to a next state. The computation begins in the start state with an input string, and changes to new states depending on the transition function.' (Black, n.d.)

At its simplest, it is a model of behaviors of a system or a complex object, with a limited (finite) number of defined conditions.

The states define behavior and may produce actions. State transformations are movements from one statement to another. Such a transition is executed when a certain transition condition is met. Usually this requires an input event, either internally or externally generated, triggering one of the rules that lead to the transition. Entry actions define the initial state, providing a starting point. The FSM is self aware, by keeping track of its current state, remembering the

product of its last transition. In Figure 55 a simple example of a FSM is given, with only two states, two conditions, transitions and possible entry actions.
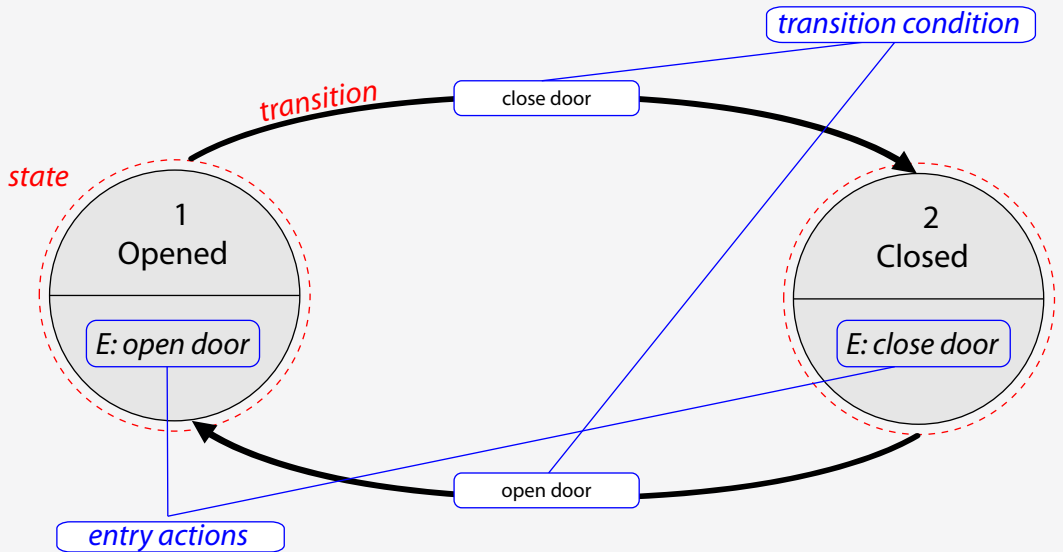
Figure 55: Example of FSM

The use of FSM originated in mathematics, where they were initially used for language representation. But they were quickly adopted by Artificial Intelligence research because of its apparent simplicity to model behavior. They have been used intensively to model the behavior of foes in first person shooters, such as Quake, which lend its game engine to Unreal Tournament and Half-Life later on.

The original FSM is deterministic; a current state together with a given input would always result in the same, predictable, state transformation. This is not always desired, a next step is creating a nondeterministic FSM. Doing this implies that the state transformation is not (easily) predictable. When multiple inputs are received at various times, each weighing into the transition

conditions individually, the outcome is less predictable, making it an event driven system.

Making the FSM even less deterministic, or making a system that upholds its logic but seems to display free will, can be done by introducing Fuzzy Logic. In this fashion a Fuzzy State Machine (FuSM) is created. Here a fuzzy value is assigned to various inputs to represent the degree an input gets defined. The FuSM would take these values into account in regards to state transitions or transition conditions. Conflicts in transitions conditions are then taken into consideration by fuzzy logic, determining the outcome transition. The fuzzy logic system uses weighted input values in evaluation of rules, triggering only state transitions above a certain threshold, making the state machine unpredictable. However, this results in a less transparent FSM, which is not always desired. Incorporating random values into a FSM is another approach, but using only random values, makes the use of a FSM more or less redundant.

In regards to interactive art, the bottom-line is that you need to have a right balance between control and exploration possibilities, while interacting with installations. Having control makes the system comprehensible, while having a world of exploration at your disposal makes sure people feel compelled to continue interacting, discovering the installation layer after layer. Having the right balance makes sure people don't feel lost or intimidated.

8.4.7.2.   On what side

I have mentioned FSM, until now, as primarily targeted towards actions, in that sense the transition conditions are sets of rules and await input of sensors, both internal as external, in order to trigger the state transition. In both human robot interaction, an essential part of interactive kinetic sculptures, as computer human interaction, essential in audiovisual installations that

not include mechanics, triggering a sensor often makes something move, whether this is a mechanical movement, a moving of pixels on a screen, or pressure waves moving through the space carrying sound. All of which imply a behavior that, within the context of FSM, can be seen as a state change.

It is a common usage for FSM to implement nested behaviors, sub states, and so on, creating high level control with individual outcomes depending on the same input signals. This is especially obvious in single mode of first person shooters, there is only one player but different enemies, all enemies share the same goal (killing the player) and thus react to its presence, but all in different ways, using different behaviors. However, the input conditions are, for a larger part, left out of the equation, rendering the input static.

In interactive art, this should be avoided, in view of the fact that we want our installation to appear sentient. Therefore, a FSM machine should include a variability of reading the sensors, according to the state it is in. The linked behavior of the installation should coincide with a measurable and, to some extent, predictable behavior of the public, making it possible to have a sensible mapping in favor of sentient behavior.

This would require a second FSM to be implemented on the sensing side, taking its transition conditions from the FSM machine on the acting side. The action of this 'sensing FSM' would involve filtering, scaling and interpreting the sensor inputs, and parsing them to the 'acting FSM'. This 'sensing FSM' can be addressed in the same manner and with the same precautions as any FSM, making it either fully deterministic or more free.

8.4.8.   Lament: A simple FSM implementation

Music centre 'De Bijloke' commissioned an installation to accompany the musical program around the Lamentation week organized in 2009.

8.4.8.1.   Technology

The installation consists out of five suspended megaphones, which are spread throughout the exhibition spaced in a circular fashion. The five Megaphones are altered to be more suited for the installation, the controls on the megaphones are overridden and the amplification and volume control of both the input (microphones) and output (speakers) is controlled by external software.

Figure 56: Installation view of Lament, as exhibited at music centre De Bijloke

The different materials used for the walls and unique room acoustics of the exhibiting space make it necessary to be able to adapt the way the installation reacts to sound input. The software, as seen on Figure 57, has independent controls for all five megaphones, and the ability to expand the installation with a sixth megaphone, when installed in larger spaces.

Each of the megaphones has two sound layers, one is a continuous ambient sound layer, the other is a singing voice, which is only heard when there is a direct interaction with the megaphone. The volumes of both sound layers, and the sensitivity of the megaphones is initiated on start up and can be adjusted according to the room. The thresholds, to distinguish between the two sound layers, is set on the first public viewing as default values, and saved with the software. Additional controls included are for reverberation and delay, to compromise for the distinct acoustics of horn speakers and any artifacts that come from the installation site. The megaphones' microphones, listen to what goes on in the room, and transfer this information to a computer.


Figure 57: Control software for Lament, written in max/MSP

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8.4.9. Implementation as a FSM

Each of the five megaphones is an independent cluster of two FSM, one FSM is listening to inputs from the outside world, adjusting states as to what they are capturing in regards to the state of the acting FSM. The acting FSM, in its turn, listens to inputs from the sensing FSM, and adjusts its behavior accordingly. The states defined for the acting FSM are (a) murmuring and (b) shouting, and on the sensing FSM the states are (a) listening closely and (b) listening afar. State changes occur in the sensing FSM because it distinguishes between two amplitude ranges, on the one hand there are the subtle differences in surrounding sounds *(listening afar)*. On the other hand, the second amplitude range is sensed when someone speaks directly into the megaphone, resulting in a state transition to *listening closely*. On the side of the acting FSM, this leads to *a murmuring state* corresponding to the *listening afar* state, or the *shouting* state which is linked to the *listening closely* state.

Together, the five atmospheric layers which occur from five simultaneous *murmuring* states, form a musical backdrop, and a possible maximum of five voices, when all megaphones are in *shouting* state, combine to a room-filling, ever changing sound installation. Because each of the five megaphones is an individual entity, and taken into account that within each state the external inputs from the microphones is continuously influencing the state behavior, the possible variations are myriad.

8.4.10. Conclusion

The use of FSM for interactive installations makes it possible to introduce Dynamic Mapping Strategies for Interactive art. However, simply implementing this, does not necessarily make the experience more meaningful. The paradigm of embodied music cognition, extended towards new media

art, may well provide a way of solving some of the persistent problems in the development of intuitive mappings. Therefore, an extended study with a combined objective approach, measuring sensor data, and a subjective approach, measuring perceived experience, on how people interact with new media art is imperative. Extending this to include monitoring robotic or virtual behavior, using measurements of their senses (sensors) and their experiences (states) is a given, since we model our interactive environments on the knowledge we obtain from HHI. This leads also to the inclusion of affordance theory both from the viewpoint of the subject (Gibson) and the object (Norman), the inclusion of the theory of mediality, since it clearly shows that there is an evolution in thinking and feeling initiated by merely using technology. For artists, this becomes even more apparent, when the concept of their work is guided by the way they are computing.

In discussing Lament, a concrete example is given on how the implementation of a FSM, on both the sensing as the acting side, helps to introduce interactivity. Although the amount of different states available in the Lament installation is limited, it is clear that this evokes an emergence, while keeping the readability of the installation. However, it should be noted that the readability lies not merely in the implementation of the FSM paradigm, but lies within the combination of affordances, mediality and usability.

It is our believe that combining theories from HCI, HRI and HHI, as supported by this paper, will result in installations that envision interactivity in a more social manner, leading to a more valued artistic experience.

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8.4.11. Acknowledgement

8.4.12. References

The references have been included in the list of references at the end of the thesis.

8.5. Mediality and Singing Performance: New Approaches to Musical Interactivity using the DIVA system (Dynamically Integrated Vocal Augmentation)

Authors. Pieter Coussement, Katty Kochman & Prof. Dr. Marc Leman

8.5.1. Introduction

According to Seifert and Kim (2008, p.178), "…mediality emphasizes the relevance of external representations and processes mediated by a 'medium', which not only serves as a passive means of conveying the message, information or intention, but also participates in shaping." Mediality thus implies that the media can function not only as a means of conveying a musical message, but that it also influences the shaping of that message.

This concept of mediality is relevant for new approaches to musical interactivity and performance, especially for those approaches in which the performer's gestural control of audio effects uses dynamic mapping strategies. Rather than being based on a fixed set of functionalities, these dynamic mapping strategies are situated in gesture-audio interactions at different adaptive levels. The technological mediators that produce this kind of interaction intervene between the performer's musical objectives and the actual realization of the performance. Mediality is an important theoretical concept, clarifying the specific nature of the technological mediators in formation and structuring of communicative processes. In this paper, our objective is to assess if technological mediators can be designed to enhance the expressiveness of

a vocal performance in a way that is natural and unobtrusive for both the performer and the spectator.

Vocal performance provides a relevant environment for the development of such technological mediators. Vocal performance is regularly accompanied by body movements (e.g. breathing, posture) and gestures (e.g. arm movements, facial expressions). When combined effectively, these factors determine the outcome of vocal performance. In operatic singing in particular, the sung message is shaped by the gestures that support the dramatic setting, giving the message a particular expression and shape within the context of a staged performance. In vocal performance, the dramatic expressivity of the sound message is regularly shaped by the gestures that support the dramatic setting, giving the vocal melodies a characteristic expression and form within the context of a specific vocal composition. Therefore, the design of a multimodal technological mediator should be focused on evaluating gestural messages that involve dramatic expressivity of classical vocal compositions. The integration of technology into vocal performance should enhance the communicative intent, performance effectiveness and dramatic expressivity, while not detracting from performer-audience interactions. For these objectives to be realized, the incorporation of technology should emerge from a necessity for the expression of communicative intent in the piece performed.

The use of technology in vocal performance involves several issues, such as the time at which technology is introduced into the production (at an early or late stage of the performance development), the role it plays within the performance and how it communicates the message. These complex issues determine the design of a system that comprises both a development of technology and of a particular performance application. In this study, these issues are examined proactively in the development of a performance application for singers. Our design model aimed at the advancement of media in vocal arts, using technology that supports effective musical communication

and that facilitates the manner in which classical vocal compositions are performed. The design resulted in the DIVA application, which is a gestural-controlled tool that extends the characteristics of the vocal performance, on a natural and unobtrusive basis.

As part of our discussion of vocal augmentation and mediation, we introduce the concepts of mediality, medium and mediator, explaining how these concepts are embedded within the development of a performance and how mediators relate to media. In the second part, we focus on augmented vocal performance, illustrating how technologies for vocal augmentation have been used in recent performances. We explain why the introduction of these technologies often has a radical effect, altering the performance tradition and the artistic messages. Our objective is to enhance the expressivity of the vocal performance in regards to message creation, without interfering with the performance tradition. In the third section, we argue that sound-facilitating gestures and the switch cost effect are core procedural concepts that should be taken part of the design process. Finally, gesture repertoires are discussed as being action-oriented schemata that facilitate the communication of expressive meanings, through encoding of musical objectives. As such, we draw a link between mediality and embodiment.

8.5.2.   Mediality, medium and mediator

In this article, a "mediator" is used to refer to a facilitator for a medium, which influences the meaning creation process. The difference between medium and mediator is somewhat problematic and the two terms could, to some extent, be conceived complementary. However, we address "medium" as a generic term integrating multilevel information such as the voice, sculpture or language. A mediator, on the other hand, can exist alongside a medium, evolving the media, facilitating connections to other media, or even simply

emphasizing the medium to which it relates the most. In practice, this will almost always result in a technology that enables the expression of meaning in a medium. The timing and placement of the technological mediator is an important aspect that should be carefully considered. Timing refers to the early or late introduction of the technology in the development process of the performance. Placement refers to the position of the mediator with respect to the performer.
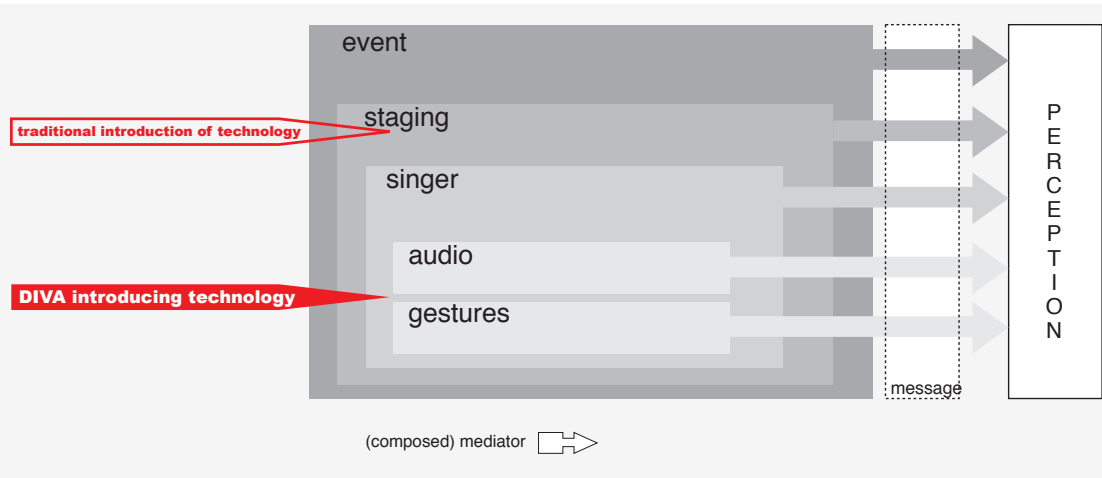
Figure 58: introduction of technology in a broader context

Figure 58 gives a schematic overview of the placement of the technological mediator within a broader context. It depicts the nested mediators of a theatrical context, for example an opera (event). The event integrates performers (singer) in a staged production (staging), while interpreting the original composition and guidelines of the composer. A singer uses both the audio (the voice) and (corporeal) gestures as mediator between intended musical goal and physical realization. This physical realization of singing, together with the theatrical and larger cultural contexts, shapes the message, which is then perceived by the audience. It is important to note that each of the nested mediators, have their own language and contribute on both micro (within the specific

mediator) and meso (within the composed mediator) levels to the message conveyed at the macro level (the whole event).

Traditionally, technological mediators have been introduced between singer and staging. A microphone (and accompanying PA system) is a good example of a technology that mediates between singer and audience. For example, microphones are used (more in popular music than in opera singing) to amplify the voice, facilitating the alteration of the message of the performance. This alteration can be both unintentional or the result of conscious decision, Microphones, in the context of mediality, can be introduced at a later stage in the development of the performance. Furthermore, audiences have grown accustomed to this technology, even if the effects on the vocal performance are very apparent, such as the change of the spatial origin of the voice to a set of speakers.

In our research, the technological mediator is placed at a level where gestures interconnect with audio. In more technical terms, the technological mediator intervenes radically with the action-perception cycle, in such a way that the gesture modifies the produced audio, so that the singer perceives the own audio as a result of the gestural interaction.

As a result, the singer's voice, to be interpreted as an instrument in a traditional sense, combined with sensors and a mapping strategy becomes a technology-enhanced mediator channeling aural and visual features to convey the musical message. The staging provides an additional level of information and complexity and is used by the performer to contextualize the performance. A composed mediator should, therefore, take into consideration the combination of the performer's movements and the staging. Furthermore, the process described above continues as new levels of multimodal information are integrated in the performance.

To summarize, compound media and mediators contribute to effective vocal performance. Acknowledging the effect a mediator has on meaning formation facilitates a critical analysis of each of the initial performance features, in order to streamline the communicative intent of the performance. When devising a system for augmented voice, we believe that the augmentation should occur at an early stage in the performance development process, so that technology can be adapted to gestures that are naturally incorporated within the performance. Technology then becomes linked to a composed mediator that is developed congruently in the remaining stages. Ideally, the performance will then function as a cohesive expressive composition, where the elements are linked to a concrete communicative intent.

8.5.3. Mediality in vocal performance

The use of technology for the enhancement of the vocal instrument is becoming increasingly relevant and there is an increasing necessity for strategies for effective mapping, integration, and remediation. With the DIVA system we sought to develop a technology mediator that is unobtrusive and compatible with the method in which operatic singing is typically performed. As a result, we focus on a thorough analysis of prerecorded existing performances by well-known artists and extract from these performances particular gesture-audio mapping strategies that are implemented within the technological mediator (see also Kochman et al., 2012). With this strategy, we aim to enable a dynamic mapping of gesture into audio. The process is moreover user-centered and developed in close collaboration with the performing artist.

Several other projects have introduced technological mediators for the augmentation of singing. However, in most of these projects, the introduction of technological mediators implied a more radical change to movements and gestures than that of the traditionally staged performance. Examples are the

Cronaca del Luogo by Luciano Berio performed in 1999 (Camurri et al., 2004) at the Salzburg Music Festival, and *Death and the Powers* by Tod Machover at the Opera de Monte-Carlo, September 2010 (Hoffman, 2010). *Cronaca del Luogo* involved the use of video tracking and FSR sensors to use create different effects for the two personalities of a single character. Machover in *Death and Powers* uses the idea of 'disembodied' performance involving offstage effects and elements impacting the action onstage. The monitoring of muscle contractions, pulse and posture are used to add audio effects that are not actively controlled by the performer to add new elements to the opera.

Current possibilities for vocal augmentation are varied and may include the use of array of technologies, such as compressors, EQ, reverb, delays, auto-tune/pitch shifting/harmonization, vocoder, bit reduction, Amp/Mic/Phone simulation, loopers, and ring modulation. In popular culture, there are several examples of technological mediated vocal performance, although there are few examples of vocal augmentation. For example, when Imogen Heap uses her voice in combination with a looper to create the entire backing for 'Just for Now', it is obvious that this performance is heavily dependent on technology. However, this use of technology is clearly detached, both in time and space, from the actual singing performance.

In contemporary vocal performance, it is common practice to link audio effects to a particular gestural set. Examples include the VAMP system (Jessop, 2009) and the One Person Choir (Maes et al., 2011). In the VAMP, a real time glove controller was developed based on the gestural vocabulary of choral conducting. Each gesture is used to create a certain desired effect. In the case of VAMP, the intuitiveness is clearly based on choral practice. In the One Person Choir, gestures are based on natural movements to harmonizing effects. Both examples are based on predefined and mapped accordingly to result in the intended augmentation. This mapping is fixed and is not dynamically changed.

In short, the introduction of technological mediators at the level where gesture and audio interconnect (Figure 58), is often accompanied by radical changes of the performance tradition. In terms of mediality, there are strategies that allow for new methods of expression that radically change the nature of the message (Jager & Kim, 2008). As a result, our goal is to introduce these changes in an early point of the creation process. Thereby, minimizing the possibility of ambiguity in the message that would arise if introduced in a later stage, as well as developing a technological mediator that is better connected with the contextual environment of operatic singing. In terms of mediality, the message should remain consistent and tied to the expressive intentions of the piece, but with enhanced expressiveness. Our challenge is very specific, supporting the compositional intentions, while at the same time incorporating new technology at fundamental levels intervening with the performance. In order to accomplish this idea, issues of embodiment should be taken into consideration. These issues are explained in the paragraphs that follow.

8.5.4.   The role of sound-facilitating gestures

The natural and intuitive practices where gesture supports operatic singing can serve as a guideline for the development of a gesture-audio mapping (Godøy, 2004). In our system, the focus will be on the performer's bodily and arm movements. Although these movements may not be not directly involved in the production of sound, they contribute to the communicative utility in the performance environment. Jensenius et al. (2010) make a distinction between different types of gestures, such as sound-producing gestures, communicative gestures, sound-facilitating gestures, and sound-accompanying gestures. Our interest is in sound-facilitating gestures that may be used to support phrasing and accompaniment of the singing, rather than movements necessary for the sound production (such as breathing) or for the communication (such as making a sign to another musician). These sound-facilitating gestures, or

ancillary movements (Cadoz et al., 2000), are used to communicate expressive content. In addition, these gestures are clearly present in the techniques of highly skilled performers. The visual aspects of performance as portrayed by the movements, gestures and other somatic information have been found to accurately convey the expressive intentions of the performance, sometimes more accurately than sound (Davidson, 1993).

However, implementation challenges also exist with regard to the effective integration of the performing body with the technology, as external equipment or apparatus is often considered a negative value in singing performance. If possible the technology used should not function as an external instrument, but should augment the existing musical instrument of the singer. Therefore, an analysis of the structure and implementation of the augmentation being implemented is of critical importance in the development of multimedia tools for singers.

Engaged singing performance requires an effective embodied mediation with dynamic interactions between the performer and the performance environment. This may be achieved through utilization of concepts that are developed within the paradigm of embodied music cognition (Leman, 2008). The structural coupling of the agent with its environment, as well as the internal dynamics of the performing agent, may characterize the concept of embodiment (Kim et al., 2007). Ideally, technological mediators would create an effective coupling between motor and sensory processes, allowing the action-perception cycle and inner as well as outer processes of the performer to integrate (Leman, 2008) and to generate cohesive embodied meaning. This can be achieved by a thoughtful implementation of multimedia tools, taking into account both the performance tradition and the general use of novel technology, while consolidating their validity from an embodied music cognition point of view.

8.5.5.   The problem of switch cost

Another challenge in designing performance technologies arises as a result of attention selection. Performance analysis indicates that switching between task sets is effortful in terms of cognitive resources (Corbetta et al., 2002), potentially distracting from the expressive intentions of the performer. When this situation occurs, the technological mediator may produce a decrease in performance expressiveness due to a 'switch cost' (Corbetta and Shulman, 2002). This is a problem that is often overlooked in the development of hyperinstruments. In circumstances where it is necessary to manually activate controllers or where specific gestures are necessary to create sound, the singer is essentially playing an additional instrument. While this phenomenon is not inherently problematic and can still result in an interesting and highly nuanced performance, it does have implications in terms of staged performance and usability. In the context of operatic singing, it is very difficult to effectively portray a character while turning knobs or pushing buttons (although in the particular case of *Cronaca del Luogo,* this aspect has been integrated in the scenography).

Switch cost may be reduced, if individuals are given sufficient preparatory time to adapt to the cognitive processes involved in the novel task (Corbetta et al., 2002). However, preparation time needs to be carefully balanced, as practice time and intuitiveness of the mediator are important aspects of the design considerations. In order to increase accessibility to a large group of prospective users, it is important that technology can be reliably used and set up procedures are accessible to nonexperts. Therefore, the developmental process should be planned not in terms of learning to play a highly specialized or idiosyncratic instrument, but rather through active integration into existing performance parameters, such as natural and intuitive gestures that accompany the singing. Hence, it is necessary for the technology mediator

to be linked with the existing gestural schemes and structures, but without gestural constraints, in order to avoid interference with audience-performer interaction. We maintain that the switch cost may be reduced if the mediator functions primarily to extend the natural actions or capabilities of the musician, enhancing the existing tendencies of the performer. Accordingly, the mediator acts as an augmented musical instrument, rather than an additional performance feature external to the singer or instrument played by the performer.

8.5.6. Gestural repertoires

The idea that technological mediators may be linked to the existing gestures schemes and structures is closely related to the concept of gestural repertoire, which is a cornerstone of the theory of musical embodiment (Leman, 2008). Gestural repertoires can be conceived as action-oriented schemata that facilitate the communication of expressive meanings. According to this theory, gestural repertoires are used by the performer to encode musical goals into messages that are then sent and perceived by the spectators. In addition, gestural repertoires are used by the audiences to decode these messages, to properly construct a meaningful interpretation in accordance with their action-oriented ontology. The gestural repertoire of a performance thus accounts for the understanding of the message at the intentional level. The gestural repertoire provides the interpretative knowledge and understanding of a specific performer and allows messages to be adequately encoded and decoded by performers and audiences. As gestural repertoires and the ability to code and decode are to a great extent linked to the media, and associated language, we believe that embodiment and mediality may be connected as useful tools in prototype development.

In vocal performance, it is likely that the performer's natural and choreographed gestures are combined, so that they can be easily attributed to their implied intentions. We maintain that technology, while perhaps causing slight alterations, can support these gestural repertoires. We thus conceive of the gestural repertoire as a medium through which enhanced nonlinguistic semantic information could be conveyed. Our main goal is to maintain the gestural repertoire of the performer as a basis for effective musical communication to occur in the enhanced performance environment.

8.5.7. Mediality: mapping & technology

The specific mapping and the technology of the mediator is discussed in detail in the following sections of the chapter. Specifically, a brief overview of the analysis that could be utilized in prototype development is presented, as well as a more detailed description of the prototype process and system development that was undertaken.

8.5.8. Gestures and mapping

The initial stage of the development process involved an analysis of several professional audiovisual recordings of an opera piece (Kochman et al., 2012). The goal of this analysis was to identify the key gestures that contribute to the dramatic and musical ideas of the score.

The dataset for the analysis is based on video recordings of live performances of the aria *Il dolce suono*, the 'Mad Scene' composed by Gaetano Donizetti, as part of the opera *Lucia di Lammermoor*. This aria has been released in several prerecorded performances. For the purpose of our study, we selected five recordings, namely by Natalie Dessay (Metropolitan Opera, New York,

2007) Edita Gruberova (Concertgebouw, Amsterdam, 2007), Mariella Devia (Teatro alla Scala, Milano, 1992), Beverly Sills (BBC Profile in Music, 1971), and June Anderson (Grand Théâtre de Genève, 1983).

Comparison between performers, during performance analysis provided key commonalities. For example, 94% of the high intensity gestures occurred in the third episode of the piece. In addition, the majority of interactive gestures (interacting physically with other performers) also occurred in this section, while the remaining interactive gesture occurred largely in the instrumental introduction of the aria. Due to the nature of the aria, many gestures expressed disassociation and separation from other performers and audience members. One could, therefore, conclude that scaling of effects should be adjusted to support these shifts in dramatic intentions. All performers showed signs of physical deterioration in the second episode. This observation provided important information regarding the range of action required for the system. In the majority of cases, there was a clear predominance for gestural communication using hands and arms, which was important for later system design in terms of sensor placement.

We also compared concert to fully staged performances of the aria. As could be expected, the range of action for concert versions was much smaller than in staged productions. Gestural categorization based on the model proposed by Davidson (1993), demonstrates further the delineation between the three sections. Performers of this piece showed a clear preference for specific gestural patterns. The majority of gestures could be classified as illustrative or display. In relation to the embodied narrative of the aria, as the intensity and frequency of gestures increases there is also a preference for illustrative gestures to communicate the narrative ideas to the audience. By not pre-defining specific gestures to control the system, the developers sought to allow for greater artistic freedom. When integrated within the proposed cyclic process, this strategy facilitates effective system design.

This type of analysis was important to help to define the range of movements and define the system's parameters. In addition, the developers aim to increase the generalizability of the mapping, determining commonalities between staged and concert settings. The goal was to obtain a mapping that should also be usable and adaptable for different artists and for different pieces.

The analysis of the individual performances of the piece assisted in defining the macrostructure and micro-features relevant to the performance of the aria. The organization of the piece was divided into three relevant episodes with key dramatic shifts. These episodes were clearly delineated according to the musical interludes separating each relevant section and by important shifts in the emotional and dramatic intention.

The overall representation of the global meaning and content of the piece was represented by the macrostructure delineating the overall theme or topic of the work. The macrostructure brings coherence to the overall structure and allows for global retrieval of relevant performance cues. Within the model, macrostructural ideas are then supported and refined by the microstructural levels, which are dynamically interconnected to the overall narrative. (Cortazzi, 1993).

The primary components of the structural coding involved:

- Staging: The key features that were coded in the staging of the aria included significant transverse or cross of area to reflect where performer interaction was necessary either with the audience or other performers and level changes. Besides creating a more interesting and effective performance, these features provide information regarding range of movement and dramatic intention of the character(s).

- Gesture: Gestural coding focused on those gestures expressing the dramatic intention or characterization. With the majority of the performances most gestural information was documented from hand and arm gestures. Facial expression, postural information, and weight changes and shifts were also coded.

- Music (Score): Expressive markings were examined from the score and referenced to performer interpretation. As the piece is performed in Italian it was necessary to translate the aria. Harmonic language and structure were analyzed. This information helped provide the foundation for the types of effects that were later integrated into the system.

- Music (Interpretive): It was also helpful to code the individual interpretative differences between performers, including features such as; timbral changes, accents, changes of dynamic (alteration between louder and softer volumes), inclusion of stylistic features that are characteristic of the bel canto period in which this opera was written.

This first stage of the prototyping process assists in the pattern recognition in terms of important performance aspects. It provides a framework with which critical features and individual nuances of performance can be identified. In addition, it provides information which could lead to great freedom of action and expression for the performer using the vocal augmentation system. In the initial stage of system review and appraisal, it is necessary to assure that constraints on the range of action were not caused by the system, key gestures and interpretative features are maintained, and key dramatic shifts are identified. A methodology involving structural analysis also assists in avoiding both interpretive limitations and/or obscuring or altering musical intention. Examination of existing performances allowed for the demarcation the system boundaries, constraints and affordances to be integrated in the system. Recognition of static and flexible elements helps identify and maintain a unique stylistic interpretation of a composition. The final mapping obtained is illustrated in Table 2:

part one	part two	part three
Hearing voices	Physical trembling	Halucination
Soft distant (reverberation) overtones (harmonizer) introduce the voice of her late husband, in harmony with the singer's voice.	A flanger and a tremelo are used to accentuate the tremors and the increase of brusque movement of the singer.	Extreme settings of a delay and inharmonic voicing, using the harmonizer, stage the singer's halucination.

Table 2: Structural analysis of musical excerpts,
as linked to audio effects integration

8.5.9. Gestures and technology

The above mapping is necessary to identify the set of variables that are pertinent to the technology mediator. Furthermore, there are several important considerations that should be taken into account in the design of the technology mediator. For example, any features that inhibit the natural range of action

or the desired performance parameters should be avoided. By applying a user-oriented development approach, such features are evaluated through performance analysis and further reevaluation as features are added and adapted. To facilitate action/perception coupling and enhance the intuitiveness and dramatic effectiveness of the piece, the system integrates gesture-based sensors that do not require the performer to change the way they move, thereby, increasing the ecological validity of the system. In choosing the technology that would optimally fit with the above constraints, photocell sensors were selected as a low cost and readily obtainable hardware component. They were connected to an Arduino Bluetooth, transmitting the data wirelessly to the computer. The number and placement of the photocells were designed to be flexible based on the needs of the performer and production. Placement of the cells as determined for this performance is demonstrated in Figure 59. This specific system, as such, should be seen as an illustration of the concept, rather than a finished product.

Figure 59: Sensor prototype and placement (left) ~ Sensors placement is easily modified and adapted for integration in costume design or based on staging (right).

An increase in environmental light results in increased electrical output. This can be used effectively in most theatrical contexts where a lighting infrastructure is commonly in place and can be integrated into the staging to

add to the dramatic context through lighting, resulting in an external scaling of the sensor range.

The inclusion of staging elements has a direct influence on the technological mediator's use and development, making an iterative analysis by synthesis approach highly applicable. Effects were alternated based on the section of the piece performed and were controlled by the photocell sensors placed between the index finger and thumb. In order to minimize problems associated with attentional redirection and switch costs, the effects available changed automatically at designated points, derived from the narrative analysis described in earlier, during the performance. The photocell placed on the right of the hand was designated as the amplitude, allowing the performer to choose when and how much of the effects would appear. These effects could be scaled to adjust and customize the augmentation to the artist and performance.

As previously mentioned, the photocell sensors were not pre-mapped on a constricted gesture or movement set. Rather, the gestures that would normally occur in performance were analyzed and the mapping for the photocells was constructed to effectively integrate into this gestural repertoire. Sensors are dramatically and dynamically integrated. Sound synthesis algorithms and music control inputs are dynamic and easily adaptable. Sensor outputs are easily scaled to allow for customization to the artistic work and performer, both through 'preset' settings, as well as through staging. The response time, robustness and predictability of the system remained consistent and reliable. The feedback modalities possible are quite extensive, facilitating multi-modal presentation. Newly programmed Max for Live modules were used as middleware to create and control Ableton Live's built in effects. However, DIVA is not necessarily specific to Ableton Live and the system

presented could be adapted to other software programs depending on needs and competencies of the composer, performer and developer.

8.5.10. Going on stage

The effects that were selected were based on the dramatic ideas of the piece. Each effect had a specific role defined by the dramatic character of the piece. The effects selected were used to emphasize the protagonist's separation from reality and steadily increasing insanity. In this context, vocal augmentation seemed highly appropriate. The effects were a natural extension of the character's gesture and instrument, as well as of her mental state and facilitating the subtext of the piece. In the first section, the singer enters, having murdered her groom after an undesirable marriage. She is completely unaware of her audience, enters and hears voices. This idea was extended with the use of a vocal harmonizer. Later in the aria, the character begins to hallucinate. Delay and increased vocal modification highlight her increasing separation from sanity, even during her relative happy reflections. Visually, a cloud was programmed serving as an ominous warning for future events. As the distress of the character increases towards the end of the performance, the character hallucinates a phantom separating her and her lover. The apparition is visualized in the background, but mirrors the actions of the singer as a reflection of her mind; her guilt having committed murder and betraying her lover.

The testing of robustness and flexibility of the system was conducted in the context of a public performance, at the Jazz and Sounds Festival in Gent, Belgium. The performance showed that future work should include extending the current prototype's functionality while maintaining validity, improving the

sensitivity of the sensors to control parameters, and reviewing the modularity of the framework through the iterative process.

8.5.11.   Discussion

It is generally recognized that a high level of technical expertise is involved in the performance and staging of an operatic work. Therefore, any system of vocal augmentation should represent an added value to the overall performance. As a result, it is necessary to take a more proactive approach in performance analysis, integrating the expert knowledge of participant performers. Each singer performs the piece with individual interpretation. The global features of performance from a subjective standpoint, involving the performer not only as a subject, but as an expert in her or his field, are necessary for comprehensive, immersive, and ecologically valid vocal augmentation system.

The issue of mediality emphasizes the significance of the medium in conveying and even structuring the mediatized, i.e. the message. The design of a mediator is highly influential on how the mediatized is perceived, not only by the public but also by the performing artist. Vocal performance can be used to illustrate this concept, as the technological mediator should as closely approximate the actual vocal performance as possible, to allow for vocal and technical nuance to be perceived by the audience. A vocal performance requires, not only aural literacy, but also an extensive visual literacy, which ideally would lead to a new found corporeal literacy involving the integration of ancillary movements in meaning formation and communication. This corporeal literacy, which is derived from embodied cognition, acts as a guide for a technological development, the refinement of the mediator, and, therefore, its effectiveness in the creation of meaning.

However, since the method selected for identifying, analyzing, and reporting patterns and themes within the performance is determined by the selection of issues which are considered most relevant in the performance, this selection process becomes an integral part of the design process as well. The manner in which a researcher observes and organizes this data is of equal importance and aids or prevents the deployment of a contextually relevant and effective augmented performance. Furthermore, the exclusion of comprehensive subjective expertise represents a normative gap in the development process.

In the case of the analyzed performances, the performing artist's expertise provides a valuable guide in ensuring dramatic integration and the generalizability of the system. As the researcher carries theoretical assumptions, theoretical concepts related to performance art help make these choices explicit throughout the analytical process. In the case of this study, narrative analysis provided a flexible and useful research tool, which provides a rich, detailed, and complex, account of the data. As such, the developmental process becomes cyclic in nature involving: careful consideration in choosing the performance analysis method, the usability of the technology used, and refinement of the overall system based on actual use within a performing context.

By combining the theoretical paradigms of mediality and embodied music cognition, and exploring the actual practice, a better method for vocal augmentation is created, resulting in an integrated intuitive musical perception. By creating a system with a better perceptual matching and a mapping strategy originated from the user's perspective, the researchers hoped to demonstrate a model for the development of more representative, responsive, reliable, and replicable vocal augmentation systems.

Our challenge was to develop a transparent technological interface that could function as an instrumental mediator, extending the performance capabilities

of the singer beyond the natural capabilities. Gestural and emotional content may be enhanced in new and innovative ways and new methods for integrating interpretive and emotive gestural communication in performance can be created. The use of technology can also allow the musical structure to evolve in ways not traditionally possible in singing performance, thereby creating a performance that is potentially more dynamic and interactive, allowing the performer and the public to explore artistic boundaries and gestural perception. The creation of new media and new media compositions allows for this exploration of novel performance capabilities. New methods in which pieces are composed, performed, and perceived are developed and are informed through the paradigm of embodied music cognition.

As stated earlier, the primary objective of this research project is to investigate how to enhance musical communication in the new media environments involving vocal augmentation and technology. However, defining effective musical communication in vocal performance may be particularly problematic. In addition, this definition might be highly variable and contextually dependent. For example, the needs and functions of the vocal instrument and bodily communication will vary highly from a dramatized operatic performance in comparison to a non-dramatized choral performance. Therefore, a dynamic and generalizable methodological framework would present a valuable tool in this performance environment.

Overall, the system proved to be reliable and the set up time was less than 30 minutes. This is often a difficult issue with regard to new applications and controllers. A system should not only be functional, but also robust enough to be transferable to multiple performance contexts. (Miranda et al., 2006)

8.5.12.   Conclusion

The DIVA system was designed to address several key implementation issues for hyperinstruments, by focusing on the development of an augmented vocal performance. The system proposed in this paper was deliberately constructed with technology (hardware and software) that is readily available, easily implementable, and cost effective. The focus, therefore, was on making the most out of simple components and upholding a methodically phased development process. This study proposed an integrated development methodology for technologically mediated singing performances. It included a critical discussion of the issues affecting the usability and interaction with technology in contemporary vocal performance. The authors undertook a phased development of a performance over several iterations. Through thoughtful reassessment during progressive stages, the authors addressed this normative gap based on the values and conclusions of the methodological model, concretely demonstrating the dynamic interaction between action and reflection.

The authors designed and implemented a system to provide concrete solutions to the developmental problems they wished to address. Each of the organized performances was situated in a specific context and background, leading to the necessity of the participants' and developers' reflections on consequential meanings inherent in the vocal performance.

The interplay between a technological development, from the field of HCI, and meaning creation, as part of performance art, proved to be central to mediality and was used as an intertwined design strategy for gaining access to experiential knowledge, knowledge construction, and sensory experience.

As media cannot be detached from meaning formation (Seifert, 2008), the development of a technological mediator also cannot be separated.

The use of technology inherently imposes certain constraints, which influences how individuals perform and interact with the technology and audiences. The authors based their choices on the embodied cognition paradigm, taking the human motor constraints as a key guideline in the development, while refining them through a detailed performance analysis. All of which is unified by the concept of mediality. When the meaning creation is undeniably embedded within certain media, the mediator should be constructed as close to the meanings formed by those media, regarding this from a multitude of viewpoints. To conclude, alternative strategies should be developed when incorporating technology to facilitate audience attention. Methodlogical frameworks should emphasize the inclusion of aesthetically important or unexpected dramatic events and/or attentional awareness. This developmental approach integrates by necessity multimodal information and subjective expertise.

## 8.5.13.	References

The references have been included in the list of references at the end of the thesis.

9. References & Exhibitions

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9.1. Exhibitions

1. Lament, (2102) Journées d'Informatique Musicale (JIM), Numediart Mons, Belgium

2. H.a.a.O, (2011) Pluto festival11 Opwijk, Belgium

3. Curator New Media festival Pluto (2011) Opwijk, Belgium

4. SoundField, (2011) ArtBots Ghent, Belgium

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20. Lecture Re-Thinking interactive art, (2012) Kersepit vzw, Gent, Belgium

21. Lecture The function of the body in interactive arts, (2010) Ontario College of Art and Design, Toronto, Canada

22. Lecture Dynamic Mapping Strategies for interactive art, (2009) Departement of Architecture University of Waterloo, Canada

23. Lecture Art and sound (2009) Bo!nk festival Hasselt, Belgium

24. Lecture DIVA-system (2009) Jazz and Sound festival, organized by music centre De Bijloke Gent, Belgium

25. Artist Lecture (2009) Timelab Summercamp Electrified Gent, Belgium

9.3.   Workshops

26.   Tutor workshop Realtime 3D and Physical Computing (2010) Ontario College of Art and Design Toronto, Canada

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