Interactive Performance Systems:

Experimenting with Human Musical Interaction

M. Koray Tahiroğlu

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Preface

Preface

The personal motivation for this research has been to establish a set of artistic means for experiencing new possibilities in music with computational tools. The interdisciplinary characteristics of this research made it possible to investigate and study human musical interaction in a broader context. These characteristics also made it possible the contextualization of the author's performances within recognized research fields, such as sonification, technology mediated musical performances, gesture-controlled audio systems and networked music performances.

In the study of musical experience and its fundamental structures, research exploited sound as a primary source for carrying information and aesthetics in interactive contexts. This applies to both creating models based on computational methods and to the improvisation process. Some approaches to creating and developing experimental musical instruments have been also introduced in the dissertation.

The live-practice of art methodology was used as a way of gaining experience and a new perspective on interactive improvisation systems and their artistic use. The purpose of the research was not to define the qualities of a good or perfect interactive performance system, but rather to find new information and gain experience in developing these systems.

The results in this dissertation could help artists design and experiment with interactive improvisation systems which may encourage them to engage in new music making activities.

This dissertation includes an attached DVD containing documented materials of the author performing experimental music using interactive systems at the various sound art events discussed here as case studies. The DVD includes information on the interactive systems as well as recorded video, audio files and images.

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My warmest thanks to my parents, Reşit and Nevin Tahiroğlu and to my brother Utku Tahiroğlu who showed their endless love and moral support during my studies and life in general. I would like to especially thank them for their patience during the writing process of this dissertation.

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1.

Introduction

The level of knowledge required of contemporary artists and designers working with technology goes beyond simply being comfortable with computing tools. There is a need to apply computational ways of thinking to artistic expression and experimentation. New computational tools and new media have become ubiquitous in the use of computers and new technologies for artistic creation. Lev Manovich (2001: 19) has discussed the effect of new media on the computerization of cultural practices in industrial societies shifting to computer-mediated production, distribution and communication. According to Manovich, when compared to the revolutions of other types of media in history, such as the printing press or photography, new media has affected all stages of communication and types of media like images, texts and sound. (ibid).

The development of computer technology in the mid-twentieth century resulted in a transformation of media types into digital environments. This process caused existing media to take new form within the computational medium. From this point of view, new media practice can be defined as creating, using and distributing new types of media which combine technology and creativity for designing new processes and tools for art, design, and entertainment (Leman et al. 2007). The integration of new media types to everyday life has brought new possibilities to the creating and producing of art and as a result new media art is nowadays a reality. New media art brings together artistic forms and technology into artistic expression.

New media art is also an interdisciplinary practice that investigates other disciplines and "hybridizes" them into various cultural and technical forms. Science, art, technology and society are merged in new media art works. The interdisciplinary features of new media make it possible for this research to be undertaken in new media art and within the contemporary art field. In addition, computational art has become the mainstream of contemporary art for many scholars, especially in music, and a primary opportunity for further investigation. The key aspect of the research process undertaken in this thesis emerges within this broad subject by questioning how new media and its artistic activity can be applied into practice to explore the new possibilities in music making. In these new types of music making, part of the research is carried out using unconventional methods or experimental practices in music. In this thesis the new represents unconventional methodologies that form musical structures. These structures are uncommonly experienced within general musical context and form unorthodox practices for musical experiences. The new differentiates itself not only from the traditional Western tonal music structures, but also from early examples of experimental and electronic music making strategies (Nyman 1999). Though this is a very broad starting point for the study, the aim was that artistic activities could be used in addressing the main research question.

Considerable effort has been placed into investigating computer music, and the advancement of technology has influenced musicians in different ways. These developments have resulted in new kinds of creative processes and new possibilities for making music. In this thesis making music is defined as expressing human intelligence by sonic means (Xenakis 1971).

Lejaren Hiller carried out a series of experiments in collaboration with Leonard M. Isaacson at the University of Illinois to enable the Illiac computer to generate several characteristic species of music. They completed a group of four basic experiments, which were designed for string quartet performance called *The Illiac Suite for String Quartet (1956)* (Hiller 1963: 100). This was the first computer-aided composition and Hiller and Isaacson were among the first to experiment with the new possibilities in music compositions afforded through the computer. The Illiac computer was programmed to generate a composition based on

a probability method, which was devised for successive note selection related to the harmonic series to produce melodic output (Hiller and Isaacson 1992).

Further involvement of computers in music continued with Max Mathews who wrote a program called Music I and played a 17 second composition with it in 1957 (Roads and Strawn 1987). Matthew's Music I–V computer synthesis programs converted sound samples after a non-realtime calculation; these were then recorded onto an analog magnetic tape for playback. Thereafter, the development of computational art involved the development of new techniques, new computational tools in music making. Gottfried Michael Koenig, Iannis Xenakis, John Cage, Pierre Barbaud and the others became the pioneers of computational-algorithmic music not only for their compositions, but also their inestimable work on the development of the music technology as well (Roads 1999: 831, Xenakis 1971, Cage 1973b).

Interactivity, as a broader subject of new media, turned into a notion as game-like events in art and design works. Beryl Graham (1997) argues with this notion of interaction in art. He further describes interaction as two sequenced actions. There is the physical action of the viewer upon the artwork that can be observed as well as the psychological effect of the artwork, which cannot be observed but must be understood. Clearly, interaction is nothing new and has existed in history where human activity can be conceptualized through interacting with each other and the world. But new media has shaped interaction to a new level with computational tools.

According to Agostino Di Scipio's (2003) more computer oriented definition of interaction, it means that a computer's internal state depends on the performer's actions while the latter may be influenced by the computer's output. Graham's and Di Scipio's definitions can be developed further by involving two-way communication in interaction where the participants influencing each other and creating the content based on the exchanged feedback. Concerning interaction as exchanging events based on feedback and event participation, in this study the term human musical interaction is defined as the voluntary or involuntary actions of human agents in a musical context. Interaction can happen simply by taking an active role in any music making process or being a member of the audience.

The study of the interaction possibilities of digital music systems began in the 1970s with *hybrid* music systems that allowed real-time gestural input for control structures and combined a digital computer with an analog sound synthesizer (Roads 1999: 614). The Hybrid IV system, for example, was developed at the University of California, San Diego and it used an alphanumeric keyboard as an input source for generating control signals from the keystrokes to be sent to an analog synthesizer (Fuchs 1988: 39). Involving input devices other than a keyboard brought various opportunities for real-time interaction in music making. In 1970, Max Mathews and F. Richard Moore developed a program for real-time music synthesis, GROOVE (Generated Real-time Output Operations on Voltage-controlled Equipment), which could interact with stored and computed functions through real-time human inputs to the computer (Mathews and Moore 1970).

The GROOVE system allowed musicians to use the specially-built keyboard input device that had a potentiometer associated with it and the four knob inputs to communicate with the program in real-time to modify the frequency and amplitude envelopes of the oscillators (ibid). Ever since, musicians and researchers have been developing real-time interactive systems, and exploring new forms of interaction models with new musical interfaces, such as the UPIC (Unité Polyagogique Informatique du CEMAMu) designed by Iannis Xenakis that reads lines drawn on to a graphic table and controls software synthesizer according to line's course (Fuchs 1988: 39). Using the UPIC, Xenakis (1987) composed a piece *Mycenae-Alpha (1978)* at the CEMAMu (Center d'Etudes de Mathematique et Autoatique Musicales).

Interactive systems using advanced technology introduce various opportunities for interaction in the music making process (Rowe 1993, 2001, Roads 1999). New media and new interfaces also make developing new types of musical instruments possible. This study introduces some approaches to creating and developing experimental musical instruments. One objective of this study is to develop interactive performance systems that give an opportunity to discover new possibilities to organize sounds as well as an opportunity to developing new kinds of music. The alternative interactive performance systems developed by the author are also discussed along with their performance features and system structures at sonic art events.

Curtis Roads (1999: 846) distinguishes two basic degrees of interaction in automated systems involving interactivity in music. The first is light

interaction, which can be experienced in studio-based environments that give musicians an opportunity to edit and backtrack the musical material if needed. The second is a more intense real-time interaction of working with a performance system onstage where the interaction takes place in an ongoing music process. The interactive performance systems developed by the author, which serve as case studies for the research in this thesis focus on the second type of interaction.

There have been many scholarly attempts to classify interactive systems throughout their development in history. Robert Rowe's (1993) classification is introduced in chapter 2 to clarify the structure of the interactive performance systems discussed in this study.

The methods of interaction in this research are based on the overall meta-systems including the human, machine, and the environment (Di Scipio 2003: 270). This notion of interaction emphasizes the role of musician and audience as a major component of interaction. Di Scipio refers to this as the interface between a computer and the environment. This point of view gives more importance to the human participant in the interactive performance system, since it constitutes a dynamic mechanism of the performance, which at the end is experienced as sonic variations in time.

The study of various forms of interaction among humans, machines and the environment is an active research field. However, sound has not been used efficiently in new media studies, and the emphasis has been on visual processing. Marshall McLuhan (2005) argues that although visual culture has dominated the Western world since ancient Greece, there has been a shift towards an auditory mode of perception starting from the late 20th century. This may have influenced the growing interest in sound in recent research projects. Also there has been a growing scholarly interest in sonic interaction design with COST-SID[1] activities that aim to look at sound as a rich source for carrying information that is perceived and used, often unconsciously, and therefore shapes the overall interaction experience (SID 2008). Furthermore, sonic interaction design, as

1 COST is co-operation among scientists and researchers across Europe, and SID – Sonic Interaction Design, is a COST action concerning sound design and technological opportunities. http://www.cost-sid.org/

a recognized research field, focuses mainly on how a system behaves in response to a user's behavior when designing the sonic behavior of a system or a product (ibid).

The major components of interactive performance systems described in this thesis involve sound as a central area for reflection. Sound in new media is more than a physical vibration phenomenon. In the study of musical experience and its fundamental structures, the research uses sound as a primary source for carrying information and aesthetics in interactive contexts. This applies to both creating models based on computational methods and to music making.

The motivation for this research is to establish a set of artistic means for experiencing new possibilities in music with computational tools. A new and modern experience has been brought about by technological advances beginning from the industrial revolution in Western world. Technological development in everyday life, have extended this modern experience as well as created an opportunity to experience something new. Artists, who are often compelled to experiment, use many kinds of techniques to create art (Dewey 2005). These techniques depend on variables such as the materials or instruments used during the creating process. Artistic and practical activities can be distinguished by the act of expressing oneself in and through a medium (ibid).

As the medium and environment change, the experiences and elements of a particular artistic activity also change. For instance, throughout the history of music, the musical elements used in conventional Western music have helped musicians express and create experiences through tonal music structures. In conventional Western music, tonality can be viewed as a tool for creating a form where one can build a fixed, complete structure. Tonality is centralized around a keynote, and all musical sounds in a composition are strongly connected to the keynote, which helps a composer to define the direction of the composed music in a conventional harmonic structure (Webern 1998: 61). Even in conventional music, when structural techniques change, the musical expression itself changes. Anton Webern, who was a student of Arnold Schönberg, describes his mentor's twelve-tone technique as an influential method for developing tonal techniques. It is a compositional method based on an ordered series of all twelve-notes in certain scale (ibid: 44).

The focus of this research is on contemporary experimental improvised music. The aim is to reflect on the process of artistic creation by emphasizing the continuous dialogue between theoretical approaches to interactive performance systems and their practice in experimental music. Michael Nyman (1999) tried to identify and explain musical work that exists outside conventional music as shifting the boundaries of music with respect to notation, time, space, and the roles of the composer, performer and audience. He defines experimental music as a process of generating action, involving situations or fields delineated by compositional rules, but leaving them open to the performers and the audience (ibid: 4). Throughout the history of experimental music there have been numerous artists such as John Cage, Morton Feldman, Earle Brown, Cornelius Cardew, LaMonte Young, Alvin Lucier and others who have created pioneering works with unpredictable tasks and various performing strategies (ibid, see also Roads 1999, Cox and Warner 2005, Cage 1973b).

In experimental music, improvisation also represents a deep and informed way of action, which diverges from agreed plans and standards. An insight to dispensed scores with substituted methods and the pursuit of some inexpressible and unrealizable ideal brings forth the remarkable improvisers AMM group; Keith Rowe, Lou Gare, Eddie Prevost, Cornelius Cardew and John Tilbury for example, have made a great contribution to experimental works using improvisational techniques (Nyman 1999: 127).

The descriptions of the author's works in this thesis offer some insight to the new, unusual paths in experimental music. The author's detailed theoretical works are on a radical musical direction with conscious attempts to search for new sounds and unorthodox techniques. John Cage (1973a) defines conventional music as a set of laws exclusively concerned with musical sounds, which represent the tone and timbre characteristics and seek to eliminate noise. Cage mentions that for unconventional structures, music should be based on noise; or on the lawlessness noise (ibid). In this research process, noise has been a key sound structure in experimental music.

Noise and music are usually interpreted as opposites where music is interpreted as melody, harmony and rhythm. On the other hand, Henry Cowell (2005: 22) points out that there is a noise element in the tone of all musical instruments. Noise can be maintained when a musical sound grows louder and it exists in all music in different depths comparing to pure tone elements. It is hidden, but it exists. Thus, the use of noise in music has been an unconscious attempt, however the use of noise today opens a wide field for investigation of novel structures in music making.

There has been always noise as a sound element throughout human history but originally it began to be a musical sound as it had been associated with the characteristic of a machine. Noise has had an increasingly important role with the involvement of machines in human life since the industrial revolution. In the Art of Noise manifestation Luigi Russolo (2005: 10) strongly points out that ancient life was silent and with the invention of machines, noise was born.

In the beginning, machinery noise was not a commonly experienced part of everyday life; therefore, noise was a disturbance element in a habitual sound environment. The developments of machinery in the beginning of the 20th century resulted in machines being perceived as aesthetic objects, and also created discussions on how their looks and existence affect human life. Besides the heavy industrial machines, trams, buses, coffee machines, refrigerators, vacuum cleaners, lifts, telephones, computers also became part of the environment. The interaction between humans and the world has changed regarding these new elements of life, which transformed our understanding of noise from being a disturbance to an accepted element.

Involving noise as a sound in music structures is a form of futuristic expression to bring art to life and life to art (Russo and Warner 2005: 50). Futurists were also called musical anarchists. They attempted to create noise and sound using machines. Their instruments were mechanical devices. It could be said that they were trying to make anti-music using these controversial strange machines, which often resembled loudspeakers in boxes and other mechanisms to create unpleasant sounds.

Noise has found its way to the music scene and the beauty of it has been recognized in experimental music works. It is more than a signal that one would refuse to hear. It is a musical element carrying information for the aesthetics of the music. The author's unconventional sound structures merge noise in the creation of pure electronic instruments. Some of the sound synthesis modules in the interactive performance systems clearly integrate noise structures together with pure tonal structures. Noise is used as sonic detritus and a vehicle for spiritual ecstasy (Akita 2005: 59).

1.1 Aesthetic Motivations Behind

Guy Garnett (2001) defines music as sounds made with aesthetic intent, or sounds listened to with aesthetic interest. The former gives more weight to the discoverer-creator-composer, while the second statement tends to privilege the audience. Any kind of music needs an audience. Performance is the vital part of musical work for its aesthetic values. Whether it is a musical piece with finite length and predefined structure, or a free improvisation, the aesthetic properties of the work are introduced and realized by the audience during the performance.

According to Garnett, *aesthetic* is what the artistic value of the work means and why it is important in the work (ibid). The composer, creating a self-experience, adds aesthetic properties on the elements of a piece of music and introduces them to the audience in the performance. On the other hand, during the performance of a free musical improvisation, because the music itself is constructed while performing it, the audience has an additional role in evaluating and realizing the aesthetic values. In this case, one can stress that free improvisation performance needs an informed audience, a critical audience with a rich and developed background to experience the music that is created in real-time performance. In free improvisation there is no predefined score or sound structure. Each performance becomes a new experience of the musical work as it is performed live and perceived by the audience. There is a dynamic organization of aesthetic values at every stage of a new performance. A work of art is active and experienced dynamically by the audience.

Transforming artistic creativity into an object of art does not complete or finalize the artistic process. A piece of art cannot be perceived or enjoyed without an active appreciator. Dewey (2005) argues that receptivity is not passivity; indeed, it is a process that consists of a series of responsive acts that build objective fulfillment, as perception. Engaging the audience with the work of art may turn passive recipients into an active audience, co-participants of the creation. It is relatively easy to see some consequences of the advanced development of the interactive performance systems in an audience experiencing the music as well. Artistic process requires an act of reconstructive *doing* and consciousness in the process of perception. This process turns passive recipients into an active, informed and critical audience. They are beholders who create their own experience.

In improvisational performance with interactive systems, artistic values are created in real-time and embedded in the musical activity. The act of improvisation can be interpreted as a transformation of energy into thoughtful action, which derives from the past experiences of the human performer (ibid). There is also a conscious awareness of what has happened, what might happen during the improvisation and how a conscious strategy for the next action might develop. In this thesis, the musical work and artistic values of performances have been constructed with the performers actions and the interactive system's responses. A performance-centric assumption of musical activities involves the audience with the aesthetic motivations of the artistic works in the research. Experiencing musical activity in real time – a performance period that happens at the moment of creating the experience – creates a critical point for evaluating the aesthetic values of the performances by the audience. The main aesthetic motivation of this research process is to introduce unconventional sound structures with new practices of music making in real-time performance to the audience.

Even though interactive systems play a role in the act of improvisation, there has always been a need for the human agent in the author's performances. Dewey states that there are no experiences in which the human contribution is not a factor in determining what has actually happened (ibid). In order to bring the true artistic experience of richness and expression into closer contact with the audience, it is important to involve an artist in a computer generated music process (Garnett 2001). Although the presence of artist may not be concrete in some performances, such as robotic performances, there is still a human element in the artistic creation (Werger and Mataric 2000, Sgouros and Kousidou 2001). However, through human-machine improvisation emerges an aesthetic model that gives rise to new expectation of artistic explorations both from the machines and the human partners. The concepts are open for reconsideration, and the machine is a fundamental attribute of aesthetics in interactive system performances.

1.2 Research Based on Live-Practice of Art

Practice-based research differs from other research approaches in that it uses the live-experience of art, which in this case involves music-making and computer-based interactive performances as a source of knowledge. Practice-based research is a combination of artistic practice and a theoretical approach aiming to produce knowledge (Hannula 2004: 70). This method seeks to identify existing assumptions in practice and then develop new strategies based on the gained knowledge (Candy and Edmonds 2002: 58).

Research based on the live-practice of art is a unique investigation and examination undertaken to gain new knowledge and experiences through practice. Artistic research is a new area. During the last decades, there have been different artistic research projects and experiments in various countries (Hannula 2004: 70). There is a growing interest in artistic research and a growing amount of published research material in support of this methodology. Dissertations, such as this work, help to show how research performed within the realms of artistic practice can fulfill the fundamental requirements of research (Douglas 1992, Graham 1997, Mäkelä 2003, Ikonen 2004, Summatavet 2005).

Anne Douglas (1992) analyzed her own sculptural practice in her research by an improvisation method, which was structured out of the writings of John Cage on composition as a process of improvisation. Reflecting on and interpreting the artist's process within the metaphorical framework of improvisation and focusing on the observation of her own practice as a sculptor brings forth some similarities with the current dissertation, albeit in a different art medium. Also Beryl Graham's (1997) research is based on case studies of exhibitions that were used to identify potential questions about the different possibilities of viewing art and audience participation through interactive computer-based installations in a gallery exhibition. Though the artist does not explicitly say so, Graham's work can be thought of as practice-based research with more conventional case studies attempting to deal with hybrid media.

The research in this thesis shares some similarities with Graham's work when it comes to identifying different aims and types of interactivity in interactive computer art. However, it differs from Graham's work by forming an analysis of the author's own artistic works in a particular context of music.

Another work that bears similarities with the current work is Maarit Mäkelä's work (2003). In her thesis, the research process comes to life as practice and the strategies, actions and artifacts to support theory. Mäkelä developed a series of artistic works by producing memories in clay pieces that were in exhibited. These works in turn fueled the research into the potential of gender-aware art representations of femininity. The newly gained insights were input into the already existing artifacts. In her research, Mäkelä's art works preserved, analyzed and commented on the female experience. Unlike in Mäkelä's research, for each cycle of the research process the author created a new interactive performance system, thus new performances and experiences were formed each time.

The methodology used in this research reflects the hybrid characteristics of new media art such as art, science and technology in a specific context. The hybrid methods for the analysis of case studies are based on a normative research approach, practice-based research methodology, whereas the theory of practice is used to produce the new for music activity. The research methods are also developed based on the observation of the author's own practice in performances. The author's reflections, from an uninhibited first-person perspective, on his works are included in the corpus of the thesis. That is, the artist investigates the research questions through artist's own works (Nevanlinna 2004: 82).

Observation is a methodology where visual and audible information of various activities can be gathered. For example, how the interactive system developed during the research functions, what happens during an improvisation and how it reacts. Performances with the interactive systems embody the knowledge generated in the practice. These methodologies overlap in the way strategies are developed for analyzing and evaluating theory and its practice in the experimental music works included in the thesis. In each chapter, the interactive performance systems of this research are compared with the methods of other systems in order to position the research outcomes within the contemporary research field.

In addition to the overall research questions, the questions and problems are taken from the previous work done for the research and addressed in the research methodology as the author developed the artistic activities.

The interdisciplinary characteristics of the thesis made it possible to investigate, experiment and study human musical interaction, new media art, interaction design, digital and analog sound synthesis, free improvisation, algorithmic structures and participatory design approaches.

1.3 Results

Each performance activity presents a work of art as well as information as a model of a singular case. The sound structures, mapping strategies, improvisation techniques and models that were used in developing the interactive performance systems built an aesthetic experience and generated new concepts and strategies for the next research phases. The performances were recorded in their natural states in order to achieve the objective of observation. The results of the study are based on the observation of the performance activities.

This is not the first research project applying the live-practice of art methods to interactive performance art. In fact, several research projects have been published and demonstrated, and ongoing projects exist in various doctoral study programs. The main contribution of this study is not developing a new practice-based research methodology for doctoral studies. Live-practice of art methodology is used as a means of gaining a new perspective and experience on interactive improvisation systems and their artistic use.

The study aims at gaining knowledge and experience through the live-practice of the author's artistic works. In this dissertation, the objective set of criteria can be evaluated by its ability to introduce new perspectives on an existing area. How inventive this artistic research is within experimental music can be assessed by examining the ideas generated, seeing how these alter concepts about experimentation and improvement of art work.

Georg Weinand (2006) proposes that the quality of practice-based research depends on its creative inventiveness and the emotional communication with an audience. Among the public outcomes of this research are the live performances, and their ability to engage the audience with commonly recognized artistic values of the experimental music. Weinand claims that results of practice-based research are never wrong, but inventive (ibid).

Rather than analyzing or mapping general strategies on one type of interactive system and developing it further, the research presents interactive systems, which offer alternative musical experiences for each research step achieved during the research process. This approach separates the current study from other practice-based research projects in the same field. The purpose of the research was not to define the qualities of a good or perfect interactive performance system, but rather to discover some information and gain experience in developing these systems. The results might help artists to design and experiment with interactive improvisation systems that may in turn encourage them to be engaged with new music making activities.

To conclude, the goals can summed up as presenting a technical and a performative description of interactive improvisation systems that can be used as a basis for making new music and experiencing novel musical activities. In addition, the artistic works presented in this thesis can bring new insight to other research scholars or artists in the field.

1.4 Overview of Contents

There are three main research questions to be addressed in this study. These are:

- How new media and its artistic activity can be applied into practice to explore new possibilities in music making and in relation to this, what kind of interactive performance systems give an opportunity to discover ways of organizing sounds so as to develop new kinds of music, rather than the conventional notions of musical structures?
- What kind of strategies can be developed to enable an interactive performance system that allows audience participation in the creation of art as a collective musical improvisation?

- Is it possible for non-professional musicians to experience musical activity where the pleasure is achieved by being able to play with an accurate and compact instrument, exploring and experimenting on different sound structures?

The central experimental work of this dissertation addresses the idea that computer-based interactive performance systems provide an extended paradigm for musical improvisation. Throughout the dissertation the author addresses several research topics in music technology, such as generative music, sonification, collective musical performance, experimental musical instruments, some innovative approaches to the synthesis of sound and control strategies of multiple sound sources in an interactive context.

This thesis has an unusual structure from the more conventional dissertations that normally would have a more strict separation between survey chapters and practical discussion of the research developed within the framework of the doctorate topic. However, the thesis structure intends to reflect the methodological approach in live art performance practices that requires a flexible and evolutionary mind-set. The content structure for each chapter consists of informed, descriptive and critical discussions about conceptual approaches related to the chapter's themes. The final part of each chapter includes detailed descriptions of the interactive performance systems developed and performance observations that summarize the experiences gained during the process.

Each chapter concludes with a comparison of the author's work with other related contemporary works and approaches in order to emphasizing the viewpoints and connections with the chapter's themes. In order to give direction for further investigation, questions and problems emerging during the research process are presented and reflected upon in the conclusion part of each chapter. Hannula (2004: 72) presents this final process as one of the six fundamental points of artistic research.

The conceptualized theories developed for interactive systems and the performances presented in this dissertation represent a linear time structure of the research process. However, this does not necessarily represent the order of the performances because they were performed parallel of each other, in various places and over a long period of time.

The first interactive performance system of the research process gave the author a possibility to experience a human-machine improvisation in a live performance based on tonal structured guitar music. The *Generative Musical Improvisation* performance, in 2004, was the first attempt of working on the main research question of this dissertation. The experiences and knowledge gained during this period of the research led the author to investigate and experiment with other possible methods for sound processing and synthesis. This resulted in the *SolarDuo Project* developing interactive improvisation performance systems for duo performances.

The SolarDuo Project has been a case study in this research and it has performed at various festivals, since the end of 2004, to apply artistic activities into performance practices. Not all of the SolarDuo Poject performances have been discussed in this dissertation. Instead, only two performances, which are the most significant in terms of the interactive system components of performance systems, are discussed.

The knowledge gained through the observation and practices of the SolarDuo Project performances led to research questions about audience participation in the creation of art. The research progressed further through experiments with an interactive performance system that allows audience participation in an improvisational performance. As a result, the *Clonus Patterns* interactive improvisation system was developed.

The audience participation in the Clonus Patterns performance, in January 2005, resulted in developing a more responsive system for the *Call in the Dark Noise* performance, which took place in January 2006.

Audience participation, with an everyday-life communication tool in previous performances, gave the author an idea for building an instrument that allows for a non-professional musician, with no previous experience, to participate in an improvisation and enhance the performative pleasure of music. The *EMI Project* focused on developing experimental musical instruments based on natural, expressive gestures. The EMI Project performances discussed in this dissertation represent two different types of instruments and performances. The *EMI Night !!* performance, March 2006, was based on instruments designed with digital sound processing strategies and the *Piksel Festival* performance, November 2006, used analog instruments, which were both designed during the research process.

Throughout the research process, developing interactive performance systems raised problems concerning the control configurations of audio and parameter structures. During the last period of this research, the

author progressed into experiments that were more comprehensive by developing complex control strategies for interactive performance systems. The author did this within the *ClaPD Project* in order to explore the possibilities of control and signal processing software. After the ClaPD Project, the author focused more on the biofeedback control of music and developed an interaction strategy for *IBIS*, (Interactive Bio-music Improvisation System) by adding a level of information to the feedback loop; the third state. The CalPD project control strategies were presented during the Pure Data Convention 2007, in Montreal, Canada and IBIS was demonstrated in ICMC 2008, in Belfast, Northern Ireland.

The order of the thesis' chapters is based on the linear time structure of the research process. Therefore, chapter 2 represents the first phase of the research; meanwhile chapter 6 is the final stage. Chapter 2 introduces human musical interaction in the form of improvisation in music. It also describes experimental improvisation as a new performance practice with a case study. Interactive performance systems are discussed through Robert Rowe's classification and with related works from the field of computer generated music. The first interactive improvisation system of the research is introduced in the last section. Both the technical features and the observation of the improvisation structure of the interactive system used in the *Generative Musical Improvisation (2004)* performance is described along with the conclusion achieved through the practice of the research.

Chapter 3 describes the improvisation of two performers with the musical and technological exploration of the SolarDuo Project interactive performance systems. The SolarDuo Project performances at the *Ctrl_alt_del festival (2005)* and *Ars Electronica (2006)* are introduced as case studies. The general principles of the interactive systems and performance observations are also described.

Chapter 4 presents an overview of the interactive systems with various methods of modeling human musical activities. The term *simulation* in modeling human musical perception is also discussed. The performances *Clonus Patterns (2005)* and *Call in the Dark Noise (2006)* are introduced as case studies of the observable musical actions of the audience participating in real-time improvisation activity.

Chapter 5 describes some approaches to designing experimental musical instruments and along with the EMI Project performances *EMI Night !! (2006) and Piksel Festival (2006)*, the chapter introduces analog and digital instruments developed by the author. Chapter 6 introduces the implementations of experimental musical controllers together with interactive systems for exploring alternative interaction possibilities. The control structures of the *Interactive Bio-music Improvisation System (IBIS)* are also described. To sum up, chapter 7 presents the overall research conclusion and indicates the possible direction of future research.

2.

Human Musical Interaction

In music, the improvisation process forms human musical interaction among musicians. Exchanging musical events and gestures in the moment of playing creates active participation, communication and cooperation, which in turn results in a shared interaction and experience framework. Thus, it could be argued that, human musical interaction is continuous communication that is based on listening and playing, which takes place under certain conditions in musical activities. As David Borgo and Joseph Goguen (2004) have pointed out, musical improvisation is conditioned on one's ability to synchronize one's own intentions and actions to maintain a keen awareness and connection with the evolving group dynamics and experiences. This chapter introduces human musical interaction as an improvisation process among the performers in a more abstract level as a collaborative activity both in human-to-human and human-to-machine forms.

Improvisation in its free form can be defined as performing without a musical score, or as a way of playing without preparation that gives unexpected results in a performance. Karlheinz Essl (2002) points out that during an improvisation one follows certain methods of playing that one might have thought of before or which can be negotiated in the moment of playing. One must be conscious of what has happened before and how the process could be developed further. Moreover, during a collective musical improvisation there is a continuous activity, such as exploring new sequences of sounds and listening consciously. Responding immediately and spontaneously to other players creates a process of communication in free collective improvisation. Within these immediate responses there is also a conscious awareness of how one's sound is connected to another musician's sound. Free collective improvisation, which is based on formless conversation, is a dialogue among musicians.

Musical improvisation has existed in one way or another throughout human history (Nunn 2004: 6). Improvisation practices lead musicians to experience a way of music making, which takes form in the act of performing with unpredictable methods in a collaborative environment. Moreover, free improvisation concerns itself more with creating a dialogue among musicians rather than predefined performance outcomes. According to Frederic Rzewski (2005: 270), an important ability of improvised music is to introduce a pattern of music unexpectedly at a moment when anything at all might happen. Rzewski connects the unexpected music with the precariousness of existence, in which anything such as death or disease can interrupt the continuity of the flow in life at any moment. This may be where improvisation becomes exciting because there is something that did not happen but it could at any time. Rzewski introduces his basic propositions of free improvisation as follows:

1. Anything can, and does, happen at any time.
2. At the same time things happen in predictable chains according to the predetermined conditions agreed upon conventions.
3. These chains are constantly are broken, according to the changes in conditions. Our expectations of what must or will happen also change.
4. At any moment, our activity or inactivity may influence, actively or passively the state of the whole.
5. At the same time, my perceptions of this state may influence my activity.
6. A circular causality may exist between present and future, so that not only does the present influence the future, but the future influences the present.
7. Likewise, the past determines the present, but the present also constantly changes the past (ibid: 268-269).

Listening is an important feature of the dialogue in an improvisation. During an improvisation, listening causes an improviser to focus more on the overall musical process than individual acts. Listening is not a mere activity but it is a critical feature in the improvisation process. In this context, Tom Nunn (2004: 7) states that active, critical listening is indispensable to free improvisation. Furthermore, Fritz proposes that active listening is an attentive focus on a salient acoustic feature, which is necessary for rapid task performance – occurring within minutes of a change in task requirements or acoustics (Fritz et al. 2005). Critical and active listening causes the improviser to be consciously aware of what has happened and to respond accordingly during the act of improvisation. Critical listening does not only takes place among the improvisers, but it is also conscious activity of the audience. The listening experience of the improvisation makes the audience critical and more informed. As a result of the listening process, the awareness and understanding of different types of music increases among the audience.

In a collective musical improvisation, it is possible for the participating musicians to interact with each other and share their experiences, which can turn the interaction into a learning process. John Dewey (1929) pointed out that it is the learner who interacts with events and people, thus gaining an understanding of the features held by these. The learner constructs self-conceptualizations and solutions to the problems of an activity. The learner participates in and constructs meaning out of it. One's learning is intimately associated with the connection with other human beings, teachers and family as well as casual acquaintances. This also includes people playing together in a collective musical improvisation. In this context, language provides the most obvious means for making connections with one another. It could be argued that musicians form their musical language for conversation based on musical elements for interacting with each other. During an act of collective improvisation, the improviser constantly examines the connections between new information and past experience with the thought of developing a shared understanding.

2.1 ImproMasters – Experimental Improvisation

There are methods that are commonly used by improvisers such as improvising on tonal harmony within a complete set of rules. These help improvisers to construct music in traditional forms of improvisation (Nunn 2004: 32). However, the *new* can also be found in the process of creating and realizing music by practicing improvisation methods with unconventional and distinctive musical structures. In its free form, experimental improvisation can be described as a new performance practice.

The ImproMasters course that has been organized by Shinji Kanki[2] since the autumn of 2004 at the Centre for Music and Technology, Sibelius Academy in Helsinki, is an example of the study of performance technology in free collective improvisation. Participants in the course had a chance to apply various electronic and acoustic performance tools to free collective improvisation practices in order to discover, develop and discuss new possibilities of making live music using technology. The course aimed at building a forum for sharing thoughts, ideas and music in a creative and inspiring way and to practice experimental improvisation with certain themes for each session.

During an ImproMasters session on Tuesday, 1st of March 2005, the author brought up *modalities* as an experimental improvisation theme to be practiced in a collective improvisation process. Before the improvisation session the modalities listed below were introduced to the improvisers. This experimental improvisation was based on the improvisers' attempts to consciously form their improvisation acts to represent each modality during different periods of the improvisation. The modalities have been applied to investigate improvisation as signification in Western music compositions (Tarasti 2002). In additional to this, the author aimed at applying these modalities on a computer generated electro-acoustic music improvisation and to analyze these as models of musical semiotics.

Modalities originated in linguistic-semiotic theories on improvisation and they are one phase in A.J. Greimas's generative course (ibid). Modalities emphasize subjectivity with the following words; *can, know, will, must* and *believe.* These modalities appear in musical improvisation in various forms. Within these modalities, that are the basis of Greima's semiotics of narrative action, two phases; *being* (non-action) and *doing* (action, moving forward) form a conjunction. The act of improvising in performances frames the being/doing status and the characteristics of the improvisation acts are identified with the modalities.

2 http://silakka.fi/main.html

- *Know* represents the musical information of the improvisation. *Know* can increase when an improvised part offers new information. More repetition gives less information; on the other hand, more information causes chaos in sound structures.
- *Must* is related to following a certain genre in music. It can increase or decrease relating to the free structure of the improvisation. *Must* is also the state of a musical element, which is modalized by another.
- *Can* is stronger, dominant and it can diminish other modalities depending on the performance practice of the improvisation. This can also be interpreted as a musical element's ability to modalize another element.
- *Will* is like a kinetic energy that increases when gaps are filled during the improvisation. It is a strong comment. The inclination of music is to move forwards.
- *Believe* is a truth that music tells its audience. It is the truth-value of the improvisation (ibid).

There was no set of rules assigned to the order of the modalities. The improvisers were able to use them whenever and however their act of improvisation required. During the modality session, the improvisers agreed to set rules for improvisation and to only use digital oscillators as instruments controlling the frequency range and amplitude value. There were 12 digital oscillators controlled by six improvisers.

Musical activities in this experimental improvisation give possibility to articulate the signification in music. Improvisers' feedback on the session was about their conscious attempts of representing the modalities with computer generated sinusoidal sound structures. Although they mentioned that during some parts of the improvisation, they did not concentrate on a particular signification, they did try to recognize the modalities during the moment of playing.

Activity in a collective musical improvisation can be defined simply as the improvisers' actions, which are under continuous development. Using Greimas's definition of modality, one can investigate how activity is structured in a particular improvisation session (ibid). In computer generated music or in traditional music improvisation, signs occur with the activity of the improvisers. Activity can carry pre-assigned socio-cultural rules for the actors. In the improvisation where *modalities* were practiced as methods, rules were framed by the early electronic music structures. As a result of framing these rules for the improvisation, significant meaning emerged through action. Following these particular rules, improvisers represented the meaning of the actions in various ways. Signs became messages through the meanings they were carrying. The messages of one improviser influenced the actions of others and thus they also influenced the response messages. This created continuous development in the improvisation structure.

Improvisation can be seen as communication or as signification, which are both connected through various circumstances such as time, history and the future of the improvisation product. Improvisation, according to Tarasti, is finding a good balance between rules and creativity (Tarasti 2002).

2.2 New Computational Tools and Classification

Computer-based interactive improvisation systems were developed in their early representations in the late 1960s. Peter Zinoviev and his colleagues developed one of the first systems in 1968 at Electronic Music Studios, Ltd. The system could rearrange a melody whistled to an attached microphone, calculate variations and respond back by performing on an attached analog synthesizer (Roads 1999: 685). Through the development of algorithmic tools and technical aspects of real-time performances, computational systems made designing various interactive systems easier than before (Winkler 1998).

Robert Rowe (1993: 6) has introduced a classification of interactive performance systems in three different dimensions. This has helped to identify the musical motivations behind types of input, interpretations, and methods of response. Rowe has argued that any designed interactive performance system may show some combination of these attributes (ibid).

Initially Rowe separates score driven systems from performance-driven systems in order to refine his classification scheme. Score-driven systems are designed to execute pre-programmed musical events. Curtis Roads (1999: 681) further describes score-driven systems as accompaniment systems that play along with a human musician. Roads also introduced Roger Dannenberg's computer accompanist system that can perform real-time pitch detection on a trumpet performance. Unlike a score-driven system, a performance-driven system depends directly on the performer's input. In this type of system a computer generates an output based on free performance by the performer.

Rowe identifies the systems' similarities and relations by categorizing the responsive methods of the interactive system to three different groups of musical input. Transformative methods apply transformation on incoming musical data to produce outcome variations. The outcome may be transformed into musical material, which is not identifiable as the original input. A system that uses a set of rules or generative algorithms based on randomized techniques to generate a musical texture is categorized under generative methods. Sequenced techniques are musical response methods that use pre-recorded materials to respond to a performer in real time.

Rowe's classification scheme distinguishes between two main paradigms in interactive music systems. In the instrument paradigm, the system augments the human performer's gestural inputs as an extended musical instrument. The player paradigm involves human-machine interaction where the machine behaves like an improvising partner as another musical presence that has independence weight in outcome musical texture apart from the human performer's musical response (Rowe 2001: 302). Interactive improvisation systems are classified as following a player paradigm based on their ability to analyze and understand the human improviser's contribution.

In addition to these systems, Rowe (2001: 308) introduces ensemble improvisation systems that enable collective improvisation performances. Ensemble improvisation systems allow human musical interaction to be practiced in a collaborative environment. According to Rowe, designing appropriate control structures for ensemble improvisation systems might have difficult solutions. In general designing an interactive improvisation system that responds in real-time is challenging. Moreover, involving complex interaction methods for a collective improvisation process might cause more difficulties in system design.

In this chapter the author's performance work, *Generative Musical Improvisation (2004)* is shown. This work explores human musical interaction with machine contribution and discusses the generative methods of an improvisation process (Tahiroğlu 2004). The attached DVD, which accompanies this dissertation, includes technical materials of the interactive performance system used in this work as well as recorded video files from the performance and the rehearsal.

2.3 Generative Musical Improvisation Performance

GENERATIVE MUSICAL IMPROVISATION, MILAN, 2004

The Generative Art conference is an annual festival for artists, researchers, designers and professionals working with generative computational tools. The purpose of the festival is to open new fields and enhance the understanding of creativity as an indissoluble synthesis between art and science (Soddu 2008). The Generative Design Lab of the department of Architecture and Planning at the Politecnico di Milano University in Milan, Italy has organized this conference since 1998. The event comprises paper sessions, poster sessions, and installations with presentations and performances. The conference chair and a scientific committee review all the

abstract, paper and poster submissions along with artworks / installations and performance proposals. The author's performance proposal *Generative Musical Improvisation* was accepted as a live performance and was scheduled for the 7th International Generative Art Conference, Wednesday 15th of December 2004. Wednesday's performance session line up was; *Three Row Poles to Enlightenment* by Thomas E. Brady (USA), *Clipscore* by Paolo Bottoni, Stefano Faralli, Anna Labella, Claudio Scozzafava, Stefano Faralli (IT), *Generative Musical Improvisation* by Koray Tahiroğlu (TR) and *Prometheus (Hysterical Duet)* by Yiannis Melanitis (GR).

The performances took place in the exhibition hall, alongside the installations. Therefore, the performers had to find locations to set up each performance place. In order to have a balanced audio stream during the performance, the Politecnico di Milano University supplied two active speakers for the author's performance and they were placed in the middle of the exhibition hall. Other technical equipment used in the performance was; a Washburn electric guitar, a Roland electric guitar MIDI sequencer, a Yamaha Mu90R sound module, a MIDIMAN MIDISPORT 1x1 USB MIDI interface, a G3 Apple Macintosh Powerbook (Pismo) with 400Mhz, 512 Ram, and Mac OS X 10.3 Panther operating system and a Behringer Eurorack MX 602A audio mixer. The performance session began at 20:00 and the author performed an approximately six minutes long session of *Generative Musical Improvisation*.

2.3.1 Generative Musical Interactive Improvisation System

The interactive performance system is designed to be used in the context of generative musical improvisation. The system can be classified according to Rowe's taxonomy as *following a player paradigm*. That is a system that behaves like an improvising partner in a performance with a human musician. The system is responsive and engages in continuous conversation with the performer participating in music of a particular style. The computational methods of the interactive performance system can further be categorized under interactive computer response methods (Rowe 1993: 7–8).

Randomness and generative principles are the key terms for the *Generative Musical Interactive Improvisation System*. During the improvisation a certain amount of control remains with the performer while a part is given up to the randomness. The interactive performance system's generative methods employ randomness to create and realize the unexpected practices in the improvisation process. The random decision-making process provides a certain framework for a question-reply improvisation method, which supplies the psychophysical basis of performance action as *intent impulse*. The intent impulse is the concentration on the moment in performance for very rapid decisions (Nunn 2004: 24). As with other free improvisation performances, the first sound is entirely impulsive in this improvisation process. It is followed by the first spontaneous response both from the performer and from the interactive performance system. The performer assigns the structure of the musical scale; however, the interactive system randomly proposes certain scales as well. Randomness is the core statement of the decisions in the system's response process. The performer's musical inputs are analyzed in this randomness context to give immediate response to a response to develop a free collective improvisation process. As the improvisation progresses, the performer's conscious musical expressions develop further.

The random outcomes in the performance are determined so that the generated notes will not be dependent on any predefined order in the structure. Even though certain scales are followed, there is no predefined structure for the notation order. In an improvisation with the interactive performance system, no two performances are identical. The controlled random identity of the interactive system is created by using certain scales with notes that have not been predefined.

The overall system architecture of the interactive performance system has been constructed and developed by using the Pure Data environment. The Pure Data environment is a dataflow programming (visual programming) language for audio and multimedia (Puckette 1996, 2007a). The application is a recent and pioneering development in the contemporary art field.

Pure Data

Pure Data is an open source graphical dataflow programming environment for real-time audio and graphical processing. Pure Data has been written and maintained by Miller Puckette. However, as an open source application, the development process includes the work of many developers, which makes this environment a community effort. Pure Data runs on Win32, IRIX, LINUX and Mac-OSX platforms, and it is still a work in progress[3]. In this research, Pure Data has been chosen as a programming environment for creating and developing interactive performance systems, because of three main reasons. Firstly, Pure Data is an open source environment, not only a freeware application but also it is free for any use. It provides access to its code structure so it can be modified to suit requirements. Another important factor is that its digital signal processing performance has been identified as more efficient and powerful when compared to the other graphical programming languages. On the other hand, the most important reason for choosing Pure Data as the main programming environment for this research process is that in the Pure Data community users are able to consult each other on various problems.

Note generator module

The *Generative Musical Interactive Improvisation System* modules are interconnect as shown in Figure 2–1. A MIDI[4] guitar interface transforms analog signals into MIDI messages and transmits them to the computer through another MIDI interface, which is connected directly to the computer with an USB port connection. Analog signals of the electric guitar are processed through the analog chorus[5] and over-drive[6] effect processors. During the improvisation, MIDI messages that are transformed from MIDI guitar interface represent the author's musical information. The in-

3 Pure Data community site can be found at http://www.puredata.info and a wiki based resource at http://pdpedia.org

4 Musical Instruments Digital Interface (MIDI) is a communication protocol standard between instruments and computers regardless of hardware manufacturer; however, it requires a certain method for data communication and hardware interconnection scheme (Roads 1999: 972).

5 Chorus effect is a combination of delay and phase shifting (ibid 1999: 419).

6 An audio signal distorts the incoming waveform of the audio signal into a different shape when it is passed through a transfer function, which is used in the linear analysis of the input and output signals. In this process, the amplitude of the input waveform affects the shape of the output waveform. If the input is a decaying sinusoid, the output in the beginning evolves from an early square wave form to a pure sinusoid at the end. This effect is known as over-drive audio effect (Puckette 2007a: 138–139).

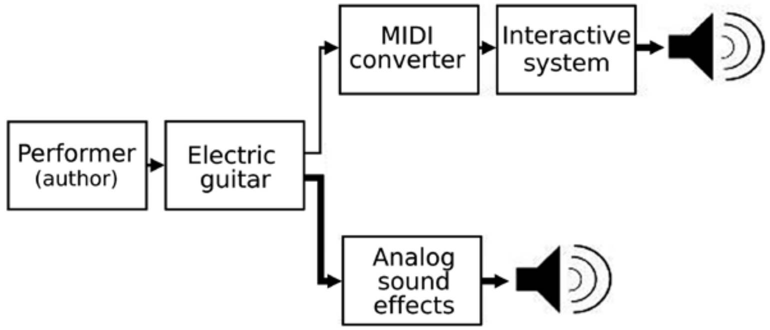


Figure 2–1: Block-diagram of the *Generative Musical Improvisation* interactive system.

teractive performance system filters and analyses this musical information and responds through three decision making modules in parallel, which are the *note generator*, *tempo-rhythm generator* and *record-sample* modules.

The incoming MIDI pitch number messages[7] are received and distributed through the *notein* object[8] in the Pure Data environment. The *Note generator* module generates notes based on the random walk[9] probability method. Received MIDI pitch messages activate random walk and drunk[10] walk patches to generate a pitch class note in the following musical scales; minor harmonic, blues, pentatonic and the major scales. These are the key points in the harmonic algorithm structure of the interactive performance system. Random walk probability method is assigned for the minor harmonic path and drunk walk patch is assigned for the major, blues and pentatonic scales.

The Interactive performance system registers the octave information

7 Key number specifies the integer number range between 0 and 127, which represents the MIDI pitch scale on a piano keyboard.

8 Objects are the main building blocks of the functions that are linked to each other for processing the data flow in Pure Data.

9 Random walk is a weighted random probability distribution, which is based on the results of a sequenced of events.

10 Drunk is a Pure Data external object from the cyclone library that generates numbers based on a random walk probability method.

related to the musical outputs of the author; however, the harmonic scale is randomly determined by the system. The random choice also determines the MIDI instrument and the level of velocity of the generated note. Two different instruments have been assigned in the MIDI sequencer and connected together with scale paths in the *note generator* module. The acoustic grand piano, GM[11] instrument channel number one, is connected to blues and pentatonic scales and the acoustic guitar (nylon), GM instrument channel number 25, is connected to major and minor harmonic scales. The velocity value for each note is set at level 110; however, each generated note has a different duration value. Notes generated by the major scale have 1300 milliseconds duration, blues scale notes have 2000 milliseconds, pentatonic scales have 1500 milliseconds duration and minor harmonic scale have 4000 milliseconds duration. Duration millisecond values are assigned related to the sustain characteristic of musical instruments.

Tempo-rhythm generator module

The *tempo-rhythm generator* is a sub block that calculates global tempo and time divisions for the bass and the rhythm instruments. The *notein* object outputs MIDI messages to *tempo-rhythm generator* module. The amount of MIDI messages received is counted and every ten seconds the sum of the number is sent to a number box in *rhtm* sub patch[12]. This value represents the author's output activity in a period of ten seconds and it is used as a source for identifying the initial metronome information for the improvisation performance. In two minutes time, the last value stored in the number box is transmitted to the *rthstr* sub patch. The value is assigned as the metronome and the initial pulse-tempo of the improvisation session. The metronome activates the *tempo-rhythm generator* patches and once the initial tempo is set, the value is stored at the *rthstr* sub patch. As the author interacts with the system, MIDI message streams are counted in

11 GM, also known as GM1 (General MIDI 1) is a specification, which was designed to provide performance compatibility among MIDI instruments (http://www.midi.org).

12 Sub patch is a hidden layer on the main patch. It acts like an object box with inlet and outlet structure; however, inside the sub patch there is another patch, which is constructed to take inputs and give outputs to the main patch.

first pulse partition	8.8–17.6	fifth pulse partition	140.8 - 211.2
second pulse partition	17.6–35.2	sixth pulse partition	211.2 - 281.6
third pulse partition	35.2–70.4	seventh pulse partition	281.6 - 352
fourth pulse partition	70.4–140.8	eight pulse partition	352 - 422.4

Figure 2–2: Octave bands in bpm for the metronome value 70.4 bpm.

tempo-rhythm generator and every two minutes they are sent to the *rthstr* sub patch. The last value received does not change the metronome; however it is counted to assign the number of pulses that each rhythm section instrument will generate related to the metronome value. Whenever the *tempo-rhythm generator* module sends the metronome information to the *rthstr* sub patch, the metronome value is processed with simple integer ratios and results are stored. These results structure the pulse partition values in the *rthstr* sub patch. The *rthstr* sub patch assigns the amount of beat per minute (bpm) value related to the initial metronome information and generates pulse outputs. Every two minutes when a new value is sent, the *rthstr* sub patch assigns the partition of the pulse structure and activates the new pulse output. The module generates variance values in the rhythm partitions while keeping the tempo intact. As a practical example, if the initial metronome value is set at the value 70.4 bpm, the *rthstr* sub patch generates partitions of pulse structure as in Figure 2-2.

The *rthstr* sub patch sets pulse output as 70.4 bmp for the acoustic bass instrument, which is the same as the initial metronome value. If 83 bmp would be the new value that would arrive to the *rthstr* sub patch, 83 bmp would be in the range of the fourth partition and the pulse output would be set at the smaller value in the partition structure. In this case, the pulse output would be 70.4 bmp regarding to 83 bmp as the sum information. The main reason for assigning the partition structure is to keep the initially assigned metronome value static, and also to have different possible rhythmic structures related to the performance activity. When the author responds with more outputs in a short amount of time, this causes the system to respond with more pulse outputs; however, the pulse period of the system always remains in the initial metronome range.

Pulse outputs activate the *drunk* object to generate pitch class notes for the acoustic bass instrument GM channel number 33 in the MIDI sequencer. The bass instrument outputs notes that are in the second MIDI octave. The *note generator module* sends the scale information of these notes to the *rthstr* sub patch. Velocity value for bass notes is set at the level 75 and the duration at 1800 milliseconds. In order to have various different rhythmic structures, pulse per minute values of the drum percussion and the cymbal instrument are calculated so that they will not be the same with the acoustic bass instrument.

On GM Channel 10, each MIDI Note number (key number) corresponds to a different drum sound. General MIDI[13] Level 1 compatible instruments supports verity of drum sounds including acoustic bass drum, closed hi hat, hi wood block and open triangle. Drum sound instruments and cymbal instruments are the rhythmic instruments in the *tempo-rhythm generator* module together with the acoustic bass instrument.

The pulse partition structure to generate pulse information for drum percussion instruments is shown in Figure 2–3. Pulse information activates a *drunk* object and a number is generated between 0 and 14 with 12 magnitude value using a random walk probability method. The generated numbers are filtered through a *select* object in order not to output every beat or every other beat. Numbers 3, 6, 8, 10, 12 are filtered by the *select* object and only numbers 0, 1, 2, 4, 5, 7, 9, 11, 13 can pass through as output. Having a drum sound for each pulse information is restricted by filtering the *drunk* object outputs. Filtered numbers specify the instrument to be played among the drum percussion instruments. Drum percussion instruments that can be activated in *tempo-rhythm generator* module are:

Open Hi-Hat instrument key number 46
Low-Mid Tom instrument key number 47
Hi-Mid Tom instrument key number 48
High Tom instrument key number 50
Ride Cymbal 1 instrument key number 51
Ride Bell key instrument number 53
Splash Cymbal instrument key number 55

13 General MIDI instruments are the standard instruments that have the same instrument channel number in MIDI sequencer hardware. All the instrument channel numbers for General MIDI can be found at http://www.midi.org/.

first pulse partition	x/8 and x/4	third pulse partition	x and 3x
second pulse partition	x/4 and x	fourth pulse partition	3x and 5x

Figure 2–3: Pulse partition structure for drum percussion instruments. x represents the initial metronome value of the improvisation session in bpm.

first pulse partition	x/8 and x/4	fourth pulse partition	x and 2x
second pulse partition	x/4 and x/2	fifth pulse partition	2x and 4x
third pulse partition	x/2 and x	sixth pulse partition	4x and 6x

Figure 2–4: Pulse partition structure for Ride cymbal 2 instrument in bpm.

Crash Cymbal 2 instrument key number 57
Ride Cymbal 2 instrument key number 59

Unlike the drum percussion instrument structure, the third instrument in this module, Ride Cymbal 2, generates sounds for each pulse information it receives from the *rthstr* sub patch. However, the pulse rhythmic information for each instrument is differed from the main assigned tempo value. The partition pulse structure of the Ride Cymbal 2 instrument is shown in Figure 2-4.

Notein object transmits MIDI messages to the record-sample unit in order to record samples from the performer's MIDI output. The *Record-sample* unit randomly records the performer's MIDI messages, and plays them back after a randomly determined amount of time. The Acoustic grand piano and acoustic guitar (nylon) instruments play back the recorded MIDI messages.

2.3.2 Performance Observations

In the performance, and rehearsals at the 7th International Generative Art Conference, the system's responsive improvising ensemble brought together the ever-changing musical identity of a free improvisation and the human machine interaction in a musical activity. Beginning parts of the improvisation involved *intent impulse* action to exchange rapid responses in order to figure the common scale and register the convenient octave parts. There was not a high level of critical listening in the beginning; both the author and the interactive system were trying to investigate the knowledge of the early scale information. Later on with the involvement of more critical listening, the improvisation strategy changed into a question and reply method. The musical actions of the author were formed as questions to which the interactive system then replied. During the improvisation process, the question and reply method changed itself into another form with predefined scale structures. *Completing the sentence action* was based on generating a structure using possible notes within the scale and stopping playing immediately.

The responses of the interactive system filled in the missing notes generated in the scale, and used after author's pulse action. *Completing the sentence action* was also used with roles reversed; author completed sentences that the interactive performance system had began to construct. Thereafter, improvisation turned into a dialog of music between the author and the interactive system. In the beginning the interactive system activated only the *note generator module*, and after monitoring the author's actions in the first two minutes of the improvisation, the *Tempo-rhythm generator module* and the *record-sample module* began to take part in the improvisation as well. When the *tempo-rhythm generator* module began to activate the acoustic bass, drum instruments and the ride cymbal instrument, the improvisation strategy turned into a solo instrument and accompanying instruments actions.

The interactive performance system caused the author to play within the pre-determined scale; however, out-of-scale responses of the author indeed created different sonic variations in the context of tonal music structures. The generated responses of the interactive performance system later on turned the improvisation back into a question and response method. When the author stopped playing for a short period, the system did not become silent immediately. The rhythmic instruments continued playing through the generative algorithms that were triggered by the speed of the pulse, and also the *record-sample module* was re-sampling the previous musical input of the author. For most of the performance the author was the lead instrument player; however, when the *record-sample module* brought back some samples of previous musical inputs, it became a solo instrument. The author's immediate reaction was to play a rhythmic arpeggio loop to highlight the re-sampled sounds as lead instrument outputs. Changing between the high and low pitches and also moving in and out of the scale resulted in the interactive system responding in rule-based generative methods. This changed the timbre allowing for different sonic relations. When the *record-sample module* captured out of scale responses of the author and played them back, the author continued playing out-of-the scale notes and it created rich sonic relations in time.

Active listening, attentive focus on salient acoustic features, resulted in the role of questioner to switch from the author to the system. At times, the system-generated structure became the lead in questions or sentences that needed to be completed, and the author accompanied the interactive system. The author took the role of a passive rhythmic instrument player, which gave more autonomy to the system. The improvisation ended after a period of time when the system monitored no further musical input from the author.

2.4 Conclusion

An electric guitar was chosen as an interface because of the author's previous playing experience. The Washburn electric guitar and the Roland electric guitar MIDI sequencer were chosen because they were available in the Media Lab Helsinki TaiK library. In addition, the electric guitar as an interface has a lot of cultural baggage, and its musical instrument structure brings forth many design opportunities. The algorithmic structure in the Generative Musical Improvisation interactive system is based on chromatic western guitar music structures. The rule-based modules of the interactive performance system generate outputs in certain tonal musical scales that are commonly used in guitar music performances.

The Generative Musical Improvisation interactive system is limited

with the musical output of its system, which is in certain patterns of a guitar music genre. On the other hand, musical instrument structure brings forth the physical limitations of the instrument in an improvisation activity. The Generative Musical Improvisation interactive system could be further developed computationally to expand the limitations of the guitar as an interface.

Matti Karjalainen and coworkers have developed the "Virtual Air Guitar"[14] instrument to study synthetic guitar playing with hand-following sensors (Karjalainen et al 2004). The Virtual Air Guitar is a playable virtual instrument that consists of hand-held controllers and a guitar synthesizer with sound effects without the physical existence of an electric guitar instrument (ibid). Virtual air guitar expands the limitation of the guitar as an interface. In designing the virtual instrument system, the research group focused on gesture recognition in the act of guitar playing, which allows users to investigate the possibilities of guitar playing without the physical boundaries of the instrument. Sound synthesis modules of the Virtual Guitar instrument are strongly tied up with the "cultural baggage", but user can act freely within the "guitar music" segments. The computational part of this system is based on the synthesis of guitar sounds relating to the captured hand gestures from both hands. The system is designed for solo free playing modes. Improvisation could be possible only with the involvement of two different users running two different instances of the system. There is no physical existence of the guitar, but the system responds using a set of allowed guitar matching tonal structures.

The Generative Musical Improvisation interactive system can make use of "cultural baggage" and "guitar music" for scaling system responses and improving user engagement during an improvisation. During the performance when the author was playing simple, blues-like patterns the system replied in a similar fashion. The system could have been designed to go beyond its limited output structures. If the author would have played fusion-like or free jazz patterns, the system could also have altered the complexity of its outputs. A deeper level of interactivity could have been

14 Air guitar is a physically non-exciting guitar, which refers to acting the playing guitar with a musical playback. There is an annual Air Guitar World Championships competition organized in Oulu, Finland since 1996 (http://www.airguitarworldchampionships.com).

achieved with more analysis of the incoming guitar signal's pitch. Rather than have the computer choose scales based on random processes, a more sophisticated listener could have been implemented to analyze scales used by the performer. In addition, the fixed 10-second window for tempo analysis could have been implemented as a more flexible running average, allowing for much shorter response times of the computer.

Miller Puckette (2007b: 1) has designed a personalized computer music instrument based on an electric guitar with a possibility of six channels mapping modules. The sound synthesis module of this computer music instrument differs itself from standard guitar synthesizers by using alternative waveshaping techniques and algorithms. Sound processing and synthesis of the instrument computationally give alternative musical textures beyond the "guitar music" genre. During the performance of the Convolution Brothers (Zack Settel, Cort Lippe, Miller Puckette) at the Pure Data Convention 2007 in Montreal, Canada, this instrument was used and directed the piece *Convo. Bro's Guide to Live Performance*. The performance was an improvised electronic music-theater performance. Puckette's improvisation responses with his computer music instrument formed experimental musical structures, which encouraged other members of the Convolution Brothers to develop their improvisation both in musical and theatrical structure. The sonic palette of the author's work could be also altered with non-MIDI synthetic sounds or effects processing by using advanced computational techniques and algorithms in the interactive system design.

The limited sonic variations of certain types of tonal structures can be expanded further by choosing another musical instrument as the interface of the system. Robert Gluck (2005) has designed a distinct instrument, called eSaz, which is a new hybrid acoustic / electronic instrument. It is based on the placement of sensors on the Saz, which is a Turkish long-necked stringed instrument. eSaz is a nontraditional western musical instrument interface, and it is used as an alternative gesture controller for the computational part of the performance system. The eSaz performance system maps finger pressure and position through the sensors to allow simultaneous control over many aspects and the multiple layering of sound (ibid). Thus a non-western musical instrument interface can go beyond the twelve-tone structure and make the system respond with microtonal ways.

The limited sonic variations of the *Generative Musical Improvisation* interactive system led the author to investigate alternative strategies in developing computational sound processing, control structures, developing new

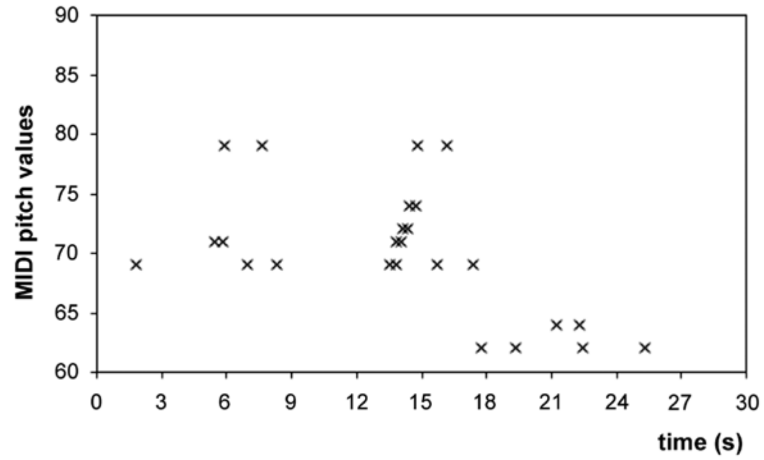
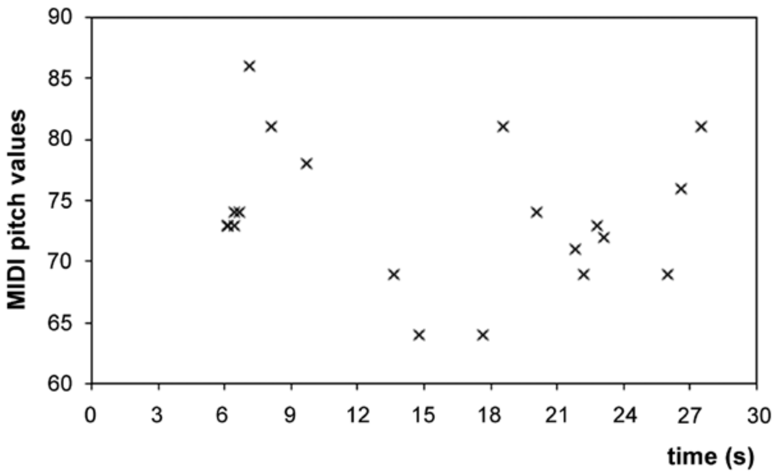


Figure 2–5: The Author's musical output from a rehearsal on 12th of December 2004.
Figure 2–6: The Note Generator Module's Data set from a rehearsal on 12th of De-

interfaces and algorithms for new sound structures to expand the sonic palette of the musical improvisation during the research process.

Data set diagrams

The author's musical activity in a 30 seconds period of time is shown in Figure 2–5 with the MIDI pitch values versus time (seconds) diagram. The data was recorded during a rehearsal on Sunday 12th December 2004. Responses of the interactive performance system to the author's output are shown in the Figure 2–6 during the same time period in the rehearsal session. The comparison diagram of the author's responses and system's responses makes it possible to follow the random walk plots in Figure 2–7. The acoustic bass instrument's responses are also shown in Figure 2–8.



cember 2004.

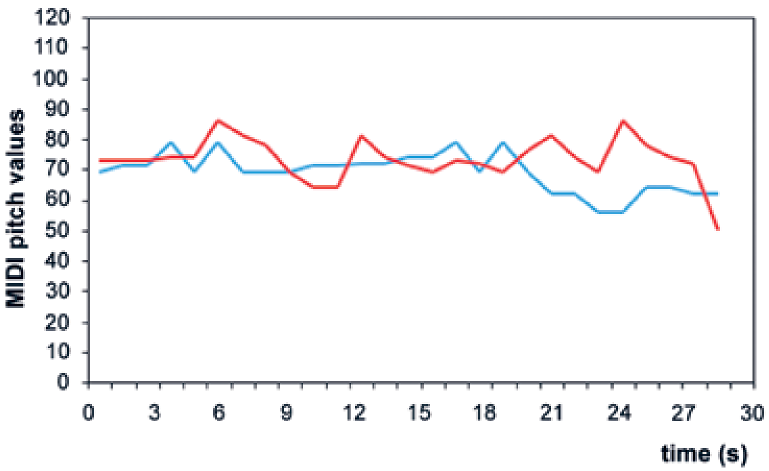


Figure 2–7 The blue pattern represents the author's live input and the red pattern represents the Interactive Performance System's data set. This figure represents the combination of Figure 2–4 and in Figure 2–5.

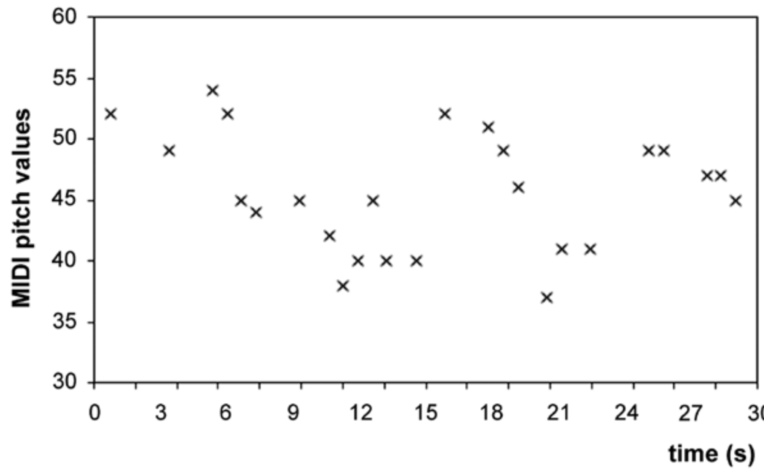


Figure 2–8: Data set of the acoustic bass instrument in the Tempo-rhythm generator module in MIDI pitch values versus time plot.

3.

An Improvisation of two Performers

John Dewey has noted how every experience is the result of the interaction between humans and the environment and how the interaction of humans and the world is cumulative (Dewey 2005). It could be argued that, as a part of our lives, art has the potential to turn this interaction into pleasurable activity.

The cyclic process in interactivity brings forth communication, which is the most commonly experienced form of interactivity. In general, communication is used as a metaphor for interaction but the forms of activity involved in conversation represents the process of interactions in every medium. Listening, thinking and responding are the main processes that determine the interactive context (Crawford 2004). Sonic interaction bears similar characteristics of interaction in general, such as principles that help to create a sense of interactivity and feedback.

In this chapter, sound is introduced as a primary source for conveying information and aesthetic meaning in interactive contexts. Following the human-machine improvisation performance system described in chapter 2, the research concentrated on studying and developing novel computational methods for new sound structures. Focusing on sound as a source for representing information and aesthetics, sonification has been a key strategy in developing the next generation of interactive improvisation performance systems for duo performances. The SolarDuo Project (Tahiroğlu and Lyytikäinen 2006) is introduced in this chapter with sonification strategies and interactive improvisation system structures. In the SolarDuo Project the author was responsible for the majority of the technical and conceptual work. As a result of the nature of the work the author and Joni Lyytikäinen are jointly responsible for the performances. The SolarDuo Project has performed at various festivals in Finland, Turkey, Norway and Austria since 2004.

The DVD material of this dissertation includes technical materials of the SolarDuo Project interactive performance systems, recorded video and audio files from the performances, sonification data files and images of SolarDuo Project musical instruments.

3.1 SolarDuo Project

The SolarDuo Project experiments with the sonification of solar data, and how sound structures can be created with light waves. The project utilizes analog and computer-generated sounds together and it releases an unexpected richness of sound processing in real-time performances.

The project originated in the Local Motion sound design workshop at the Media Lab, Helsinki in 2003 when the author and Joni Lyytikäinen[15] tried to connect a solar panel directly to the audio input of a sound mixer. The electrical charge in a solar panel is directed so that it will produce a low voltage direct current (DC). However, it became apparent that other electric components were needed to achieve different sound structures from a solar panel. A solution was found by attaching more electric components to the circuit structure. This made it possible to alternate the voltage and generate sounds with the solar panel.

The first SolarDuo Project circuit structure was based on an example

15 Joni Lyytikäinen, MA in New Media, completed his master degree with his final thesis Organizing Sound with Circuit-Bending and Data Sonification and the thesis involved the SolarDuo Project as a case study as well.

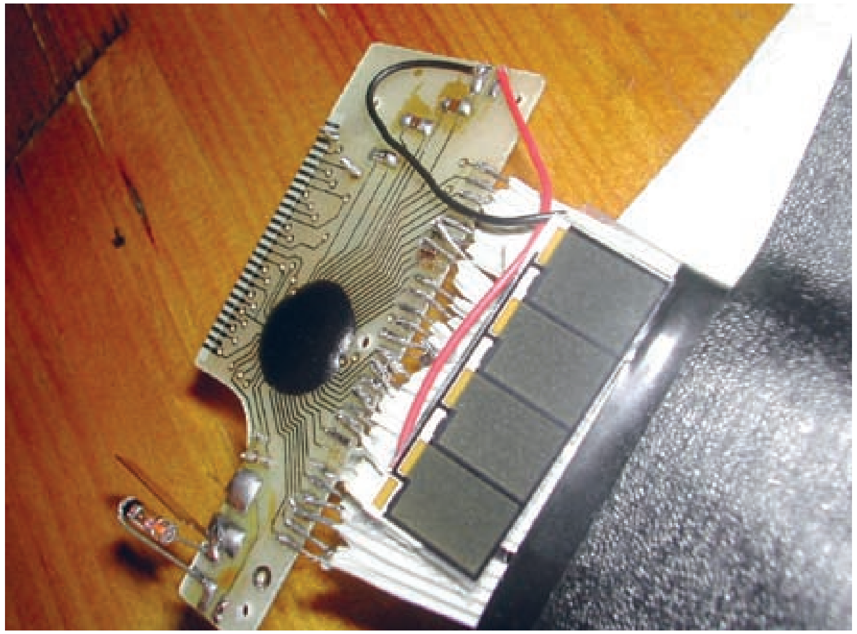
by Ralf Schreiber[16]. Later, the author and Lyytikäinen began to develop self-made solar panel instruments. Instruments 0/1 and 5/4 were the first examples of the SolarDuo Project musical instruments. Some of the approaches used to design experimental musical instruments are introduced later in chapter 5.

Instrument 0/1 is the part of a pocket calculator that uses a solar panel as source of electricity. Figure 3–1 shows the components of instrument 0/1, which are inner parts of a *bent* calculator. Modifying technology, usually electronic toys or other circuit-integrated components for experimental sonic findings, has resulted a considerable interest in hacking and circuit bending practices in music. For example, while exploring potential sonic varieties of electronic component circuits in compositions such as, *Rainforest (1968)* and *Rainforest IV (1973)* David Tudor, a pioneer in the field of circuit designing, has developed a modular approach in his designs (Hultberg 1988).

Circuit bending can be seen as free style sound design based on accidental circuit interaction. According to Collins the main difference between hacking and bending is the extreme experimentalism that bending provides; bending produces unexpected results for the designers while hacking is based on an idea of what is possible before opening the circuits (Collins 2006: 91). The modified pocket calculator instruments of the SolarDuo Project were made using the bending approach.

It is often possible to get a sudden release of a burst sound from the instrument 0/1. Making a short circuit between two points on the board slows down the burst sound. The capacity of the human body to function as a conductor, by allowing electrical charge to move between two points, has been used as an experimental technique not only in history but also in contemporary art (Elsenaar and Scha 2002). Following the short circuit strategy, Lyytikäinen developed a playing technique by simply connecting two points on the circuit with his thumb. Touching the circuit caused the instrument to produce long sequences of sounds with different frequency values. If there is no physical contact with the circuit, the produced sound is a frequency-wise stable square wave. The amount

16 Ralph Schreiber is an artist experimenting in minimal robotics which are driven by solar power. www.ralfschreiber.com



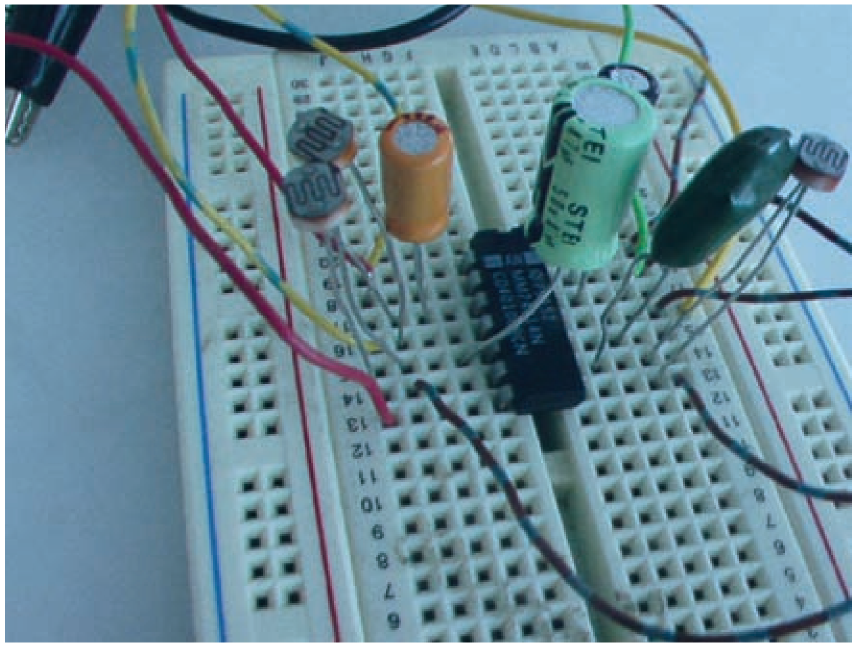


Figure 3-1: SolarDuo Project instrument 0/1.
Figure 3-2: The first version of SolarDuo Project instrument 5/4.

of light that the instrument receives also causes changes in the amplitude and pitch values.

During the project, the lack of a control area on the circuit of instrument 0/1 caused Lyytikäinen to separate the solar panel and the circuit. The instrument was reconstructed with the same structure on a bigger triangular piece of wood. A quarter inch guitar plug and a switch were attached to the instrument so that it could be connected to the mixer. The instrument is called "0/1" because of the printed numbers 'zero' and 'one' on the switch, which represent the "on" and "off" signs.

Instrument 5/4, as it is shown in Figure 3–2, is a modification of Schreiber's circuit structure and it is powered by a solar panel. The instrument is named 5/4 because of the 5/4 sign, which is written on the back side of Panasonic BP–376634 solar panel. It is a module of an oscillation circuit with a Hex Schmitt Inverter, resistors and capacitors. The key element of this module is the IC hex Schmitt inverter chip, which is an integrated circuit of several Schmitt triggers. The Schmitt triggers change the polarity of an incoming voltage into an opposite sign value and produce continuous square wave sounds in the circuit of instrument 5/4. The frequency of these sounds depends on the values of R (resistance), C (capacitance) and the threshold points of the Schmitt trigger. The speaker is connected to the minus point and to the alternating point on the circuit. The amount of light causes the sound module to produces a wide range of sounds from a continuous pitch to different rhythmic structures.

In a stable lighting condition, the electric signal produced by SolarDuo Project musical instruments is monotonous in timbre as well as in temporal characteristics. Sound signals represent electronic noise properties – dry, sharp attacks, repetitive rhythm. In order to achieve alternative characteristics of analog sounds, the output of solar panel instruments were passed through a metal plate object, which created a resonating environment for the sound coming from the instrument. Transducers that were originally components of a pyramid shape cardboard speaker (SoundpaX) were attached to the metal plate to transmit analog sounds from the instrument onto the metal panel. A contact microphone was also attached to the metal plate to transfer the sound to the mixer. The resulting sounds were rich, full and still represented the characteristics of an analog musical instrument.

It is possible to achieve similar sound structures from instruments by using a battery as an electricity source instead of a solar panel. However, hand gestures, and the distance of the light source to the instrument have a strong diverse effect on the produced sound. Using different types of light sources, such as a flashlight, table lamp, direct sunlight, also affect the output of solar panel instruments.

It is not always possible to achieve full control over SolarDuo Project instruments and there is a possibility of receiving unexpected sounds during a live performance. However, sonic feedback of hand gestures, and contact with the circuit board through the thumb, and investigating new strategies and techniques with the use of light sources transformed these artifacts into musical instruments of live SolarDuo Project performances.

Improvisation of two performers, the use of solar powered and light controlled electronic devices along with sonification strategies, were the aim of the musical and technological exploration of the SolarDuo Project. Algorithms generate modifications according to different parameter changes. These parameter changes are controlled and manipulated related to over all sound structures during an improvisation process. Sampled sounds are usually pre-recorded sound materials; however, real-time manipulations create completely new sounds from the existing ones. One type of algorithm that is used in the SolarDuo Project is based on manipulation of sampled sounds. The other types of algorithms used in the project are built on generative methods and the sonification of solar data, which is gathered from terrestrial and orbiting solar instruments.

Algorithmic strategies and the musical work done in the SolarDuo Project rely on the improvisation process by framing an area to a way of performing that gives unexpected results. The SolarDuo Project has been using the following open source environments in developing algorithmic structures of the project; Pure Data, the Python programming language[17], and PHP scripting language[18].

17 http://www.python.org

18 http://www.php.net

3.1.1 Sonification

Design strategies in developing the SolarDuo Project instruments are focused on sound modeling and developing new algorithms in order to create novel sonic interaction between the performers and the interactive performance systems. One of the motivations of the SolarDuo Project has been the attempt to investigate alternative ways of developing sonic interaction with a source, which cannot originally generate any sound structure.

The process of developing algorithmic structures for a live improvisation involves focusing on sound as a source for representing aesthetics in experimental music performances. The SolarDuo Project performances aimed to produce sonic variations of all kinds. On the other hand, from the beginning, sound was elaborated as a primary source for representing information within the developed sonification strategies. Focusing on sound as a source for representing aesthetics and information, made sonification a key strategy in developing interactive performance systems in the SolarDuo Project.

In the early algorithmic structures of the SolarDuo Project digital interfaces and random processes controlled the interactive performance systems. During the project, some parts of the internal control system were replaced with a dataset, which was gathered from solar instruments of research centers in SOHO organization[19]. Using solar data to manipulate the parameters of the interactive system resulted in different sound structures than the previous ones, which led the project to focus on developing alternative data mapping structures. By changing the mapping strategy of the data, the sound structure brings out new characteristics in sounds, which represent the information of the sonified data.

The Webster's Dictionary defines sonification as the act of producing sound like the stridulation of insects (Webster 2005). This means that any sound production can be called sonification – speaking, guitar playing, rubbing hands together, hitting a ball, wind shaking the trees and so on.

19 SOHO, Solar and Heliospheric Observatory is a collaboration project between ESA and NASA. The project is aimed to investigate more about the Sun and the solar wind (http://sohowww.nascom.nasa.gov).

Hitting a ball for example is not usually an activity that produces sound intentionally; in this case sound is a side effect of the main action.

The International Community for Auditory Display (ICAD) defines sonification as the use of non-speech audio to convey information (ICAD 2008). This definition takes a completely different direction, as it implies that sound can be used to present information about a subject that does not naturally represent itself in an audible format without including any written description. ICAD's disciplines involve psychological research in perception and cognition, development of sonification tools for sonification design and applications (Kramer et al. 1997).

In order to have a shared language and vocabulary, researchers in the field have agreed on the ICAD's definition of sonification. Thomas Hermann, a member of the ICAD Board of Directors, is sharing this agreed definition and questions more on the criteria, which ought to be fulfilled in order for a sound to be called sonification (Hermann 2007). His definition of sonification pays more attention to the data being used as an input to generate sound signals if and only if the following conditions are fulfilled:

(A) The sound reflects properties and relations in the input data.
(B) The transformation is completely systematic.
(C) The sonification is reproduceable.
(D) The system can intentionally be used with different data, and also be used in repetition with the same data (ibid).

Hermann's conditions are more in the direction of outlining the characteristics of data mapping strategies for sound artists using data for compositional purposes. Sonification research is an interdisciplinary field. It integrates human perception, acoustics, design, arts, and engineering. Other than artistic purposes, sonification has been used in variety of ways. The stethoscope and the sonar are examples of devices that use sonification before the ICAD's definition. Some car repairmen and technicians have been using sonification and auditory display techniques for decades. They turn the engine on to listen to the sound and by observing the sonic changes, they try to identify what kind of problem the car might have.

Software that enables blind chemists to examine infrared spectrographic data via auditory presentation, auditory mapping of anesthesiology workstations and factory production controls, airplane cockpit sounds for pilots and auditory displays for stockbrokers are examples of more recent sonification applications. The research field is quite new and a common methodology is still in development.

Hermann and Hunt (2005) have defined interactive sonification as the discipline of data exploration through the interactively manipulation and transformation of data into sound. Through this definition, they acknowledge the importance of human interaction for understanding and using auditory feedback. The SolarDuo Project sonification strategies in sound modeling and organizing improvisation events can be discussed as artistic rendering of interactive sonification. Observed data can be used to control sound synthesis parameters. Interactive sonification also covers general techniques to develop auditory icons in everyday human interaction. Auditory icons are sounds from the everyday environment that help users understand what kind of information they are dealing with (Bjur 1998).

3.2 SolarDuo Project Performances

CTRL_ALT_DEL FESTIVAL PERFORMANCE, ISTANBUL 2005

Ctrl_alt_del[20] is one of the first sound art festivals realized in Istanbul. ctrl_alt_del 2005 took place in the "positionings" section of the 9th International Istanbul Biennial. The festival launched on 16th September 2005 with an opening night performance at Balans Music hall. It then continued on the Bosphorus, the Golden Horn, Istanbul Technical University's MIAM studios and concert hall until the 22nd of September. Performance nights of the festival, that included a series of

20 http://project-ctrl-alt-del.com/

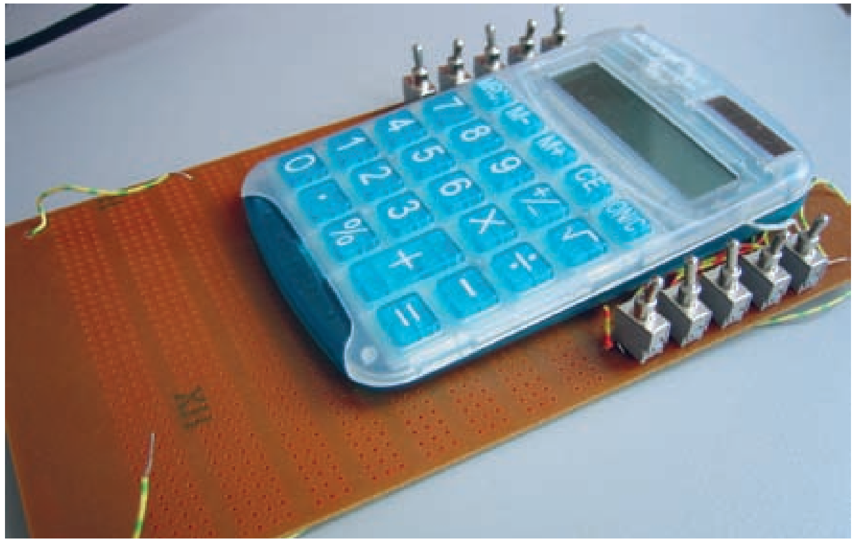


Figure 3–3: SolarDuo Project instrument Aurora.

compilations[21] and live performances, were organized at Mustafa Kemal Anfisi, Macka campus of Istanbul Technical University. The SolarDuo Project was chosen by the festival jury for a live performance on Tuesday, 20th September 2005. The lineup for the concert was; Rec Magazine Compilation – compilation (TR), Kerem Aksoy, L.U.T.M – compilation (TR), Paul Devens – live performance (NL), Pieter Snapper – compilation (TR/USA), EKW 14.90 – compilation (AT) and SolarDuo Project – live performance (TR/FI).

The SolarDuo Project performed a 20 minutes and 40 seconds long improvisation with live electronics[22]. Various algorithmic structures,

21 Compilation is prerecorded music material, which is played back to the audience of the festival during the performance session. Compilation music material usually could have been composed for an earlier music album or a musical activity; however, it might still represent the common characteristics of the festival or the event.

22 Performing with live electronics is a particular Sonic Art or electro acoustic music performance style where the sound processing and the synthesis of sounds are organized in real time with newly developed electronic devices. The use of electronics in live improvisation performance has been moving slightly into a new practice with the development of increasingly fast and affordable personal computers over the last decade. Programming computational processes is considered as a way of doing electronics in software (Emmerson 2007).

SolarDuo Project musical instruments *5/4*, *Aurora* instrument and the sonification of the solar data, which was gathered from terrestrial and orbiting solar instruments, were used in the improvisation process. MTOF/PM Data by Carrington Rotation[23] from the 11th of July 2005 to the 8th of August 2005 was used as a source for sonification during the live improvisation. The other sonified data types were EIT 171, EIT 195, EIT 284, EIT 304 and MDI data sets[24]. The SolarDuo Project musical instrument *5/4* consists of a CD40106BCN Hex Schmitt Trigger, four photo resistors, three 50v 47μF, 50v 15μF, 63v 10μF electrolytic capacitors, one 1K50v polyester capacitor, a Panasonic BP–376634 solar panel, a torch flash light with connected jump wires. Boss Super chorus and Turbo overdrive analog effect pedals were connected to Instrument 5/4 before a Behringer Eurorack Mx 602A audio mixer connection. The *Aurora* instrument is a modification of a pocket calculator, which sonifies calculations. Figure 3–3 presents an image of the SolarDuo Project instrument *Aurora*. The Behringer Wah–Wah analog sound effect was connected to *Aurora* and it also controlled the volume of the instrument.

ARS ELECTRONICA PERFORMANCE, LINZ 2006

Ars Electronica is an annual festival for art, technology and society with exhibitions, seminars, symposia, performances and events designed to underscore the impact of technological changes in society (Ars 2007).

23 SOHO spacecraft has twelve instruments on board and CELIAS (Charge, Element, and Isotope Analysis System) is one of the on-board instruments that consists of three different sensors with associated electronics to study the composition of the solar wind (SW) and interplanetary energetic particles on SOHO (http://www.space.unibe.ch/soho/). The solar wind Mass TOF (MTOF), the Mass Time-of-Flight spectrometer, is one of the sensors on CELIAS instrument and it allows measurement of the elemental and isotopic composition of the solar wind over a wide range of solar wind bulk speeds. MTOF sensor measures the compositions by Carrington Rotation, which is a period of 27.2753 days, a full rotation of the Sun as observed from the Earth (http://wso.stanford.edu/words/Coordinates.html). Solar wind data from the MTOF Proton Monitor is available at http://umtof.umd.edu/pm/crn/

24 EIT, Extreme-Ultraviolet Imaging Telescope is one of the instruments on SOHO spacecraft. EIT observations aim to study the dynamics and evolution of coronal structures and mechanism responsible for coronal heating and solar wind acceleration. Telescope mirrors can observe data in four different wavelength bands. 171, 195, 284, 304 are the wavelength types on EIT telescope. EIT data is available at http://umbra.nascom.nasa.gov/eit/eit-catalog.html and http://umbra.gsfc.nasa.gov/eit/EIT.html. MDI, Michelson Doppler Imager, instrument can make wide range of observations to study the interior structure and dynamics of the Sun (http://soi.stanford.edu/data/).

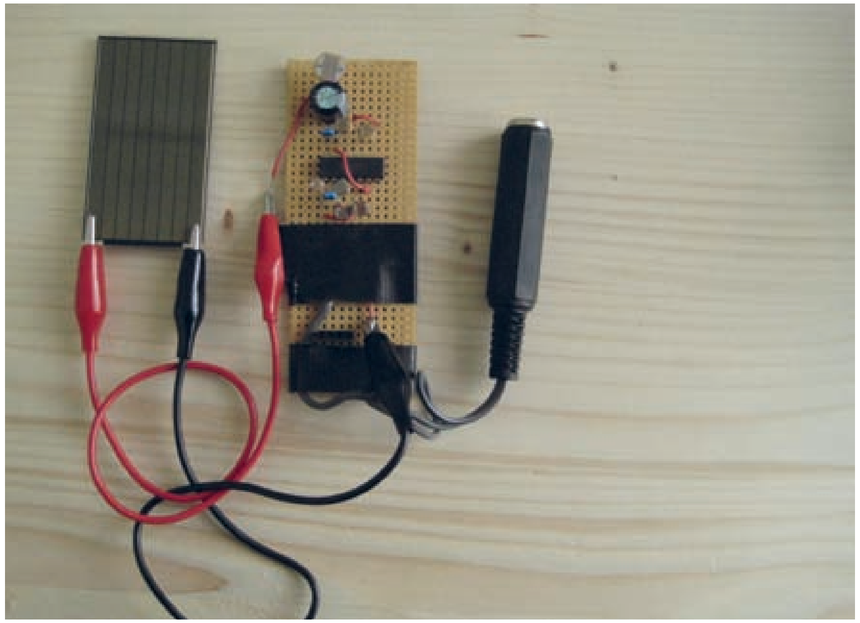


Figure 3–4: SolarDuo Project instrument 7-h8208. Images of other SolarDuo Project instruments can be viewed on the attached DVD.

Figure 3–5: SolarDuo Project performance at Ars Electronica festival.

Ars electronica is one of the world's foremost festivals since 1979 and brings together media art, and new technologies to Linz, Austria. In 2006, Media Lab Helsinki was invited to organize the Ars Electronica Campus Exhibition. The Campus Exhibition presented a selection of over 20 works by Media Lab Helsinki students, researchers and alumni. The SolarDuo Project was invited by the Media Lab for a live performance at the Ars Electronica festival. The SolarDuo Project and Washer + Revolver dog (AT/DE) were lined up for the performance night on Saturday, 2nd of September 2006 at Roter Kreb[25], Linz. Performance night began at 21:00 and SolarDuo Project performed a 19:20 minutes long improvisation. Besides instrument *5/4*, *Aurora* and *Arduino*[26] based instrument, a new SolarDuo Project instrument *7–h8208* was introduced during the performance. Figure 3–4 shows the image of the instrument *7–h8208*. *Arduino based Instrument* is a no-name solar panel connected to the Arduino microcontroller to transfer light changes into binary codes in order to stream the data to the associated digital instrument. Instrument *7–h8208* is another combination of instrument *5/4* components with seven photo resistors, two 104 ceramic capacitors, one 6.3v 470μF electrolytic capacitor and a SN74HC14N Hex Schmitt Trigger. A ZOOM 9000 sound processor was connected to instrument *7–h8208*. Boss Super chorus and Turbo overdrive analog effects were connected to instrument *5/4* and the Behringer Wah–Wah analog sound effect was connected to *Aurora* before the audio mixer. The sonified data type was MTOF/PM, MDI and EIT data. Figure 3–5 shows the stage set up for the *Ars Electronica* performance.

25 In the context of 2006 Ars Electronica's Campus exhibition, Roter Kreb the Institute for Expanded Art's event space, provided a performance space and sound system for the performance-based concerts. http://www.roterkrebs.net/

26 Arduino is an open-source physical computing platform aiming to provide the design and art community with a tool to create alternative electronic interfaces. Arduino consists of a simple 8-bit microcontroller and a port to communicate back to a computer. http://www.arduino.cc/

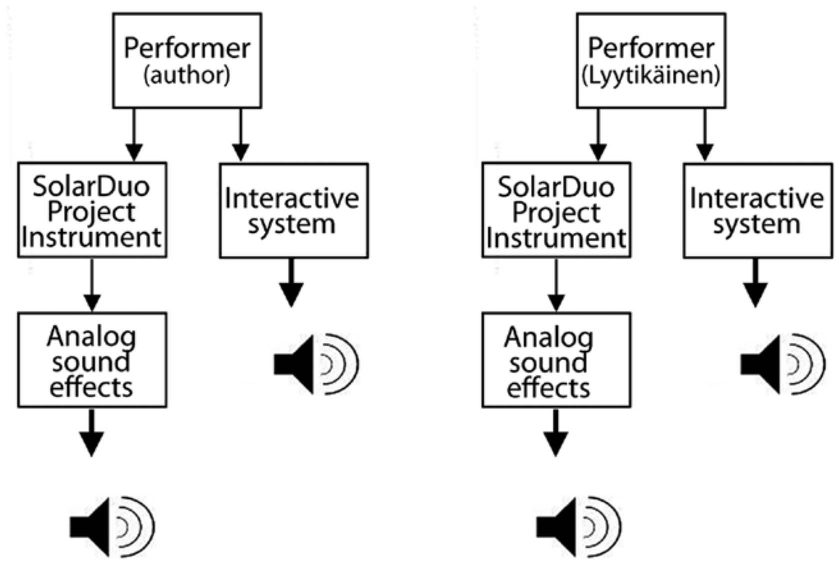


Figure 3–6: Block-diagram of the SolarDuo Project performance system.

3.2.1 SolarDuo Project Interactive Performance Systems

The overall sonic structure of the SolarDuo Project performances is based on analog sounds received from SolarDuo Project musical instruments and the output of digital sound processing of SolarDuo Project interactive performance systems. Figure 3–6 shows the performance system modules. SolarDuo Project interactive systems rely on the *performer acts, computer re-acts* ontology (Di Scipio 2003). The system is based on several computer generated musical instruments that are interconnected and play together with performer's control operations. The system itself works like a musical instrument. Interaction between the performer and the system is based on control data parameter changes that determine the interactive system's internal state changes.

The SolarDuo Project interactive performance systems are designed for live performances. These systems can be identified as new electronic music instruments for music performed in real-time with live electronics

(Montague 1991: 85). SolarDuo Project performances have never been based on compilations or re-performance of any prerecorded materials; improvisation is performed in real time.

The SolarDuo Project interactive performance systems can be outlined as a linear structured system, where the interaction begins with the performer's actions, which activate parameter changes in control devices. It is followed by the system's internal states changes, and as the last part of the linear structure, sound synthesis generates audio output. A SolarDuo Project performance is a live improvisation for two performers. Therefore, the system's linear improvisation structure turns into a closed loop between the performers and the output of the systems. Critical listening during performances completes the loop and creates the dialog in the improvisation process. SolarDuo Project performances are structured improvisations in order to control the duration of the performance. Each performer's improvisation acts have been structured before the performance; however, they have never been pre-defined. One of the project members generates the impulsive sound and the improvisation performance begins.

The interactive system's response methods can be classified as both transformative and generative (Rowe 1993). Other than these methods, sonification strategies, and analog sound synthesis of the SolarDuo Project musical instruments bring the richness of variety in an improvisation process. The structures of digital sound synthesis and the algorithms for each module have been constructed using the Pure Data environment.

Transformative module

The Performer's control operations can change the internal state of the interactive system through three different modules; the *Transformative Module, Generative Module* and *Sonification Module.*

The *transformative module* applies parameter changes to the transformations of sampled sound materials and use sound samples as a source for the synthesis of new sound output. Transformation is done through polyphonic sampler synthesis (Puckette 2007: 98–101). Polyphony is used as a term for maintaining several copies of the same process in parallel (ibid: 98). The *iNSTCOOK1* and *iNSTCOOK2* patches were *used in* the *transformative module* during the *ctrl_alt_del festival* performance. These patches load five different sound samples in advance into five different arrays in order to use these samples in real-time as voice sources for a polyphonic synthesis patch. There are three instances of polyphonic synthesis patches and two of them can use two different sound samples as an instrument for sound manipulation. One of the polyphonic synthesis patches has only one sound sample that is used for periodic repetition of a certain manipulation. Each polyphonic synthesis patch has eight instances of a *sampvoice* sub patch[27] and each one produces one output related to the parameter changes. The parameter control changes are connected to each *sampvoice* sub patch in order to produce several separate outputs of the same parameter changes. *Sampvoice* sub patches are also interconnected through an audio connection, which gives more alternative output combinations.

Each polyphonic synthesis patch has seven different parameters. MIDI pitch value, amplitude, duration, the number of sound samples from the wavetable, starting point in milliseconds in the wavetable, with rise and decay time values can be controlled by the performer's actions. The *Transformative module* has an abstraction object that generates the starting point of the samples in the wavetable by random processes for two polyphonic synthesis patches. The *mchain* abstraction[28] object generates random numbers in order to determine the reading points, and the duration for random processes is controlled through the envelope generator object[29].

Generative module

The *melo* and *meloars* patches, in the *generative module,* each generate frequency values for six oscillators and determines the order that they will process the assigned frequencies. *Random walk* probability method used as a generative method to determine the number of the active oscillators and also the MIDI pitch values for each one. During the Ars Electronica performance the *meloars* patch was used together with a solar panel. Electrical

27 Polyphonic synthesis patch in transformative module is modified from Miller Puckette's polyphonic patch example that can be found in Pure Data audio examples.

28 Abstraction is a patch, which is loaded inside another patch, where the dataflow can be controlled through its inlets and outlets. Abstraction has the similar inlet-outlet patch structure as a sub patch; however it cannot be embedded in any main patch, instead it can be loaded by typing its name inside an object box. The location of the abstraction patch should be typed before the abstraction name in the object box.

29 Envelope generator is a 3rd party external object by Yves Degoyon.

changes in the solar panel were transmitted to the *meloars* patch through the Arduino microcontroller. Analog changes were scaled into a MIDI pitch value range and these values are assigned to each oscillator. However, the order of oscillators processing the transmitted frequencies into sound still was determined by the random walk probability method.

Sonification module: Mapping strategies

Connecting solar data with music and sound has fascinated the SolarDuo Project members for a long time since they started the project together. Rapid advances in real-time computational tools have enabled a variety of creative strategies to connect data and sound. One of the main strategies is the simple direct data mappings in frequency or time domain in order to elaborate data with a tone or timbre characteristics to have different interferences that create interesting sounds.

SOHO (Solar and Heliospheric Observatory) constructs still images and videos with the solar data that is obtained from a satellite orbiting the Sun and they publish visual materials on their website[30]. Twelve different instruments including Doppler imaging, solar wind detectors and spectrographs are using different filters to collect data once a minute. Each instrument has a specific set of filters that eliminate unwanted spectrums of light. For example the EIT (Extreme ultraviolet Imaging Telescope) images are filtered to the wavelength of Fe (iron) and He (helium) at 171, 195, 284 and 304 Å (angstrom; 1Å = 1.0 × 10–10 meters) and the intensity of each point is stored in the file. Filter colors represent a transposition of the wavelengths to a visible spectrum and they identify images. The raw data is transported in a multidimensional file format called FITS (Flexible Image Transfer System), which can hold multiple images[31].

The parameter mapping strategy of the sonification conditions whether the value of the raw data is used in its original range or is scaled to another one. Lyytikäinen used the data received from points in the solar disc to control sound generators in SolarDuo Project performances. In one type

30 http://sohowww.nascom.nasa.gov/

31 Joni Lyytikainen discusses solar data specification in his Master of Arts thesis, which can be found at Media Lab, TaiK.

of generators the pitch changes according to the difference of two consecutive values. In another generator, a beating pattern is created by two or more oscillators with very close-range frequency values. As the difference between two intensity values increases, the beating patterns get denser.

The raw data collected from the SOHO satellite is used for different analysis. One statistical analysis based on data of MDI (Michelson Doppler Imager) is the daily number of sunspots. The daily sunspot dataset from the early 1800's to 2004 is used by reading all the values into an array in Pure Data and normalizing the values from zero to one. It results in a 1.6 seconds audio clip with 44.1 kHz sampling rate. The tremolo envelope demonstrates the 11-year cycle of solar activity. The number of sunspots increases at the end of each cycle. The data is also used to control different parameters of sample playback; however, the main mapping strategy is to create a unique tonal structure that represents characteristics of the data.

The Solar wind data is mapped through following parameters; measurement time (year, day, hour, minute, second), proton speed [km/sec], proton density [protons per cubic centimeter], the most probable proton thermal speed [km/sec], arrival direction [degrees from north-south, with (+) sign it means from the south). SOHO orbit data is not used for parameter mappings. In this module, sonification strategy is built on only the solar wind parameters from the SOHO Cellilas Proton Monitor.

The main strategy in solar wind sonification parameter mapping is to connect each type of data to an oscillator sound processing in a Pure Data patch. Resulting output of the direct mapping represents different frequency changes in a specific time. Original data is used without any value scaling for frequency parameters of oscillators. Solar wind data starts at 23:00 on the 11th of July 2005 and ends at 03:00 on the 8th of August 2005. The sum value of *the day of the year*, *minute* and *second* is assigned as a metronome value for the data reading of each line. Changing metronome values result in irregular processing times for each line and create a natural wind effect with the continued increasing and decreasing of solar wind values. Each solar wind oscillator in the Pure Data patch has a separate volume controller and the author controls the order of the oscillators to be played during improvisation performances.

3.2.2 Performance Observations

The SolarDuo Project performance duration is approximately a 20 minute period of time and it is divided into several different improvisation forms. The first period of the improvisation began with the sonification modules in the ctrl_alt_del festival and Ars Electronica festival performances. The *impulse* action that Lyytikäinen made started the improvisation process. His solo improvisation period with interactive sonification and transformative modules turned into a duo improvisation when the author began to control the sonification module of the interactive performance system. During the first period of the performance, only sonification and transformative modules were used to structure the improvisation. Sonic patterns that were repeating with smooth changes contained inharmonic structural parts. The first developed framework of the improvisation slowly built itself up to the next period of noise structures.

The musical actions were developed in different directions. Lyytikäinen continued with the smooth sonification module output, while the author was building the noisy structures with the transformative module. After a while, smooth sound structures were more obscured and downplayed; greater weight was placed on noisy structures, which resulted in extremely unstable pitch variations with tone widely distributed across its original bandwidth. The noise structure was created by the polyphonic manipulation of four different sound samples and it attempted to portray on model the acoustic sensation of roughness and tension.

In the Ars Electronica performance, only one sound sample was used with the polyphonic module to create the noise period of the improvisation. While the author was building up roughness and tension, Lyytikäinen was controlling the sonification module that was still playing even though it was not audible because of the author's noise structures. The second period of the improvisation ended when the author reached a high point of pitch and amplitude levels and finalized the period of noise structure with a sudden pause on the signal-processing module of the Pure Data patch. A long continuous tone with a stable pitch and loudness took over the improvisation structure. A more intuitive improvisation began within this period of the improvisation. The performers were controlling different parameter structures on the sonification modules. The third period was a relief after a heavy noise structure. During the

Figure 3–7: ctrl_alt_del festival performance set up.

ctrl_alt_del festival performance a generative module was also used in the third period. Frequency values of the oscillators in the Pure Data patch were generated by the random walk method and supported the long tone sonic structures.

Video documents related to the sonified data are screened during all the SolarDuo Project performances. The purpose is to give an idea to the audience of what the sonified data might look like while they are listening to it. The audience connects the characteristics of an image and sound immediately in a performance. Besides screening solar data video documents in the ctrl_alt_del festival performance, the computer screens were also projected to the sidewalls of the performance place, as is shown in Figure 3–7. The audience could follow computer mouse actions controlling the parameters of the related patches. Both video documents and the projected patches created visual contact with the audience. One of the observed activities during SolarDuo Performances was to note that audiences still seek something visual at concerts.

The relief section involved sonification modules being highly active

in the Ars Electronica performance. The transformative module also supported the calm and smooth sonic mood of the improvisation. The improvisation strategy in this period was to develop a specific musical activity as an accompaniment state for the SolarDuo Project musical instruments. The structure of the improvisation was to find a reasonable loop structure, which would highlight the solo state of the solar instruments.

The instruments *5/4* and *Aurora* were the solar panel instruments used in the ctrl_alt_del festival performance. A new SolarDuo Project instrument 7–h8208 was used together with the instrument 5/4 and Aurora at the Ars Electronica performance. The instrument 7–h8208 is named after the identification number of the capacitor that is used in the circuit and the number of the photo-resistors connected to its components. The sonic characteristics of instrument 7–h8208 involves high pitch, and continuous sinusoidal sound structures.

Being unable to achieve full control over SolarDuo Project instruments has always been a big challenge in organizing sound structures during the improvisation periods; however, resulting attempts were always satisfactory for the author and Lyytikäinen. Instruments 5/4 and 7–h8208 have more control possibilities as opposed to the instrument Aurora. It is possible to achieve similar sounds if the instruments 5/4 and 7–h8208 receive the same amount of the light through the fixed angle position.

The fourth period of the improvisation involved two performers being active at the same time with two lead solar panel instruments. There was also critical listening in this period and at some moments of playing, improvisation form turned into more supporting, accompanying modes. Both performers played continuously at the same time; however, roles of the performers were switched from a solo state to an accompanying state based on the mood of the improvisation. Besides three solar panel instruments, there was another solar panel which was directly connected to the generative module in the Ars Electronica performance. The values of light changes were transferred to a generative module through an Arduino microcontroller. They were assigned as the frequency values for the digital oscillators. Sinusoidal oscillator sounds were processed and passed through a digital reverb effect. The generative module was actively used together with the SolarDuo Project's musical instruments in the fourth period of the improvisation. During the fourth part of the improvisation, the performance also got more attention from the audience. When the audience noticed that the light movements were synchronized with the sounds of the SolarDuo Project's musical instruments, they began to pay more attention to the gesture movements and to the sonic structure of the improvisation.

The performers stopped playing with the solar panel instruments and the last period of the improvisation began. In the previous period, a transformative module generated a fixed loop sound structure in order to accompany the solar panel instruments. In this period, the performers controlled the sound structure with parameter manipulation of the transformative module. After a while the performers began to drop out audio patches one after another, and they stopped the signal processing with an agreed gesture movement, which finalized the performance.

Even though the SolarDuo Project performances can be called structured improvisations, however, no two performances have been identical regarding the musical structures. The SolarDuo Project aimed to experiment with new sonic design pattern alternatives for each improvisation performance.

3.3 Conclusion

Designing the SolarDuo Project interactive performance systems required studying and experiencing alternative strategies for designing musical algorithms and developing analog devices for unconventional sound structures.

Transforming light into sound with only basic electronic components gave more weight to investigating sound as a subject and not just as an aesthetic representation of the performance. Being able to achieve light-to-sound transformation in a considerably short period was a benefit. However the structures of the physical device of the SolarDuo Project instruments could have been tested using some other components and developed further to achieve different sound structures. Once instruments 5/4 and 7–h8208 were developed, the research focused more on investigating alternative strategies for using these instruments together with the SolarDuo Project interactive performance systems in a real-time improvisation process. The SolarDuo Project musical instruments and the interactive performance systems were integrated within the interaction feedback loop system of the improvisation performance. Another method for this integration could have been processing the sounds of the solar panel instruments through algorithmic structures of the interactive systems.

Stephan Vitiello[32], electronic musician and sound artist, set up photocells to record view-light from the 91st floor of World Trade Center in New York for weeks, and later translated them into his music (Kim-Cohen, 2005). Vitiello developed the photocell controller, which translates the vibration of lights into tones. Recorded materials served as the basis for his album Bright and Dusty Things[33]. In his live improvisations, he amplified the lights on the mixing board through a photocell. The received lights vibrated at certain frequencies and by amplifying them, he transformed light frequencies into sound. He also processed the amplified frequencies through his algorithms during the live improvisation performances (Marcus 2001). The SolarDuo Project has focused on alternative sound structures that analog sounds generate together with digital ones. It was an earlier decision by the SolarDuo Project members to process analog and digital sounds through separate sources but find ways to use them together during an improvisation process. There was only a one case where a solar panel was connected to the Arduino microcontroller to transfer the light changes into a digital environment. This could be related to Vitiello's strategy for amplifying frequencies of the lights through photocells. Transforming light into frequency values for digital oscillators could be identified more as a sonification method in the SolarDuo Project interactive performance systems.

A variety of sonification techniques have been proposed in the context of musical sonification for representing available data types and information about them as related sound objects in music. The techniques used in the SolarDuo Project rely on parameter mapping for audio signal processing and direct mapping-manipulation techniques that automatically extract solar data content information for audio signals that are subsequently hidden in data structures. By sonifying solar data, the project took

32 http://www.stephenvitiello.com

33 Stephen Vitiello's album Bright and Dusty Things released from New Albion Record in 2001, http://www.newalbion.com/NA115/

advantage of the dynamic pattern abilities of the data structures to discover improvisation structures and modules for live music performances. The explicit sonification as direct mapping to pitch information and its integration with timbre and rhythm is a common strategy for sonification in music. One of the biggest challenges in any type of sonification is developing extensive models, which can serve alternative data integration for musical structures.

Model-Based sonification was introduced by Hermann and Ritter (1999) as a model equivalent to the environmental sound production in the real world. The model associates material properties with the objects and the received acoustic feedback through the messages. The model maps material properties from variables of the data domain and they claim that the resulting sounds merge the same way as individual raindrop sounds merge to the soundscape of raining. The advantage of model-based sonification would be that the produced sounds might be more pleasant than direct mapping, if the mapping strategies follow the equivalent rules of sound in real world. Herman and Ritter point out that comparing parameters mapping to the direct mapping, the model may be controlled by a limited number of parameters, which would cause the sonification to be used, recognized and understood easily (ibid).

Sonification has been used in various abstract levels in musical context. *Life Music*, a sonification of protein data by John Dunn and Mary Anne Clark (1999), is a collaboration work of art and science. The audio CD *Life Music* is the sonification of protein data and the strategies are aimed at discovering the music in proteins. Dunn and Clark developed methods for using protein sequences and direct mapping strategies for musical compositions. *Molecular Music*, by Therry Delatour, is another example of a musical approach in the scientific domain. Sonification methods used in *Molecular Music* construct molecular waveforms using experimental data. Delatour discovered that molecules oscillate under various conditions. He points out the characteristic spectrum that each type of molecule has, thus mapping the molecules vibrations into the acoustic realm produce a distinctive timbre for each type of molecule, which forms the sonification strategy for *Molecular Music* (Delatour 2000).

The work done in the SolarDuo Project can be outlined as sonic investigation of the invisible and inaudible. Current interactive sonification systems are often designed for building interaction into sonification techniques (Hunt et al, 2004). In addition to that, the SolarDuo Project

views sonification as a part of an interactive performance system to be used as one of the modules for the interaction that occurs between two performers. The field of sonification is new; therefore, related techniques are still a *work in progress*. During the research process, the ideas in the SolarDuo Project served as a seed for the development of interactive improvisation performance systems for exploring unconventional sonic relations, experiencing novel musical structures and expanding sonic interaction between two performers for developing experimental musical instruments. The direction of the research is to further investigate alternative computational possibilities for interactive improvisation performance systems.

4.

Human Observable Musical Activity

The *Clonus Patterns (2005)* and *Call in the Dark Noise (2006)* performances presented in this chapter add a significant dimension to the body of research: audience participation. During these performances, the use of HTTP messages sent over the Internet, and SMS messages sent from the audiences' mobile phones make use of new technologies and also provide an opportunity for commenting on the role of interpersonal / social communications and their relationship to interaction in human actions and reactions towards music.

The interactive improvisation system used in the performance of the *Call in the Dark Noise* was developed based on the interactive system used earlier in the *Clonus Patterns*[34] performance. Unlike in the *Clonus Patterns* interactive system, the SMS messages received were not directly mapped to the interactive sound manipulation modules, but rather, they were used to build a generative responsive set for interactive sound synthesis. The interactive improvisation system developed by the author for the improvisation piece *Call in the Dark Noise* is based on observable musical actions – which will be explained below – of the audience participating in the real-time improvisation activity.

There has been scholarly interest in developing interactive performance systems to find out more about brain processes, such as learning and other representations of human activities, including musical think-

34 Koray Tahiroğlu, Joni Lyytikäinen, Sanna Karmakka, Sami Karmakka and Richard Widenberg are the members of the Clonus Patterns improvisation band.

ing. Some researchers in this field share the common goal of simulating human music understanding, perception and behavior for computer modeling of human musicianship. For decades researchers have been developing various models such as, neural networks, computational tools like parallel distributed processing models and connectionist networks. It is often felt that these networks provide considerable insight into the many realms of human behavior and offer new points of view for investigating details of musical experience (Todd 1991).

At the same time that scientists began developing computational methods for understanding human cognition, researchers were producing computer simulations to illustrate new cognitive processes. Rumelhart and McClelland (1986) introduced a new set of computational tools, including parallel distributed processing models of human cognition. These offered the possibility of musical uses of new computational tools and a new way of looking at human musical activity. According to Mark Dolson (1991: 10–12), one of the major features of the parallel distributed processing model approach is that it replaces strict rule-following with regularity-learning and generalization. These methods rely on learning the structure of existing musical examples and generalizing from these to compose new pieces. Besides the learning structure of the network, Dolson discusses the potential use of network models to synthesize sound. He states that neural networks are probably not well suited for the direct creation of a sound waveform, but they show some promises as an interface mechanism to low-level synthesis algorithms (ibid: 12).

Researchers are excited about the networks possibilities of learning and predicting musical structure with a style from given examples. Johannes Feulner (1993) for example claims that neural networks have proved useful in various musical areas. However, Otto Laske (1991: 260), while commenting on connectionist composition models, has criticized the musical systems as representing model-based composition. Laske argued that while computers have already begun to free composers from existing music structures, by giving possibilities to experience music that has never been heard before, the connectionist model of composition is moving back to model-based compositions. According to Laske, composing music with learned structures from any given composition example is a composition that is based on remembered music of the past (ibid). Generalizing from learned structures of existing music pieces can help compose music in the same style. However, compared to generative models, one can question whether network models bring something novel to the musical composition.

The learning and performing ability of neural networks has encouraged researchers to explore and experiment with various approaches in simulating human musical behavior for developing interactive improvisation performance systems. On the other hand, there are still some aesthetic concerns and questions, which have not been sufficiently addressed regarding the musical output generated in network models and what these models attempt to simulate.

Cognitive science research is not the main focus of this research, but if there were a more critical look at the terminology of simulation of human musical behavior, one could see that it can convey multiple levels of meaning related to the direct observation of the term simulation. Simulation of human musical behavior might not mean exactly simulation of a musician's mind; instead, what can be simulated with the models based on computational tools is a musician's external operations that occur at a certain period of time.

Jean Baudrillard (1998: 11–15) defines simulation as a model of the real, which becomes the determinant of human perception of reality. In his book Simulacra and Simulations, he gives an example to point out the difference between simulation and dissimulation, "Someone who feigns an illness can simply go to bed and pretend he is ill. Someone who simulates an illness produces in himself some of the symptoms –Littre. Thus, feigning or dissimulating leaves the reality principle intact: the difference is always clear, it is only masked; whereas simulation threatens the difference between "true" and "false", between "real" and "imaginary". Since the simulator produces "true" symptoms, is he or she ill or not? The simulator cannot be treated objectively either as ill, or as not ill" (ibid: 13). According to Baudrillard, for a simulation of human musical behavior to be real, computational tools should produce all the symptoms of human musical perception, such as musical experience, learning, thinking musically, behavior, performance and control.

Many cognitive scientists state that the study of artificial intelligence has illuminated many areas of the human cognitive system that are governed by rules, which can be implemented using computational methods through programming environments (Cook 1999). However, the nature of musical experience causes one to question about the possibilities of computational tools capturing the rules of creativity that a musician has

Figure 4–1: Clonus Patterns improvisation performance at Art's Birthday event.

during a real-time musical activity. Or is it some sort of illusion that can be created very easily with a simulation?

The research focused on observation of human musical activity when developing interactive performance systems. Observation was based on what performers or participants did or explained that they did during a certain period of time. As Otto Laske (1992) comments in his interview with Marvin Misnsky, there is no single best way of representing knowledge.

In *Clonus Patterns* performance, the author was responsible for the majority of the technical and conceptual work. As a result of the nature of the work the author, *Clonus Patterns* improvisation band members and the audience of this performance are jointly responsible for the performance.

The attached DVD includes technical materials of the interactive performance systems that were used in the *Clonus Patterns* and *Call in the Dark Noise* performances, recorded video and audio files and the log data files of audience's responses as SMS and HTTP based text messages received during the performances.

4.1 Collective Improvisation Performance Mediated through Technology

CLONUS PATTERNS PERFORMANCE, HELSINKI 2005

Art's Birthday is an annual exchange-art event celebrated around the world on the 17th of January by a group of artists and artist organizations (Art's Birthday 2008). Based on an idea by a French artist called Robert Filliou, since 1989, the Western Front[35] has held annual events on the 17th of January. This annual event first started in 1963, when French artist Robert Fillio suggested that 1,000,000 years ago, there was no art: however, on the 17th of January Art was born when someone dropped a dry sponge into a bucket of water. Fillio even proposed it to be a public holiday to celebrate art's birthday. Recently it has been celebrated with various network art events all around the world.

The author contributed to the Art's Birthday 2005 celebration by organizing the Noise City Helsinki electro-acoustic music event on 15th January, 2005 at KokoTeatteri[36] in Helsinki. Figure 4–1 shows the performance place and *Clonus Patterns* members. The lineup for the event was, *Clonus Patterns*, 21:30 (GMT+2), Petri Kuljuntausta 22:00 (GMT+2), SolarDuo Project 22:30 (GMT+2) and Erkki Kurenniemi 23:00 (GMT+2). The event began with *Clonus Patterns*, which was a 17:00 minute long improvisation performed bt members of the group with their computer based interactive systems.

35 The WesternFront Society is one of the first artist organization based in Vancouver, Canada. http://front.bc.ca/

36 KokoTeatteri is an independent, free, open professional theater located in Helsinki. Besides the regular theatre schedule, KokoTeatteri hosts various experimental art events. http://www.kokoteatteri.fi/

4.1.1 Clonus Patterns Interactive Improvisation System

The author developed an interactive performance system that involved audience participation in a collective musical improvisation. The improvisation process relied on the audience responding to the improvisation by sending SMS messages to a specific mobile number or HTTP based text messages from the website of the event. Elisa, a Finnish communications company, supplied a temporary mobile service number for the Art's Birthday's event. The service number *14561* was available only for Elisa mobile phone subscribers whom could send SMS messages. They needed to type "nc" (NoiseCity) first and then the message itself.

The improvisation band Clonus Patterns constructed their sound synthesis modules using the Pure Data environment to process the data in a variety of ways with very loose rules. They used various pre-recorded materials, pure sinusoid sounds, and generative algorithms.

Once the SMS and HTTP messages were received, they were sent to each band member's computer with a Perl script[37]. Perl script sent the text message to a certain port number of each computer. Figure 4–2 shows the system structure. Through netclient port communication, Pure Data patches received the text messages as sequences of letters. The author had pre-settings for the words, *Helsinki, art, moi, hello,* and *birthday.* Whenever the system received one of these words, sound synthesis processed higher amplitude and quick manipulation that had different parameters for each pre-set word. Each letter of the received text was transformed into an ASCII code representation with the Pure Data spell object.

The sequences of letters were written in an array table and then another patch began to read each value with a 600 millisecond duration. Each ASCII value is unpacked and separated into number boxes. Numeric representations of the ASCII were used to create different sound modules. In one of the sound generator modules, ASCII values were used to create different frequency values for different digital oscillators to produce

37 Perl is a an open source, cross platform programming language used for mission critical projects in the public and private sectors. http://www.perl.org/

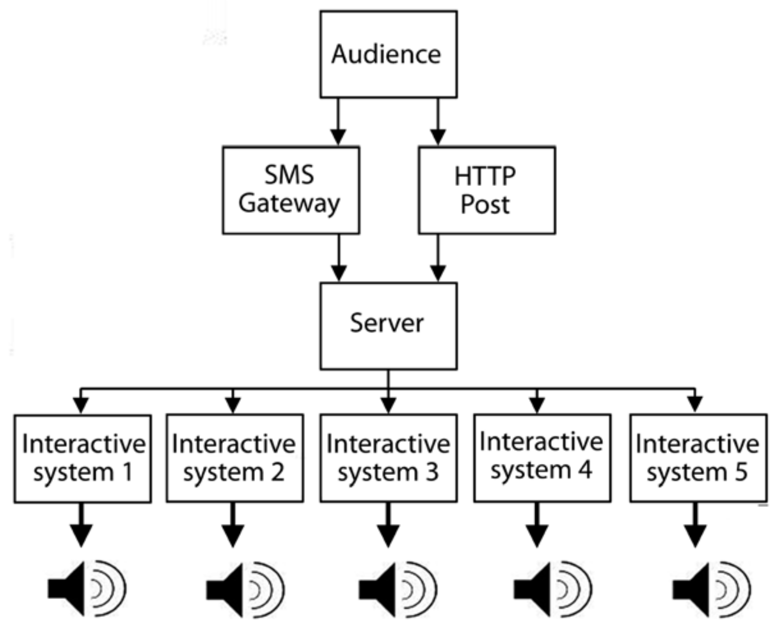


Figure 4–2: Clonus Pattern improvisation system diagram.

sinusoid sounds. The main sound synthesis module of the interactive improvisation system was based on the manipulation of pitch, sample point and duration values of a sound sample.

The sound synthesis of each system was designed to perform only simple tasks and manipulations in order to have an overall sonic structure of the collective improvisation. Members ran the interactive performance systems on their individual computers, and they were all connected to the main audio mixer of the audio system.

The interactive improvisation system can be classified as Di Scipio's (2003) *performer acts, computer re-acts* ontology. What differentiates this system from the other interactive performance systems that were developed during this research, besides the sound synthesis modules, is that the internal state changes of the system are determined by the text messages of the audience.

4.1.2 Performance Observations

In the improvisation, sounds were generated only by the incoming SMS and HTTP-based text messages. During the approximately 20 minute long concert moments of different intensities were clearly recognizable. The unexpected responses to the messages also encouraged the audience to send different messages, just to see what the text messages would sound like. Members of the *Clonus Patterns* also participated in the improvisation by sending text messages; however, the overall improvisation process relied on the participation of the audience.

An important part of this kind of collective improvisation is what the received texts will sound like. The combination of the text message and the sound will affect the way the audience is going to respond. There is no way of knowing what messages will contain, how long they will be or how often they will arrive. These parameters are dealt with in the sonification design.

Each interactive system had the same technique for receiving the data, but they differed from each other with their individual representation of “city noise”. It was constructed intentionally so that the overall soundscape would be diverse enough for there to be a variety of different sound structures. Some improvisers used only long and sustaining sounds while others worked with accents or rhythmical structures and various sound effects. During the performance, without any agreement or planning beforehand, controlling the soundscape was avoided as much as possible by members of the improvisation band. The overall composition was created in the process of the audience participating in the collective improvisation.

The latency between the audience sending messages and the interactive system transforming them into a sound structure was in the range of 4 and 6 seconds. This low-level latency encouraged the audience to participate more actively in the improvisation process; however, because of SMS gateway service provider’s restrictions, the total amount of messages was only 29. Some of the received text messages are shown in Figure 4–3. On the other hand, the NoiseCity Helsinki website received 148 messages during the improvisation session. Web based text messages allowed distant participants to take part in the improvisation process. The event was streamed through the Internet, so that distant audience could also listen and respond to the improvisation.

Log time period	SMS Text messages
Sat Jan 15 19:33:33 2005	Wellcomes evribodis.
Sat Jan 15 19:36:38 2005	Heippa kaikki!
Sat Jan 15 19:37:37 2005	I feel like ninetynine sometimes...
Sat Jan 15 19:37:47 2005	happy birthday
Sat Jan 15 19:38:08 2005	Noise keeps swinging!
Sat Jan 15 19:38:23 2005	teretulemast
Sat Jan 15 19:39:07 2005	clonus patterns is on
Sat Jan 15 19:39:44 2005	noise is out there
Sat Jan 15 19:40:38 2005	antaa palaa lapset
Sat Jan 15 19:41:40 2005	ihanaa rauha ja maailman rauha
Sat Jan 15 19:43:11 2005	Noise will be noise!
Sat Jan 15 19:43:24 2005	(“”~-..___..-~””””~-..___..-~””) Happy Birthday (“”~-..___..- ~””””~-..___..-~””) ${[
Sat Jan 15 19:43:24 2005	Sanna is buutiful
Sat Jan 15 19:43:26 2005	aika antaa ja ottaa
Sat Jan 15 19:43:31 2005	Jarmo rakastaa Katia

Figure 4–3: Some of the SMS text messages received during the improvisation.

Impulse action was the first HTTP based message *“sound”* received by the system, which was immediately followed by the SMS message *“Wellcomes evribodis.”*. The improvisation system was triggered by the messages, which resulted in sounds that started the improvisation process. In the beginning, the number of SMS messages received per time frame was quite low. There were up to three minute long breaks between received messages. This meant that the improvisation started with smooth sounds and there was not a lot of activity in the sound processing modules. Both SMS and HTTP based messages were projected in the performance space, and the audience was able to see the texts while listening to them.

After the first quarter, the number of SMS messages rose to one per 20 seconds. Meanwhile the average number of web-based based messages was approximately six per 30 seconds. During the second quarter a total of eleven SMS and forty HTTP based messages were received. The audience became more active once they got more familiar with the environment and sound structures they heard. The interactive systems began to alter the messages quickly after receiving them. The rapid changes of sonic variations created a dynamic sound structure during the improvisation.

The number of SMS and HTTP messages received during the third quarter was five and 60 respectively. The third quarter seemed like stable period for SMS messages. Even though there were fewer SMS messages than during the second quarter, the number of HTTP based messages kept the sonic structure equivalent with the second period. however, during the last quarter, the number of messages received decreased to 38 HTTP messages and six SMS messages. The overall text messages per time analysis also represents how active the audience was during different time periods. The level of activity at different times reflected on the improvisation sound structures.

CALL IN THE DARK NOISE, HELSINKI 2006

NoiseCity Helsinki II[38] was also organized by the author as a part of Art's Birthday on Saturday 14 January 2006 at Koko Teatteri and brought together four different performances. The event was streamed through the Internet to the participants of Art's Birthday celebration in other countries. The performers and the lineup of the event was: Ibrahim Terzic 21:00 (GMT+2), Koray Tahiroğlu 21:30 (GMT +2), Petri Kuljuntausta 22:00 (GMT +2) and Pink Twins 22:30 (GMT +2). The author performed a piece called *Call in the Dark Noise*, which is a musical improvisation process that was generated together with the audience response to the improvisation in the form of SMS messages and HTTP based submitted texts.

The interactive performance system altered these messages and transformed them into individual sound structures. These altered sounds became a collective musical activity for the author during his performance with experimental musical instruments and live electronics. A sensor-controlled digital musical instrument, which can be controlled through

38 http://mlab.taik.fi/noisecity/

distance changes and the SolarDuo Project musical instrument *5/4* were the experimental musical instruments used. The sensor-controlled digital musical instrument consists of two Parallax PING))) ultrasonic sensors[39] and related algorithms for sound processing. The Interactive performance system was controlled only by the SMS or HTTP based messages sent by the audience, and it accompanied to the author during the improvisation. Received SMS messages were projected onto a screen at the performance place during the event.

4.1.3 Call in the Dark Noise Interactive System

The performance *Call in the Dark Noise* intended to provide the audience with a responsive environment for participating in an act of musical improvisation. The interactive improvisation system allowed the audience to use an everyday life communication tool as an instrument for taking part in the performance. Designing such a system to include audience participation required bringing together different technical platforms and managing the complexity of their integration. The structure of the performance system is a combination of several digital electronic music instruments where the author and the audience make the decisions. The interactive performance system is built together with a solar panel analog musical instrument and two sensor control systems and its structure is shown in Figure 4–4.

Robert Rowe (2001: 308) has introduced a new term for interactive improvisation systems that is algorithmic improvisation for ensemble; a collective improvisation with interactive systems. *Call in the Dark Noise* is an improvisation process where the author and the audience perform interactively with the interactive improvisation system. In Rowe's, taxonomy, it can be classified as an ensemble improvisation system.

While the messages sent by the audience caused decisions to be made

39 The PING)))™ sensor measures distance using sonar; an ultrasonic pulse is transmitted from the unit and distance-to-target is determined by measuring the time required for the echo return. Output from the PING)))™ sensor is a variable-width pulse that corresponds to the distance to the target. http://www.parallax.com/detail.asp?product_id=28015

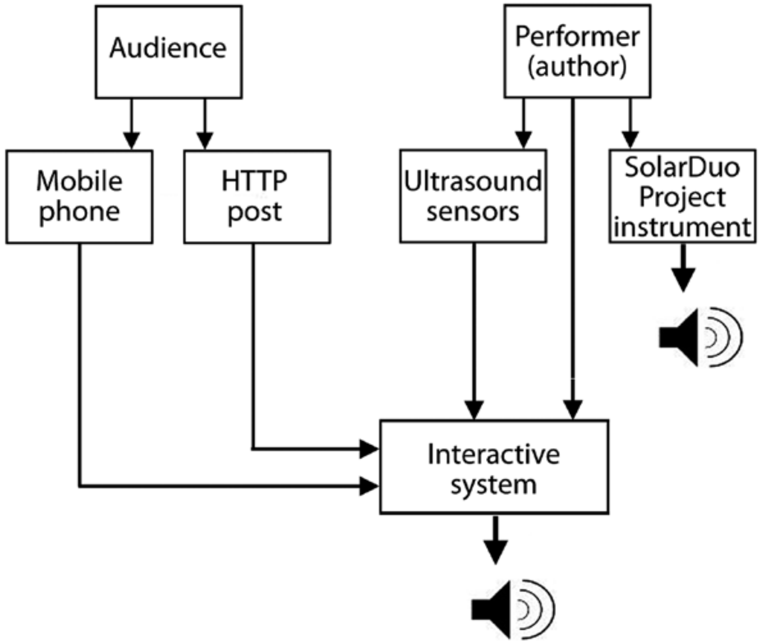


Figure 4–4: Call in the Dark Noise performance system structure.

for the playing structures of the digital instruments, the author performed on the SolarDuo Project musical instrument 5/4 and the sensor-controlled digital musical instrument. The Interactive improvisation system's algorithmic improvisation and transformative modules were designed with Pure Data and Python programming languages[40].

Algorithmic improvisation module

Data was provided to the *algorithmic improvisation module* in the form of SMS messages and HTTP based submitted texts. The received SMS messages were transmitted to the interactive system through a Python routine, which was loaded on a Nokia 6600 mobile phone. Because

40 Python is a dynamic object-oriented programming language that offers strong support for integration with other languages and tools. http://www.python.org/

Nokia mobile phones with Symbian series 60[41] can run a version of the Python programming language, a Nokia mobile phone with a prepaid card telephone number was chosen for receiving SMS messages. A prepaid telephone number made it possible to not to be restricted with any mobile operator dependencies for the participation. Subscribers of all mobile operators were able to send SMS messages and take part in the improvisation.

The Python program was used to transfer incoming SMS messages from the mobile phone to the computer so that the messages could be received by the Pure Data environment for further sound processing implementations. The Python script, *bt_sms_k_17_3.py,* was loaded onto the phone so that the incoming SMS message folder could be accessed and the messages transferred. This Python script in the mobile phone also counted the number of received messages every 1.5 seconds, and whenever it detected a new message in the inbox folder, it opened a socket connection through a Bluetooth device and sent the last received message to the computer. On the computer, Python script *artssms.py* read the incoming data through the Bluetooth serial port gate.

Audience participation in the improvisation process was based on their SMS text messages, which represented the musical activity of the audience during the performance. What the system can read through the SMS messages is the external operations of the audience during the participation. The external operations, which were the text structures in the received SMS messages, were used to create a model for responding to the audience. Based on the received text structures, the interactive performance system generated a respond text message. Markov chain probability method was used as a model to generate a response to the incoming SMS messages. A Markov chain Python module[42] is embedded inside *artssms.py* script. Whenever a new SMS message was received by the computer, *artssms.py* split the words into letters. Then it applied Markov chain probability methods to the structure of the letters to generate new

41 More information about Python for series 60 can be found at the Nokia research center, http://opensource.nokia.com/projects/pythonfors60/

42 Markov chain Python module that is used in the interactive improvisation system is modified and developed from the original version by Max M. (http://www.mxm.dk).

sets of letters based on the module achieved from audience responses.

Response to a response improvisation method can be observed on a textual scale as well as musical scale. The interactive improvisation system responded to the incoming SMS message by generating a text message. The generated message was sonified through the sound synthesis module and the author responded to the sound output within the improvisation structure. The received SMS messages and the generated messages were projected onto the screen at the performance place to maintain the textual communication during the performance. The Markov chain method was chosen because of its sequence based generative outputs, the characteristic of randomness, which enables discovery of new solutions and a degree of control over the generated output that cannot be determined precisely.

Markov chains

Statistical methods have been used to create a process to derive music composition from mathematics and logic. In this context, statistical analyses have been used as a model to transform the process into randomness with the concept of chance for the unpredictable outcome in computer music. One manner of statistical analysis that has been used in algorithmic musical compositions is the Markov chain. The Markov chain is a probability method, in which a possible future event is determined by the state of one or more events in the immediate past (Roads 1999: 878) Probability is the core statement of the decisions in the Markov chains process. The structure of the letters in the received SMS messages are linked together in a series of situations based on the probability that the letter A will be followed by letter B. The process is continuously in change. Various researchers and musicians have used the Markov chain probability method in a variety of compositions. Lejaren Hiller and Leanard Isaacson are known as the pioneers who employed Markov chains in their composition Illiac Suite, where they used a computer as an experimental device to synthesize musical textures based upon mathematical models (Hiller and Isaacson 1992). Iannis Xenakis extended Markovian Stochastic process with the theory of chain events, matrices and laws of probability and used mathematical concepts further as models for musical structures translating mathematical formulas into musical notation (Xenakis 1971).

The computer that was running the interactive system had low-level technical capacities; therefore, two instances of the Pure Data program were used during the performance. One of the instances was receiving messages and generating the responses and the other was responsible for the sound synthesis of the interactive performance system. The transaction between two instances was connected through a *netclient* communication module. Pure Data patch *artt5* transformed each letter into ASCII code representation. The generated messages were transferred from Python script to Pure Data with the pyext[43] library. *Arttinstr* Pure Data patch separated the ASCII values and sent them to *inst3* Pure Data patch.

Each data set of ASCII values was mapped to the pitch parameters of a polyphonic sound synthesis instrument in the *inst3* Pure Data patch. The ASCII character values were in the range of 0 and 127, which fits exactly into MIDI pitch value scale. The range of ASCII character values for the capital letters start from value 65 (letter A) and for non-capital letters it starts from value 97 (letter a). In order to avoid continuous high pitch values, the system scaled the data so that it falls within the middle pitch range. The data was also mapped to the frequency values of the digital oscillator in the *inst3* Pure Data patch. HTTP posted messages were not processed through the Markov chains probability method.

The deficiency in the performance of computational tools required a significant reduction in both data processing and sound synthesis modules. Therefore, HTTP posted messages were mapped directly to the pitch parameters and the frequency values of the oscillator in the *inst3* Pure Data patch. On the website of the event[44], HTTP posted messages sent with a PHP script to the server purenoise.uiah.fi, which allowed a distance connection to its specific virtual port. The ASCII values of the posted messages were received from the purenoise.uiah.fi server through the *httpget* Pure Data patch.

43 pyext is a Python external Pure Data library written by Thomas Grill (http://grrrr.org/), that enables the user to run and control Python scripts through Pure Data patches.

44 http://mlab.taik.fi/noisecity/calltext/

Transformative module

The internal state changes of the interactive system were controlled by the author's actions in two different ways. The sound modification module in *gulurtu3* Pure Data patch is controlled by changes in sample reading points and the duration values. Three sound synthesis parameter structures modify the same sound source within alternative strategies. The other controller parameter changes were received through external controllers. Two Parallax PING))) ultrasonic sensors were used as the controller interfaces for the parameters of *melo2* and *sin2* Pure Data patches. *Melo2* Pure Data patch is a modification of *Melo* patch used in the generative module of the SolarDuo Project interactive system. An ultrasound sensor measures the distance to an obstacle by receiving the transmitted echo signal back. Changing the physical distance of the obstacle forms a way of controlling the interactive performance system. The distance value changes are transformed to the computer by using an Arduino microcontroller as a transmitter interface.

The ultrasound sensor values assign the frequency values of the oscillators. One oscillator plays at a time and the order is determined by random choice. The second ultrasound sensor values were assigned to depth modulator parameters of an oscillator in a frequency modulator sound synthesis patch. The *Sin2* Pure Data patch has a carrier frequency, which is set to the value at 65 Hz. The set of values from the ultrasound sensor changes the sound output with various depth values by altering the modulator frequency.

4.1.4 Performance Observations

The scale and intensity of emotion that exists among the individuals participating in any kind of event is vastly amplified when participation is done by a group of people or a community. Stage performances, religious or political ceremonies, songs, and dances are aimed at making participants act together. In order to participate in an event, actual physical participation might be necessary; however, telecommunication models have reached such a high level of development that one can find new models for organizing physical existence through group participation. Such models might provide alternative methods for taking part in a certain event without physical restrictions.

The level of excitement established by the general characteristics of an event might also generate more attraction between the audience and performance. The exciting scenes of a concert, the witnessed interaction between band members, the rituals, the lights and performance setup, can make this observable connection interesting enough for the audience to become participants (Winkler 1998). A desire to experience an unusual event, or bringing the unexpected onto stage in the form of a performance, may encourage audience to join and participate as well. Giving the opportunity for an audience to participate in a collective musical improvisation by sending SMS or HTTP-posted messages to an interactive system can create an exciting framework. The process allowed for an artistic creation opportunity for everybody. Using an everyday communication medium, such as mobile phones, as a musical instrument made the audience feel comfortable about participating in the improvisation session, and the text messages themselves created a form of verbal communication among the participants.

Eero Tarasti (2002: 185–196), a Finnish musicologist and semiotician, proposes that communication and signification are two main focuses for analyzing musical improvisation. Firstly, the activity of the improvisation is mainly concerned with the subject of the improvisation act. If the activity of producing is more involved than the actual product itself, the approach to improvisation is perceived as a richer process than the simple analysis of the product. In this context, Tarasti maps Umberto Eco's semiotics of communication and the semiotics of signification types onto these two viewpoints of improvisation. When improvisation is interpreted as communication, the improviser and the improvisational act become more central. If the improvisation is explored as a sign, the product of this activity comes forward (ibid: 185).

According to Roman Jakobson's sender-message-receiver theory, improvisation can be also considered as communication. Jakobson's theory is concerned with the different situations of the roles of sender, message and the receiver in the process of improvisation (ibid: 186). When the message is an improvisation, the result sounds more like an improvisation than a complete composition. In addition to the view of improvisation as communication, Charles Sanders Peirce explores improvisation in iconic and symbolic methods and as a series of several signs, which become meaningful and assume their improvisatory character through its entity (ibid: 191). Using SMS and HTTP posted text messages to generate collective musical improvisation makes contact with both communication and signification improvisatory concerns. The messages formed the improvisation structure during the performance of *Call in the Dark Noise*. The messages also carried their own meanings for the improvisation process with verbal symbolic signs communicated through the use of language.

Messages carry their meanings

Besides being significant elements of the performance, the audience's text messages carried their own linguistic meanings into the improvisation. Both in *Clonus Patterns* and *Call in the Dark Noise* performances a verbal conversation was created with the language signs used in text messages. Figure 4–5 presents an image of the received messages that were projected in the performance space. The audience began to communicate with each other, not only with the sound structures they created, but verbally as well. At one point, a question and answer method of free collective musical improvisation was followed with the audience's text messages. Musical significations in these collective improvisations are not only related to musical elements. Signs in SMS messages are also connected to the musical outcome of the improvisation. SMS messages, while representing verbal symbolic signs, carried their own meanings into the improvisation structure. Pentti Määttänen (2004) argues that meanings are not attached to individual entities; instead, they are attached to the habitual use of these entities. It could be argued that in the practice of sending SMS message, text messages carried their linguistic meanings with the linguistic expressions. In this process, musical meanings are created when the musical expressions are generated with the practice of transforming text messages into sound structures.

Even though these two interconnected practices were based on a series of actions, both text based linguistic structures and the musical structures expressed their own meanings and communicated with the audience using their individual methods of perception. The audience also attempted to see how their text messages were sonified into musical expression. The structure of the sound synthesis modules did not aim to structure any specific method that would generate a direct musical representation of the linguistic meanings. The word "*Good*", in Figure 4–6, did not transform into sound structures where sounds will be related to the expression of the word "*Good*". Following Määttänen's line of thought, the word "*Good*"

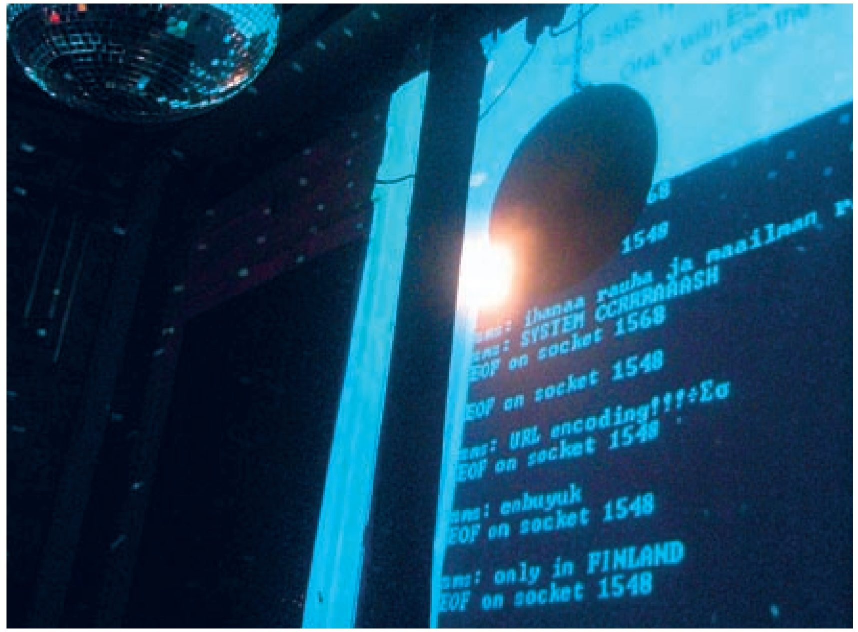


Figure 4–5: Audience's responses as SMS and HTTP based text messages.

can have different expressions and different meanings consisting of the practice of its use. Instead of having an assumption of musical representation, these linguistic signs were used as a source for the interactive performance system to create an improvised musical expression.

Sound structures that were generated by the interactive improvisation system, turned into a musical expression when the audience actively listened to the sound output. This activity of listening turned the expressed sounds into improvised musical meanings. When the audience responded to the sound structure with SMS messages, they did not aim to form the representation of those musical expressions in linguistic signs either. Indeed, the audience attempted to have a linguistic communication among themselves through the projected text messages. Two different systems of meanings were brought together with the sequenced actions in the context of collective free musical improvisation (ibid.). The distant audience was able to participate in the improvisation process by sending HTTP posted messages from the website of the event. The received messages were displayed on the same webpage. The event was streamed through the http://purenoise.uiah.fi:8000/noisecity.ogg URL and the audio stream gave a possibility to the distant audience to *listen and respond* by submitting texts.

23 SMS and 60 HTTP posted messages were received during the improvisation. The author began the improvisation by building a low frequency noisy structure. The audience joined the improvisation with an impulsive message sent by one member of the audience, "*I gave at the office, sorry. And you're kidding me: There ain't no sanity clause*". The interactive system responded with the generated message "*g n d y T a f y n s T y a A e u c f e ' i I r e e u i . c g c l e l g s a n g e e t I i e y t i d y i n y y e e I i s o i i c : a e g e i e d g T : o i : r s f T*" and the improvisation began to develop further. During the first quarter, the author was accompanying the audience responses. The sound synthesis modules of the audience responses were designed to be the lead instrument for the improvisation session. The role of pitch in the sound synthesis was combined with loudness and duration in order to keep the audience responses as the lead instrument sound output. This process structured the overall improvisation strategy.

The author's initial improvisational behavior had been to accompany the lead instrument. The audience responses were minimal in the first quarter; however, the author still continued accompanying with a noisy structure. In the second quarter of the improvisation, the audience began to respond more actively with SMS and HTTP-posted messages, and that made the author play the first sensor controlled digital musical instrument generating oscillator sounds. Following the oscillator sounds, the second sensor controlled digital musical instrument was activated and frequency modulation sounds began to fill in the sonic structure.

The control movements for these instruments required the use of large hand gestures, which caused the audience to pay attention to the hand movements. While the low frequency noisy structure was accompanying the audience responses, oscillator sounds and frequency modulation changes turned into lead instruments as well. However, the control structure of frequency modulation changes or the oscillator sounds were not aimed at taking over the lead instrument role of the audience responses.

During the third quarter, a significant *response to a response* method of improvisation was recognizable between the author and the audience. It was not easy to establish any critical listening, because of the irregular audience responses; however, *intent impulse* actions created an intensive sonic

SMS Text Messages and Generated

Hello everybody,happy birthday!!
p h l h , , o h l b o o ! l , y y h y l e p y l y y p r ! t e e

Yo baby yo baby eat this!
y o b b b b b Y Y e o o a a Y ! a b e b o h e Y s

O jea!!
! j e O O a

N n n nnn n n
n n n n n N n n n n n n n

Anyone out there? Bring the noise.
e s e n y r g h s i s n r t t g t B ? B n r n e r r ? r h r u t ? n

ars est technee
n c n e t e t s e a t r e

Good luck!
d c d ! o o G d o u

May the force be with you, Luke.
i w e o b e k h u h L . h h h c e i w L , b u h y M y h f o e f

Thank you!
h o k a y T n k y T u

Figure 4–6: Examples from the received SMS text messages and generated messages during the Call in the Dark Noise performance.

structure. The SolarDuo Project instrument *5/4* also supported the overall sounds and the improvisation took its own development strategy. The final quarter was made up of the audience responses with accompanying noisy structure. The author sent a "*Thank you !*" message and the generated sound structure of the message "*h o k a y T n k y T u*" was the final sound together with the buzzing sound emitted from the monitor speakers, when the author received a confirmation for the delivery of the SMS message.

These are unconventional improvisation systems with unconventional mechanisms of participating in a collective musical improvisation; however, the audience felt comfortable with the interaction and enjoyed the sonic structure in both performances. The audience feedback was positive and supportive. It would not have been possible to create this improvisation session without the act of the audience in the improvisation process. While the traditional aesthetic experience has always meant one-way communication between the work of art and the audience, contemporary art and computational tools allows a two-way involvement, with the possibility of input from both sides altering the creation of ever-changing music.

4.2 Conclusion

The *Clonus Patterns* and *Call in the Dark Noise* improvisation processes were based on the sounds created by the audience participation, which was mediated through interactive performance systems. The structure of both experimental performances was designed to enable audience participation in the act of improvising and combine the benefits of interaction and musical activity in a collaborative and improvisatory manner for engaging and enjoyable musical experience. Involving the audience in a collaborative improvisation process with alternative interactivity opportunities may lead to novel musical experiences and outcomes.

The main objective of both performances was to design an interaction method that would encourage the audience to interact with an interactive system in an expressive and intuitive manner. The log data files of audience's replies as SMS and HTTP based messages are documented in the DVD material that is attached to the dissertation. The audience's reaction can be identified according to the improvisation time structure. The interaction strategy of both systems was planned so that it could provide appropriate sound feedback to the audience that would allow the audience to guide the direction of the musical experience in improvisation.

The interactive improvisation system allowed the audience to use an everyday life communication tool as an instrument for taking part in the performance. It allowed the audience to become more familiar with the collaboration process and experience an unusual way of making music. The role of the audience has been critical, not only for the design process of the system, but also for the organization of such an experimental music event. The fundamental role of the critical audience made the performances a reality. In order to improve the performance process, the sonic structure of each sound synthesis module could be designed in a way that would allow the audience to better recognize and identify the sonic characteristics of each interactive system in the *Clonus Patterns* improvisation performance. This process would also make it easier for the audience to experience the improvisation.

The technical limitations of the computational tools set conditions to the sound synthesis design of the interactive systems. Furthermore, during the *Clonus Patterns* performance, the restriction of using SMS gateway communication for receiving SMS text messages limited the amount of participation achieved during the performance. The sound synthesis modules had been designed for simple processing tasks. Even though the audience's responses were assigned to be the lead instrument during the *Call in the Dark Noise* performance, the generated data mapped directly to change pitch value parameters of polyphonic sound synthesis modules. In addition to that, the sonification strategy could have been extended further with advanced parameter mapping and categorized alternative improvisation moods.

The Hub[45] is a well-known group of musicians who developed various performance strategies for interactive network computer music in the San Francisco Bay area. Their roots are with the League of Automatic Music Composers, founded by Jim Horton, who originally had the idea of a computer network ensemble (Gresham-Lancaster 1998: 40, Rowe 2001: 309). The principle of The Hub is based on self-designed electronics with a network system enabling remote collaboration and audience participation. They had their first networked performance collaborating with composers Nick Collins and Phil Niblock in the fall of 1987. They played

45 The Hub included Chris Brown, Scot Gresham-Lancaster, Mark Trayle, Tim Perkis, Phil Stone, and John Bischoff. http://crossfade.walkerart.org/brownbischoff/

simultaneously over a phone line via a modem connection by changing information between two groups in two different places in New York. Later they developed the system into a version that allowed MIDI communication between the members during a live performance. Following The Hub 2: The MIDI Hub, they extended the third generation of Hub into the Internet based on network-music performances by using Open Sound Control[46] protocol (ibid).

Two performance pieces of The Hub, *Vague Notions of Lost Textures (1987)* and *Role'm (1987),* are free improvisation music performances based on exchange text communication (Brown and Bischoff 2007). In *Vague Notions of Lost Textures,* the performers sent text messages between each other and this exchanging formed a primitive chat-room. The topic of the conversation in this chat-room coordinated the improvisation process. Increasing note density, timbral brightness and amplitude peak levels were the general parameters mapping strategy. In *Role'm,* text messages were used as the conductor of the improvisation. The conducting decisions of the improvisation were also made by randomly choosing one of the six descriptors for each five categories of musical textures with the following,

ENSEMBLE: solo, duo, trio, quartet, quintet, tacet
ROLE: boss, lead, accompanist, filler, wall-flower, submissive
TUNE: chromatic, 8-note, 6-note, 4-note, 2-note, drone
RANGE: hi, hi/mid, mid, lo/mid, lo, all
TIME: gallop, trot, walk, crawl, drift, snooze (ibid)

The *Clonus Patterns* improvisation strategies show similarities with The Hub *Vague Notions of Lost Textures* performance. Moreover, combining audience text messages together with *Clonus Patterns* members' messages

46 Open Sound Control (OSC), a communication protocol developed as a successor to MIDI, and used for networking computers to multimedia devices, synthesizers and other music technology. http://www.cnmat.berkeley.edu/OpenSoundControl http://opensoundcontrol.org/

was beneficial for the performance. On the other hand, the *Call in the Dark Noise* improvisation strategy could have been developed further with more detailed descriptor categories in order to have a variety of alternative sonic structures.

In previous improvisation practices with the interactive improvisation systems, the control either remained with the performer or a part was given to the algorithms of the systems. According to Rowe making an appropriate control structure is one of the problems with ensemble improvisation and arbitration between competing sources of control information becomes harder as the number of control sources increases (Rowe 2001: 310). However, Joel Chadabe (2002: 2) points out that when a performer generates control information to which the interactive system reacts with a substantial amount of unpredictable complex information, it results in the performer sharing the control with the interactive system. Shared control has been part of the performative act of collective improvisation. Turn taking solo strategies of a collective improvisation reflect the common understanding of shared control in an improvisation process. Shared control in the *Clonus Patterns* improvisation performance brings the control of the improvisation to the audience. In the *Call in the Dark Noise* improvisation the audience and the author engaged in a conversation with a shared control manner due to the audience participation and the development of a combined aesthetic experience of the improvisation performance.

Christopher Dobrian (2001) questions whether the aesthetic judgment of a musical piece would be still artistically compelling if the audience controls the process of creation. Some musicians and composers with a conventional understanding might not be willing to give full control to an audience or to play an important role in an improvisation piece. The reason may be that a traditional way of composing or performing might not involve the interactive control process of an audience for the artistic development of an improvisation performance. However, these new performances offer innovative ways of experiencing music with alternative participation methods in an improvisation process. They have changed the role of the audience from enjoying the pieces as passive observers to taking part in the actual performance. Interactive performance practices brings the artistic experience of the new process that involves the audience as the main actors of the artistic creation.

netpd is another project that enables networked performances. Roman Haefeli has developed a Pure Data based environment for electronic musicians to have jam sessions on a network (netpd 2008). Musicians can make their own digital musical instruments by using netpd abstractions; on the other hand, musicians can also share their Pure Data patches with other musicians on the network. This networked jam session is based on sharing data. Whenever a client loads a patch, it gets loaded on every connected client. This a client-server system, which does not allow sharing any sound; however, the network makes it possible for the musicians to share their control structure and organize distant collaborative music.

All the participants of the running jam session use the same patches to control the sound structure of each other. Unlike the *Clonus Patterns* or *Call in the Dark Noise* performance structures, netpd gives a possibility to the audience to create their own Pure Data based instruments for the improvisation session. However, participation in the jam session requires at least basic knowledge about the Pure Data environment, which might limit the diversity of the participants. A musical instrument that requires an everyday life tacit knowledge to control and organize sounds can be crucial for designing experimental musical instruments for participants with all kinds of musical backgrounds.

The research process focuses on alternative opportunities for designing experimental musical instruments with digital and analog sound synthesis techniques to explore sonic structures beyond conventional ones. The research moved further with the process of making experimental musical instruments and their performance in collaborative improvisation sessions.

5.

Experimental Musical Instruments

A number of experimental musical instruments that experimented with differentiation of tones under various instrument design principles were invented at the end of 19th century. The most significant early electronic instrument is the Telharmonium (1906), by Thaddeus Cahill. It was constructed as a massive keyboard based instrument that used dynamos for alternating the currency of various audio frequencies. It was controlled by several keyboard gears and wires and was amplified by large acoustic horns (Roads 1999: 83).

Cahill connected the machine to a telephone network to stream music into restaurants, stores and theaters. This instrument was developed several decades before the first electronic keyboard was created. However, Cahill's most important contribution to the development of experimental musical instruments however was developing beat frequency oscillation with Lee De Forest. In this technique, known as heterodyning, two inaudible high-frequency sine waves are combined to produce an audible low-frequency wave (Hypnotique 2008).

In the world of experimental musical instruments, the invention of the vacuum tube valve was a great breakthrough after the invention of the electricity in the world of experimental musical instruments. Designing portable instruments was possible for the first time. The most famous was the Theremin. It was built by Leon Theremin around 1918 and it is a box with two antennas, which create an electromagnetic field. Within this field the human body's capacitance interacts with beat frequency oscillation. Using hand gestures towards or away from the instrument it is possible to create variable pitch and volume of a tone.

The invention of Theremin was another break through in history and since then, the field of experimental musical instruments has developed considerably with various experimental works. Developments of computer technology combined with musicians who have attained a wide range of skills has also helped to develop various synthesis methods, control structures and interfaces for experimental musical instruments. Development of experimental musical interfaces is a significant area of research today. For example, an entire conference that is held yearly and considered important in the field, is the New Interfaces for Musical Expression Conference (NIME)[47]. This event focuses on the idea of musical expression and the importance of gesture.

The research process of this dissertation involved studying and exploring experimental musical instruments through a collaborative project called the EMI Project. EMI stands for Experimental Musical Instruments and it was born from the collaboration between Koray Tahiroğlu from Helsinki Media Lab. (Finland), David Cuartielles from the School of Arts and Communication, Malmö (Sweden) and Enrique Tomas from the Media Lab. Madrid (Spain). Like the SolarDuo Project, the EMI project, was a project where the author engaged as an electronic luthier in the process. One of the important new elements that this project brings to the thesis' research, is the concept of *gestural* control and feedback.

In this context, an important aspect of the EMI project is the idea of building an instrument that allows a guest performer, with no previous experience in performing with the author, to perform using one of the author's instruments. The concept was to attempt to build an instrument that was intuitive to control, and based on natural expressive gestures.

The EMI Project as a group consists of an engineer, a composer and a sound artist experimenting using unusual artifacts as instruments. The EMI Project members are laptop performers and *DIY*[48] designers, researching alternative gestural controllers for performances of ultra-noisy textures, which do not include traditional narratives but instead hedonistic noisescapes. The EMI Project musical instruments[49] have been designed as a set of Copyleft boards for noise-based performances. In the EMI Project, the author was responsible for the majority of the technical and conceptual work. As a result of the nature of the work, the author, David Cuartielles and Enrique Tomas are jointly responsible for the performances and the instrument designs. The EMI Project has performed at various festivals in Sweden, Spain, Finland and Norway. This chapter describes the EMI Project design strategies, *EMI Night !! (2006)* and *Piksel Festival (2006)* performance descriptions and observations as case studies.

The DVD material attached includes technical materials of the EMI Project interactive performance systems, recorded video and audio files from the performances, circuit diagrams of the EMI Project instruments together with images of them.

47 http://www.nime.org/

48 DIY: Do It Yourself

49 EMI Project actions have been commissioned and curated by the Swedish/Danish Art group E.A.T. Sweden

5.1 The EMI Project

The work done during the EMI Project was developed from existing academic references such as Wilson's paper on the creation of microcontroller-based instruments, and from in the inspirational work by John Cage and other electronic musicians (Wilson et al. 2003). The EMI project aimed at creating and experimenting with instruments that would be suitable for performers who do not have a background in music.

Unconventional computational tools present the possibilities of creative freedom in music and develop it into open form musical activities. The EMI Project gives a possibility to non-expert performers to experience a musical activity. The pleasure of musical activity is being able to explore and experiment with varying sound structures using accurate and compact instruments. The characteristics of the instruments used in the EMI Project, like *easy use and control* means that it does not require much effort for people without a background in music to participate in a collective improvisation and to experience ever-changing music. In a collective musical improvisation, pleasure is maximized in to a higher scale.

The standardization of personal computers has resulted various input / output devices that simplify the interaction between the user and computer. Input devices have been designed to optimize certain tasks. Some equipment like the mouse or the keyboard have become everyday objects to most people to the extent that users have gained the ability to interact with them in a natural manner. However, this type of input devices have limitations when it comes to performing very precise actions, like those of a musician playing an instrument. Sergi Jorda` (2002: 23) points out how one of the main practices in designing musical controllers is to include capabilities that have been unavailable in traditional mechanical instruments. A mouse or a keyboard may be insufficient for controlling certain types of sound synthesis. However, Jorda` also points out the fact that many existing graphical user interfaces are controlled with mouse-keyboard actions, which makes them somewhat useful. (ibid: 26).

In his foreword to the book, *New Digital Musical Instruments: Control And Interaction Beyond the Keyboard*, Ross Kirk brings forth the arguments of some musicians about how MIDI keyboard playing technique has limited performers' contributions in future technological evolution. In spite of this, in the late eighties MIDI keyboard devices were accepted as the natural way of communication in electro-acoustic art (Miranda and Wanderley 2006). This argument could be easily extended to the mouse and keyboard paradigm. Being the most common way of interacting with a computer, these have anyway been used as a musical controller as they are. Their use in computer generated music technology could be regarded as similar, and limited, as the MIDI keyboard's contribution.

This need for new capabilities, and tools for interaction, has been a starting point for musicians and researchers to create alternative tools. This aim is to give musicians new possibilities to control their instruments. Arduino is yet another microcontroller interface of these initiatives. It is the result of an open source hardware[50] project aimed at providing the art and design community with a tool for creating alternative electronic interfaces. By allowing users to interact in various new ways, these new interfaces can be seen as enabling more natural bonds with computers.

Arduino consists of an 8-bit microcontroller and a port through which

50 Open hardware, open source hardware is referred to open source software as its source code is available for everybody those who would like to bring the necessary components together to built up their version of the hardware. It is possible to do modifications and make changes in design documents as well. Arduino design documents are distributed under a Creative Commons license. http://www.arduino.cc/en/Main/Hardware

to communicate with a computer. This allows a connection to existing software packages like Processing[51], PureData, VVVV[52], or MAX/MSP[53], which are commonly used in the creation of multimedia performances.

It could be argued that one of the main strengths of Arduino resides not in the technology itself, but in the community of users that has grown around it. There are hundreds of artists and designers who create new installations and tools using this platform. Users have documented their experiments using sensors such as, accelerometers, ultrasound and infrared range finders, light detectors, temperature and humidity sensors. The use of sensor technology in the EMI Project enabled new possibilities for creating devices that allow embodied interaction in an "outside the box" paradigm. These interfaces can offer alternative designs to the keyboard-mouse option. The development of musical interfaces should move towards alternative physical ways of playing instruments in order to explore unorthodox interaction possibilities. According to Jorda` for example, the increasing availability of new sensing technologies such as programmable microcontrollers causes many musicians to find alternatives rather than *mouse music* (Jorda` 2002: 25).

New software approaches

In human computer interaction, the study and development of new interactive systems attempts to provide new methods and tools as well as more sophisticated modes of communication (Jacob et al. 1993: 69). For example, new input devices can represent sensor-monitoring actions, which in turn can provide increased human-computer communication techniques.

The developments in human-computer communication take place in multiple domains; a new style of input requires new devices, new types of interaction techniques, and new software approaches (ibid: 71). During the last few years there has been development in several open source

51 http://www.processing.org

52 http://vvvv.org/

53 http://www.cycling74.com/

software platforms that allow the creation of performative experiences. These new tools have been embraced by a multitude of users, who have helped further development through distributed debugging processes.

Among other new software approaches, that have resulted in breakthrough developments are the MAX paradigm; Max/MSP and its open source counterparts jMax and the Pure Data environment. Max paradigm provides the interface with pictorial diagrams where music is represented in terms of flows of information (Puckette 2002).

Developments in technology involves groups of pioneers who dedicate time to studying the potential benefits. It is possible to test different versions of the designs to see if they are functional even before the design has been finished. This process gives developers the chance to shape technology through the critique of the first users. This is precisely what is happening with Arduino and Pure Data tools. A large portion of the early users of Arduino have been performing electronic music with Pure Data. Moreover, the characteristics of open source software / hardware, which promotes the open distribution knowledge have generated strong synergies between users and developers on both sides of the community.

The EMI Project contributed to the integration of these two environments. The author who is a member of Pure Data Development Project (PDDP) and David Cuartielles who is developing Arduino have organized workshops together to introduce the possibilities of using both programmes together[54]. In the EMI Project, Pure Data is used for the software interfaces, while Arduino complements it as a hardware tool for interacting with a computer in new ways. The former is used to create software musical instruments; the later allows for the embodiment of ways to modify the software parameters. Combining the two technologies has been promising for developing performative experimental musical instruments.

54 The EMI Project introduced the Pure Data and Arduino environments at K3 Art and Communication Department of Malmö University between 12th and 13th December 2005. As a part of the Ars Electronica Festival, a series of workshops called, electrolobby were organized and within the electrolobby content the EMI Project members conducted an Experimental Musical Instruments and Pure Data workshop between the 31st of August and the 6th of September 2006 (http://www.electrolobby.org/).

Gestures and feedback

In the process of creating experimental musical instruments, the EMI project integrates Arduino and Pure Data to map physical interaction into a digital environment. The response of sound processing to a physical gesture forms the interaction between the performer and the instrument. Through this interaction, in the moment of playing, a musician's expressions are transformed into physical gestures which are then converted into sound structures by the instrument.

In the EMI Project, a gesture is considered as an act that causes resulting sounds or a human action that is used to generate sound (Arfib et al. 2004: 512, Miranda and Wanderley 2006: 5). The project aimed at exploring the notion of a gesture and turning it into related sound forms. The feedback strategy in the EMI Project was designed to balance the immediate response of the instrument with the performer's physical gestures – not too simple but not illegibly complex. This forms an attentive interaction process between gesture and feedback, that is pleasurable and instructive. The feedback characteristics of EMI musical instruments can be considered as active feedback that is produced by the system in response to certain user actions (Miranda and Wanderley 2006: 11).

The interaction methods of the input devices specify the types of possible gestures, which can affect the related mapping strategies and the interface design of the instrument. Marchelo Wandesly categorizes gesture types in two groups;

1. Gestures for which for no physical contact with a device or instrument is involved.These can be referred to as empty-handed, free, semiotic or naked gestures.
2. Gestures where some kind of physical contact with a device or an instrument takes place.These can be referred to as manipulative, ergotic, haptic or instrumental gestures (ibid: 6).

The types of gesture in many interactions with physical objects are similar. In the action of holding a book and putting it in the bookshelf a similar gesture type occurs when a person empties the dishwasher and places the plates on a shelf. All the pushbutton interfaces such as, TV remote controllers, calculators, ATM machines, computer keyboards, electric switches or potentiometer and fader interfaces such as ovens, audio mixers, stereo volume controllers use the same type of gesture interaction regarding the physical contact with the object. This similar interaction occurs even between uncommon gesture types; when a person rubs their hands together to warm them in front of a fire place, similar movement types can be observed when a person shields their eyes from direct sunlight. Everyday life experiences can easily be used for design strategies of instruments. In the *Foot, Hand, Kitchen, Wear / Ware 1997–2000* musical interface design series Perry Cook (2001: 2) focused on turning everyday life tools into controllers by embedding some electronic components. His design strategy was structured around the tacit knowledge of everyday life tools with simple one function sound modules. PicoGlove, Digital Tabshoe, JavaMug and P-Ray's Café are some of the instruments resulting from Cook's claim that "Everyday objects suggest amusing controllers" (ibid: 3).

In the EMI project musical instruments, the characteristics of control sensor devices condition the type of gesture. Defining the gesture type is crucial for the design process of the instrument. It outlines the general models for how interaction would take place between the instrument and the musician.

Accurate and compact instruments

The EMI project studies the interaction behind new musical artifacts for performers with no traditional musical education. The members of the EMI Project share a common vision of what constitutes music, as well as, what kinds of skills should be required to play an instrument along with the characteristics of the instrument. EMI Project's vision on these matters will be discussed further in this section. Looking beyond the concept of music, and performance, the project investigated the question of what makes some instruments successful and evolve in form and sound qualities, while others disappear in history.

Attempting to find an answer to this question could be done through exploring Max Mathews' arguments about experimental musical instruments. Mathews argues that even though many instruments have been invented throughout the history of experimental music, not a lot of music has been composed or played using them (Roads and Strawn 1987). His argument meets with some expectations to answer the above question.

One of the reason why some musical instruments more successfully continue their evolution and actively take part in the history of music could be that the existing compositions made for them remain and are still played over a long period of time. Performing these compositions keeps the characteristics of the instruments alive and able to survive. There are many examples of such instruments but the instrument called the Ondes Martenot is a good example from the recent past.

Ondes Martenot, was invented by a French telegraphist Maurice Martenot in 1928, and is one of the early expressive electronic instruments such as the Theremin, Croix-Sonore and Ondioline. It has pioneered new performance techniques and new electronic music sounds (Roads 1999: 622). It is similar in sound to the Theremin; however, what makes it different is a keyboard interface with a separate finger control for glissando and vibrato as well as keys to adjust the timbre.

Radiohead[55], an alternative rock band from England, is claimed to be a very important publicity agent for the treatment and development of modern electronic music (Collins 2004). The members of Radiohead are well known for their enthusiasm for experimenting with electronics and electronic sonic structures. Jonny Greenwood, the Radiohead guitarist, is a key figure in experimenting with various musical instruments and adopting new technologies in the band and in solo projects. Not only has he used the MAX/MSP programming tool in his music, he has also played the Ondes Martenot in Radiohead albums like, Kid A (2000), Amnesiac (2001), Hail to the Thief (2003) and Rainbows (2007). In addition to this, he has written a piece called *Smear (2003)* for the Ondes Martenot. This has been known as Greenwood's love letter to the Ondes Martenot that was played together with London Sinfonietta (Week 2006). While social, technological and musical features have an important role in the survival of a musical instrument, Radiohead's albums, Greenwoods' piece Smear and other musicians' compositions for Ondes Martenot, such as Olivier Messiaen, could help make it unforgettable in the history of music and keep it among current instruments.

The design characteristics of an instrument may affect its position in

55 http://www.radiohead.com

music. Usability problems, loose interaction possibilities and control difficulties can cause communicative problems between a musician and the instrument. This can halt the evolution of the instrument. Zack Settel and Cort Lippe (2003) highlight the relationship between an instrument and the music written for it by giving the piano as a case example. According to Settel and Lippe, among the design improvements of the piano was the concept of a note-independent dynamic range of keyboard music. This had the effect of inspiring musicians and composers when the repertoire for the instrument emerged after a certain amount of time after the instrument's appearance (ibid).

The design characteristics of an instrument can inspire and lead musicians into the world of discovery of sounds; however, it can take some time before the instrument is accepted and used in compositions. The following process might turn those compositions into a kind of music driven by that particular instrument. Examples of this process are piano music, electric guitar music, saxophone and Theremin music.

The adoption of technology, and its cultural absorption makes the instrument ubiquitous in that particular culture. A practice of playing an instrument several hours a day, for many years, can lead to constructing an ubiquitous instrument as well. In this case, practicing makes the interaction take place between the musician and the structure of sound. Instead of concentrating more on the physical control of the instrument, it can direct the musician to achieve an intense interaction with the sound output. In the EMI Project, design strategies for musical instrument interfaces were aimed at making the performer achieve *how to play* usability instructions through the result of tacit knowledge.

Tacit knowledge is the knowledge acquired through an embedded knowledge of previous experiences of the performer. Thomas Kuhn (1970: 254) describes tacit knowledge as the ability to recognize a given situation from exemplars. Past experiences, education and culture are fundamental for this ability. Kuhn introduces two different tacit knowledge types; the first type of tacit knowledge is that one a person uses when what they have learned to consciously recognize the similarities in different situations. The second type is a recognition that may also be involuntary in a process over which the person has no control (ibid). Performers can concentrate more on being creative with musical structures through the tacit knowledge that can be obtained through practice and experience.

The integration of electronic sensor technology with software sound

synthesis was another design strategy in the EMI Project. Digital materials, such as the cursor on a screen, can be controlled with various types of digital processes. They can be linked to other processes and the output of one system can be the input of the next one, as long as the data can be transferred between them.

EMI Project interaction design strategy was based on the *cause and effect* properties of the interaction process. The members of the EMI Project chose to assign one form to one function and also to one software patch in the modules of the instruments. According to Perry Cook (2001: 2) his PhISEM (Physically Inspired Stochastic Event Modeling) project, a shaker percussion instrument was successful with the users, because of the easy usability of the instrument since it can perform only one function. Cook argues about how the programmability of computational tools provide artists / designers infinite opportunities for experimentation and creativity in designing new musical instruments; however those who would like to play it, simply would like to pick up the instrument with a simple and obvious interaction to play (ibid). The *One form to one function* design principle gave the EMI Project's musical instruments their own identity.

The project aimed at creating instruments that could perform simple tasks, and be controllable with a tacit knowledge. When a performer figures out the usability of the instrument, then the musical activity begins immediately with pleasure and joyful interaction. However, this is not the only framework in design strategies to produce musical structures that consist of multiple events. The framework for each design strategy should be considered highly related to the target user, for whom the instrument is designed. Mixed interfaces with complex sound structures can be a good challenge for experienced musicians; however this design strategy may not be possible for instruments designed for performers with no background in music.

Enhancing the pleasure

Performers with no background in music have been the main target for designing the EMI Project musical instruments. Therefore, the *easy to play*, *easy to control* identies of the instruments do not require an extensive knowledge of music. On the other hand, the project never disregarded the sensory satisfaction of the ear. Sound synthesis modules keep the *ear pleasure* providing intensive interaction with the performer. David Wessel and Matthew Wright (2001) have a comparison argument on this design strategy and introduce their claim with the *phrase*, *a low entry fee with no ceiling on virtuosity*. Wessel and Wright outline the comparison manner with traditional acoustic instruments, which are not easy to use at first, but they support developing a high degree of musicality. They argue that the *ease-of-use* strategies should not stand in the way of the continued development of musical expressivity (ibid). It is a common fact that a balance should be sought between ear satisfaction and the *easy to play*, *easy to control* strategies. The resulting sounds should not make the instrument have a toy-like character, on the other hand, it should not give the impression to the performer that it will take years to master the instrument.

In traditional music, musicians can spend years mastering their instrument in order to be able to play musical repertoires at a level those repertoires are expected to be played. Keeping this definition of mastering in mind, the definition used in the EMI Project is slightly different.

Some sound synthesis modules are designed for direct mapping strategies, which do not require a long period of time to master the instrument. However, some algorithmic structures in the sound synthesis modules are based on random processes that will not generate the same sound structure more than once. On the other hand, getting better at controlling the instrument with basic knowledge advancing will maximize the pleasure that a performer can have when playing with an experimental musical instrument.

Pleasure is achieved when a performer explores a changing set of sonic structures while interacting with an instrument. Easy control principles encourage the performer to explore the sound structures that an instrument can offer. The overall design strategy of the project is to enhance the pleasure that a performer gets while playing an instrument. The accurate and compact instruments give performers a chance to concentrate more on developing techniques for manipulating sound structures and mastering the instrument.

The performer's attempts of exploring alternative sonic structures with various methods of decisions form an individual improvisation process. The EMI Project aims at shifting the individual pleasure of an improvisation to that of a collective musical improvisation. With the ability of *easy to use*, *easy to control*, the EMI project instruments can bring non-professional musicians together for continuous musical activity in a collective improvisation process. In a collective musical improvisation, pleasure is maximized while exploring collective sound structures and listening activities. Collective musical improvisation with accurate and compact experimental musical instruments is the process where pleasure is enhanced.

EMI NIGHT PERFORMANCE, HELSINKI, 2006

On Friday, the 17th of March 2006, the author organized an experimental musical instruments night, where invited musicians performed with their self-made analog or digital instruments. The EMI Night event took place at KokoTeatteri and the performers were; Juha Valkeapää *vocal with analog and self-made instruments,* Pilvari Pirtola *with electronics*, EMI Project by David Cuartielles, Koray Tahiroğlu, Enrique Tomas *with digital instruments interfaced with sensors* and Kalev Tiits *mechanical calculator, electrical motors, kitchenware, various audio electronics and computer.*

The EMI project developed digital instruments using multiple sensors as control interfaces. For the EMI Night performance the project integrated Memsic 2125 Dual-axis Accelerometers, Parallax PING))) ultrasonic sensors, a Flex bend sensor, and Rotary Potentiometers sensors[56] as interfaces that can control the digital sound processing with various algorithms. The EMI project performed a 19:13 minute long improvisation.

5.1.1 Performance Observations

At the beginning of the performance, the EMI Project members decided to ask someone in the audience to be a guest performer in the improvisation. Andrew Paterson[57] accepted the invitation and picked up the flex sensor controlled *metal plate* instrument, which is shown in Figure 5–1. The improvisation began with an impulse action by Andrew Paterson.

56 The Memsic Accelerometer is a dual axis thermal accelerometer capable of measuring dynamic acceleration (vibration) and static (gravity) acceleration http://www.memsic.com/. The flex sensor changes resistance only when it is bent in one direction. Flex sensor has 10K ohms nominal resistances. Maximum resistance can increase to 30k ohms to 40K ohms, proportional to the degree of bending (http://www.jameco.com/). 10k ohm potentiometers are used as variable voltage dividers.

57 http://mlab.taik.fi/~apaterso/

The *Metal plate* instrument's sound synthesis module is manipulating a prerecorded sound sample but various technical problems during the performance caused the instrument to produce continuous distorted glitchy sounds. For approximately the first three minutes of the improvisation the *metal plate* instrument dominated with unexpected sound output. These unexpected sounds affected the EMI project members' improvisation acts as well, and the improvisation did not develop with any particular flow decisions. However, the surprise-sounds became a part of the improvisation and rather than developing any dominant sound structures, EMI Project members' acts were directed to accompany the unexpected glitchy sounds. At the end of the first quarter of the improvisation, the *metal plate* instrument sounds turned into a controllable sound structure and the improvisation proceeded further. The performance setup as a result of the guest performer participating can be seen in Figure 5–2.

An accelerometer sensor-controlled instrument manipulated the sampled sound structures, which were loaded to array tables in the Pure Data environment. The parameters for pitch values and the reading point of the sampled sound were controlled by dual-axis acceleration values. Pre-recorded sound materials could be loaded to array tables, on the other hand, capturing live audio segments and loading them to array tables for further manipulation is also possible with an accelerometer sensor controlled instrument. A dual-ultrasound sensor controlled instrument also manipulated the pre-recorded sound samples, changing the parameters for pitch and read points. The pre-recorded sound samples for the dual-ultrasound sensor instrument were chosen dynamically during the improvisation. The sampled sounds varied from continuous wind turbine noise samples to piano sounds. The second dual-ultrasound sensor controlled instrument was integrated with a rotary potentiometer controller. Ultrasound sensors controlled the frequency and the pitch values for the modulation. A potentiometer was used to control a polyphonic sound module.

During the second quarter of the improvisation, the accelerometer sensor controlled instrument was the leading instrument and the other sensor controlled instruments were accompaniment. The improvisation continued without switching between any improvisation modes, the general attitude was to keep accompanying when one of the improviser was playing solo for a period of time. At the end of the second quarter, a potentiometer polyphony instrument became the leading instrument together with the dual-ultrasound sensor controlled instrument. The accelerometer

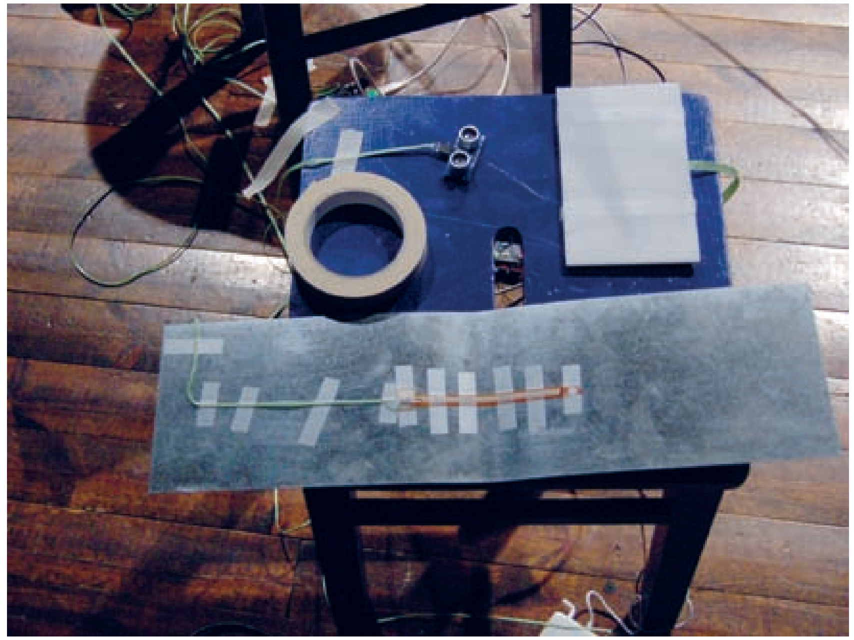


Figure 5–1: EMI Project metal plate instrument. Images of other EMI Project instruments can be viewed on the attached DVD.

instrument was totally muted after a while, however, continuous wind turbine noise sounds and the flex-bend sensor instrument were still playing through various manipulations. Thereafter, there was a sudden quiet moment. All the performers began to play with quiet and interrupted sound structures.

The guest performer became more active in the improvisation during the third quarter. He became familiar with the flex-bend instrument and its control gestures. He created short, sharp and controlled sound structures. Following the lead of the guest performer, the author started playing with similar sound structures and the tension began to rise. However, this activity did not last very long, and once again, the improvisation slowed down when the performers began to listen to each other and become less active in producing sounds. In the final quarter of the improvisation, The EMI project members were organizing the sound structure for the earlier agreed final. In the last period, a pre-recorded voice sample began to fade into the structure. The voice sample was recorded earlier in an airplane. It

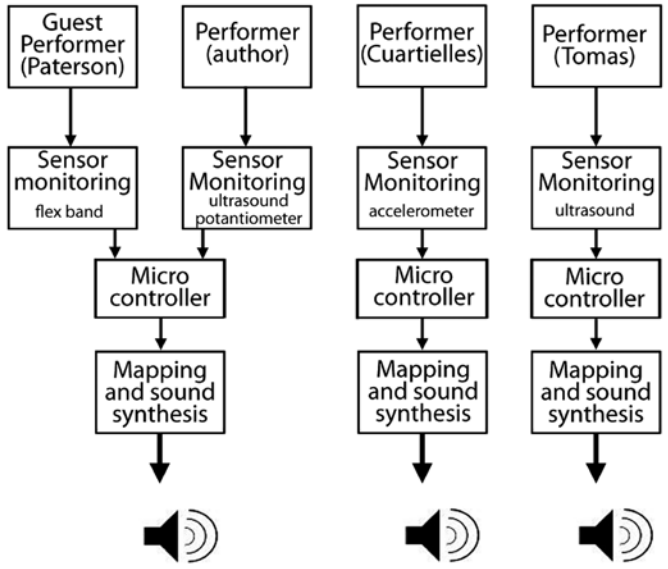


Figure 5–2: EMI Project set up for the EMI Night improvisation performance.

was an audio safety instruction spoken in Japanese language. As the sound sample grew louder, one by one the EMI projects the instruments began to fade. In the end only the voice sample, accelerometers pulse modulator rhythmic structures and piano sound sample were left. The voice sample and the piano samples dropped out after a while until only the pulse module rhythmic sounds were left and the improvisation ended.

PIKSEL FESTIVAL PERFORMANCE, BERGEN 2006

Piksel is an annual festival and a community for artists and developers working with Free/Libre and Open Source audiovisual software, hardware and art. It is organized by BEK, Bergen Center for Electronic Arts, which is a non-profit organization situated in Bergen, Norway (Piksel 2007). Live events of the Piksel festival take place in an old Second World War bunker called Tekniker Kroen. The EMI project performance proposal was chosen by the committee of the Piksel festival and was scheduled for performance on Friday, the 13th of October 2006. Figure 5–3 presents an image from the EMI Project performance.

Figure 5–3: EMI Project performance at Piksel festival.

The lineup was; Aymeric Mansoux (FR) *EtHertz*, Tom Schouten (BE) *SheepSint*, 5VOLTCORE (AU) and the EMI Project by David Cuartielles, Koray Tahiroğlu, Enrique Thomas (ES/TR/ES). The EMI Project performed an approximately 20 minutes long improvisation using the EMI Project analog and digital instruments. The analog instruments included *Distorted VCO, fx-module, hysteric-beat-oscillator, open VCO, tone generator, toy organ and vco-ic-e*. The components of these analog instruments are resistors, capacitors, NE555N and NE555P timers, integrated circuits and rotary potentiometers sensors.

5.1.2 EMI Project Analog Instruments

Voltage Controlled Oscillator (Distorted VCO instrument)

The oscillator frequency can be changed by modifying the applied voltage in one of the inputs in the *Voltage Controlled Oscillator* instrument. The 555 timer used in the *VCO instrument* is in astable mode[58]. It generates a waveform and its frequency can be controlled with a potentiometer. As shown in the circuit board in Figure 5–4, R5, R3 and C2 fix the NE555 timer to a range of frequencies. It is possible to change the range connecting the components with different values. Signal is generated continuously since the power supply is plugged. The 555 timer has eight pins, and the frequency of the timer can be controlled by modifying the voltage at pin five.

The *VCO instrument* generates a periodic signal that has only two values: 0 and 5 volts as a square wave. The frequency of the sound depends on the time that the signal is on the highest level during a given period. The spectrum of the signal does not include even harmonics, but contains only odd-numbered harmonics of the main frequency (3rd, 5th, etc). In order to define a specific range of frequencies some other resistors and condensers are connected to the circuit.

58 A 555 set in the Astable mode is basically an oscillator. It changes states by itself according to the supported components in the circuit.

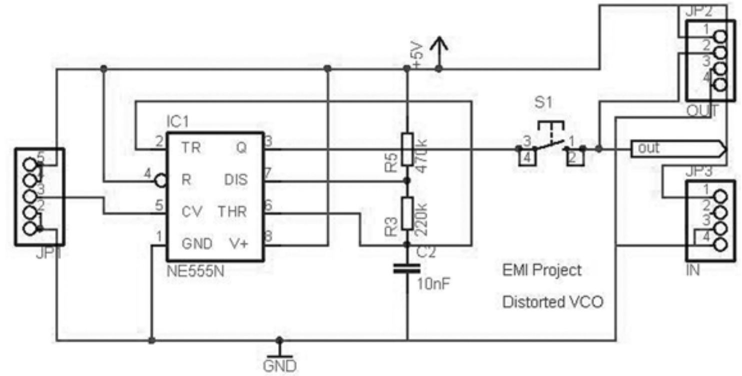


Figure 5–4: Circuit diagram of the Voltage Controlled cillator instrument[59]

FX Module instrument

There are two 555 timers connected in a cascade in the circuit of the *FX Module instrument*. The first timer generates a signal with less frequency than the second and the level of the first signal controls the frequency of the second timer. It can generate transients and chirps-like sounds. The circuit structure is shown in Figure 5–5, which is basically a combination of two VCO modules.

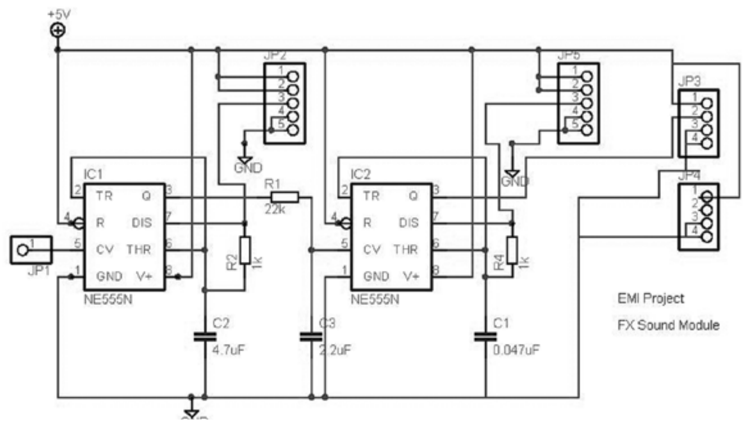


Figure 5–5: Circuit diagram of the FX Module instrument.

59 The circuit diagrams shown in this chapter are Copyleft licensed circuit designs by the EMI project.

Hysteric-Beat-Oscillator instrument

The *hysteric-beat-oscillator instrument* is the modification of the *VCO instrument* as shown in Figure 5–6. Modifying the beat rate to less than 10 beats/sec builds a variable metronome. The beat rate can be modified with a potentiometer or with various sensors.

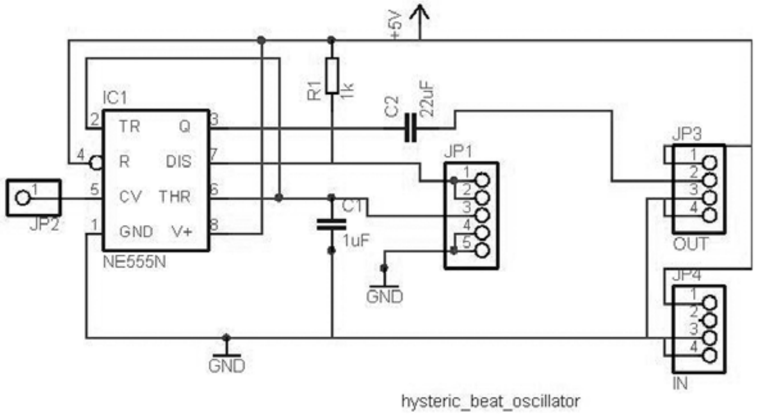


Figure 5–6: Circuit diagram of the Hysteric-Beat-Oscillator instrument

Open VCO instrument

The *Open VCO* is also a modification of the *VCO instrument,* which offers a versatile input VCO. Figure 5–7 shows its circuit diagram. It is possible to connect various sensors to the circuit's input.

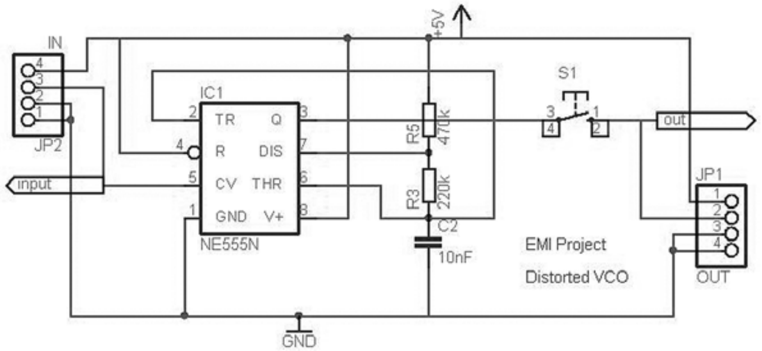


Figure 5–7: The circuit diagram of the Open VCO instrument.

Toy organ instrument

The *Toy organ instrument* is a set of capacitors added to the VCO circuit. The circuit connections are shown in Figure 5–8. The buttons on the circuit board add capacitors to the circuit, which modify the oscillator frequency. There are seven buttons controlling seven capacitors, which can be added to the circuit in parallel with other capacitors at the same time. It is possible to press two buttons at the same time, which will add two capacitors in parallel.

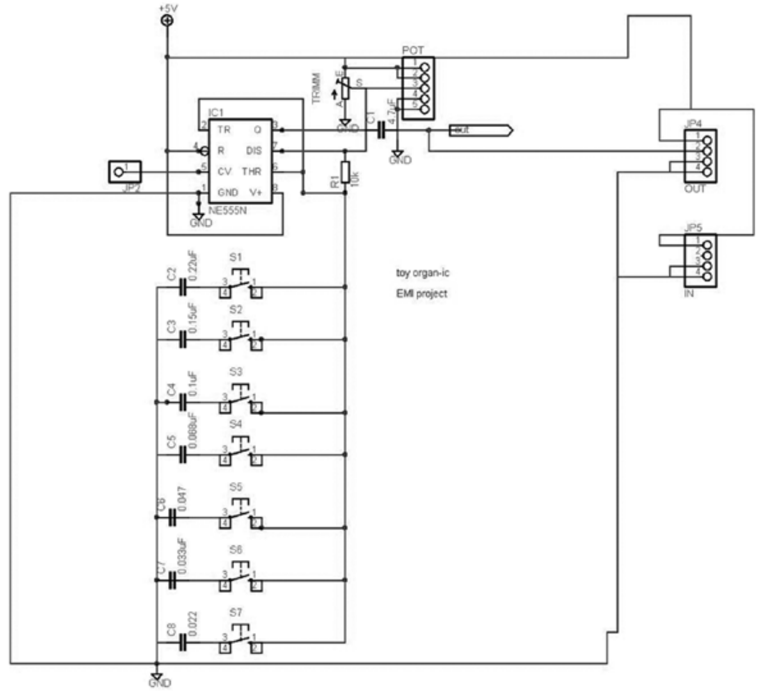


Figure 5–8: The circuit diagram of the Toy Organ IC instrument.

Tone Generator instrument

The *Tone Generator instrument* is a chirp generator, which has a 556 timer in the circuit board. The 556 timer is equivalent to the value of two 555 timers in the same integrated circuits. The circuit diagram is shown in Figure 5–9.

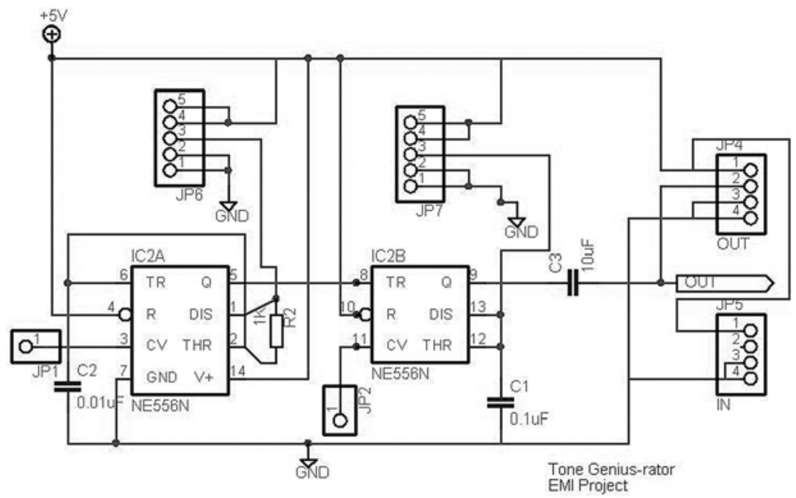


Figure 5–9: The circuit diagram of the Toy Generator instrument.

Voice Controlled VCO instrument

Tshe *Voice Controlled VCO instrument* has two main components, a VCO and Schmitt trigger. The VCO creates a waveform controlled by an external voltage. The Schmitt trigger is a circuit that offers two possible values for the output. It is a trigger and therefore, the output is always a lower value until the input value is greater than a specified threshold. The threshold and the output values can be specified. In the *Voice Controlled VCO instrument* a microphone is used to add voltage to the circuit. The generated voltage values are not enough to be greater than the threshold; therefore, the voltage values need to be amplified from the Schmitt trigger output. The VCO will only function when the input voltage value is greater than the threshold value. The circuit diagram of *Voice Controlled VCO* instrument is shown in Figure 5–10.

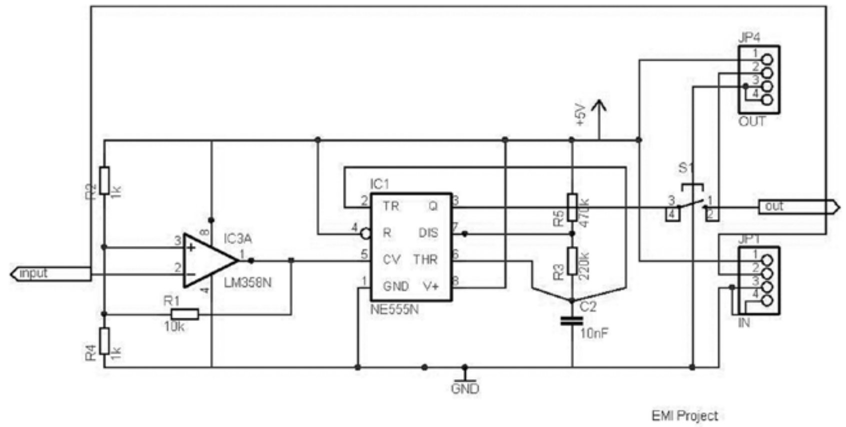


Figure 5–10: The circuit diagram of the Voice Controlled VOC instrument.

5.1.3 Performance Observations

The EMI Project members performed with EMI Project analog instruments in an approximately 20 minutes long improvisation at the Piksel 06 festival. The only digital instrument used in the performance was a flex-bend sensor controlled instrument. It was chosen because of its gesture-controlled structure, which involves direct physical contact with the instrument and its sound synthesis module, which is based on digital sound sample manipulations. Figure 5–11 shows the performance set up of the improvisation.

The improvisation began with a chirp sound from the *Tone Generator instrument*. Figure 5–12 shows an image of the instrument Tone Generator. Chirp sounds were followed by *Hysteric-Beat-Oscillator* sounds and the *Distorted VCO* instrument together with the *Toy Organ* instrument. The EMI project members developed the improvisation by accompanying each other with impulse sounds. The sonic structure crossed over from impulse sounds to a delicate balance in the first quarter period of the improvisation in a very short amount of time. The instant synchronized activity was not an earlier decision made prior to the improvisation as the performers had not agreed on any details regarding the structure before-

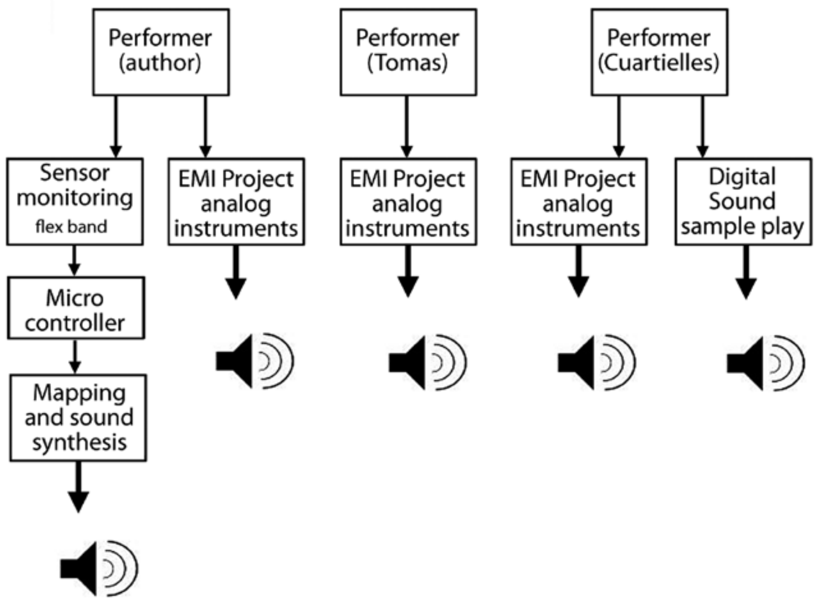


Figure 5–11: The EMI Project improvisation set up for Piksel 06 festival.

hand. However, when the balance was achieved, it formed the general rhythmic structure, which was based on the accompanying activity.

There were not any sudden or dramatic changes in the flow of the improvisation, and no plan for slowing the tempo. In the second quarter, the flex-bend sensor controlled instrument and the *FX module* instrument generated some significant points in the improvisation, which could be described as an attempt to change the flow of the improvisation. In a similar manner, the *Hysteric-Beat-Oscillator* instrument sounds kept the tempo balanced. However, at times the *Hysteric-Beat-Oscillator* became the lead instrument for a short period of time when the beat pattern was switched with the frequency values.

In the third quarter, the improvisation structure and the flow stayed similar with the earlier periods and it continued that way until the end without surprises or unexpected sound structures. The EMI project members were interacting with a certain level of continuity regarding the overall sounds, rather than interacting directly with each other by taking turns. The final period of the improvisation began with the voice sample of the airplane safety instruction in Japanese and ended with each performer fading out one after another.

5.2 Conclusion

The idea of using gestures to control sound in creating experimental musical instruments is not new, and a significant amount of interesting instruments have been developed in the past (Roads 1999: 622, Cook 2001, Miranda and Wanderley 2006 19–173). The design of new musical instruments mostly focuses on technical matters, engineering challenges, interaction possibilities and usability concerns. What can really differentiate one design from another can be a novel way in which the instruments are used. This emphasizes the value and usability of the instrument for artistic purposes. The EMI project intented to explore possibilities for performers with no background in music, to experience the pleasure of musical activity. The EMI project has been creating unconventional analog and digital musical instruments and performing with them in various sound art events. The common knowledge of EMI project would definitely be developed further with more feedback from the performers of these instruments. So far, there has been only one event where it was possible to invite a non-expert musician to use the EMI Project instruments in live improvisation.

The objective of the project was to bring non-expert musicians together to play in a collective improvisation and to explore and experiment in new ways of making music. The control mapping strategies in the EMI Project were based on the direct acquisition of gestures, which makes it possible to easily to learn and participate in the collective experience of an improvisation (Miranda and Wanderley 2006: 12). According to Settel and Lippe (2003) the amount of complexity required of an instrument for an improvisation is significant-especially if the player expects to play for more than five minutes without getting bored. There has never been any complex arbitrary mappings between gesture and sound, but instead *one form to one function* and *easy to use and control* design strategies were followed and did not cause any obstacle in developing improvisation structures during the EMI Project performance, which could be interpreted as the benefit of collective musical participation. However, current limitations of the EMI

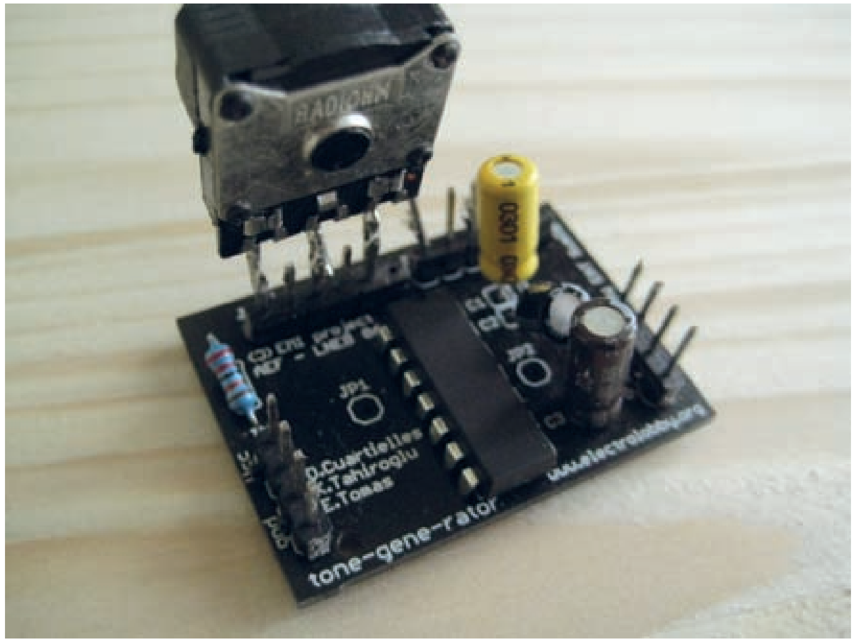


Figure 5–12: EMI Project Toy Generator instrument. Images of other EMI Project analog instruments can be viewed on the attached DVD.

Project instruments have mostly to do with the need for a visual feedback mechanism. During a performance with the instruments, visual parameters for any sound output is limited with the computer feedback on the screen. For analog instruments it is much more limited since the potentiometers positions are not clearly recognizable at all. A feedback mechanism which outputs sound parameters in a visual form may offer more support for the decision making process of non-expert musicians during a collective improvisation.

Open source environments are being developed continuously. The EMI Project members are in touch with the developers of open source environments, which the EMI project helps to evolve as well. Another important effect of using open source technologies for developing instruments is the democratization of the tools. It is not only that the tools themselves are open as such, but often also the development process of the tools is open for participation. In fact, PureData and Arduino enable people to more easily build unique and interesting interfaces with the easy integration of

their computational code structure. Pduino[60] is a Pure Data interface for the Arduino, consisting of several Pure Data abstractions and an Arduino firmware called "Firmata". Almost all of the analog, and a number of digital sensors61 can be connected to Arduino and sensors can be easily controlled with Pure Data through the Pduino interface. Once Firmata is loaded to the Arduino board, no Arduino software changes are required on board for additional sensor connections. It is easy to connect a sensor and to immediately control it with with Pure Data without any software code updates. Pduino is based on the Firmata firmware, which is an attempt to establish a broader standard of implementation in software packages as; Processing, vvvv, Python or Max/MSP (Schebella 2007). It uses a compact MIDI like message format, optimized for high-speed data transfer. The Pure Data extension of Pduino is mainly an object called [arduino] which depends on some abstractions included in the Pure Data-extended package. The object reads and outputs messages in an easy to handle message format.

Arduino is not the only solution for a practical interface of gesture acquisition. Hardware controllers such as Christian Klippel's MultIO[62], the Create USB Interface[63], STEIM's junXionbox[64], and MIDI controller-boards Doepfer[65], Miditron[66], I-cubeX Digitizer[67] and other devices that use Bluetooth, Ethernet, the serial or parallel ports already exist for artists and designers. It is relatively easy with the supported instructions to build individual interfaces, based on one of the common microcontrollers like PIC[68], Basic Stamp[69], Atmel[70]. Besides USB, serial or MIDI protocol com-

60 Pduino is written by Hans-Christoph Steiner, http://at.or.at/hans/pd/objects.html

61 The current version of Pduino does not support digital sensors that require constant pulse feedback, such as PING ultrasound and MEMSIC accelerometer sensors.

62 http://multio.mamalala.de

63 http://www.create.ucsb.edu/~dano/CUI

64 http://www.steim.org/software/junxionbox/junXion%20boX%20manual.pdf

65 http://www.doepfer.de

66 http://www.eroktronix.com

67 http://infusionsystems.com/

68 http://www.microchip.com/

69 http://www.parallax.com/Default.aspx?tabid=295

70 http://www.atmel.com/

munications, audio input to a computer is used for interfaces to connect sensors through audio streams for gestural mappings.

SensorBox is a low cost, low latency, high-resolution interface for obtaining gestural data from sensors for use in real-time with a computer-based interactive system (Allison and Place 2003). Software such as Pure Data, MAX/MSP and SuperCollider[71] may be used to interpret the acquired sensor data. One of the main differences between SensorBox and Arduino is that the former connects sensors to a computer through available audio input on a computer; and the claim is that through audio stream communication problems related to USB-serial or MIDI connections are avoided. However, the input / output connection opportunities are not as practical as in Arduino, which can limit the sensor range used for gesture controls. Existing hardware controllers and their successful integration with the software tools provides a ground to explore interaction possibilities in art and design works.

Contemporary electronic music is, in a way, moving away from laptop controllers. However, the EMI project never had any intention of avoiding or undervaluing the music made with keyboard and mouse controllers. Sergi Jorda` designed and developed FMOL, which is a mouse-driven musical instrument designed with the principle that mouse controllers are universally available, which can be considered as another important effect on the democratization of new music interfaces. Jorda` states that any research for clever mapping and better communication among the different components of an interactive music system does not imply that low-cost and widely available input devices such as mice, joysticks, or computer keyboards should be considered completely obsolete (Jorda` 2002: 24). Furthermore, he argues that there can be clever musical exceptions in mouse controlled interfaces as for example *Music Mouse*, interactive music software developed by Laurie Spiegel, which Jorda` claims as the perfect paradigm of a musical instrument designed to be played with a mouse (ibid).

71 http://www.audiosynth.com/

Feedback from the guest performer, Andrew Paterson

A reflection upon the event almost 2 years ago.

“The invitation came from Koray Tahiroğlu and David Cuartielles to join them and their collaborator on stage, both of whom I had known for a couple of years as friends and peers. I cannot remember now if we or I agreed in advance or not if I was going to participate in the performance. I have a memory of being a bit surprised to be called up onto stage, but this is a hazy memory.”

“ I consider myself as a non-musician, who has not had any substantial experience of playing musical instruments, traditional or electronic. For this reason I can imagine that I was probably a good (and considered) choice for participation as a guest performer: Friendly, sympathetic, appreciative, but without any renown for musical talent, or electronic music performance.”

“The performance was within the small venue of Koko Teatteri, central Helsinki, and the audience consisted of friends and many peers and colleagues within the Finnish Electronic arts and music scene. The intimacy of the occasion certainly made it easier to be involved, and accept. I was given an experimental instrument to play sitting on stage, on the floor, among the other 3 performers, including Koray Tahiroğlu and David Cuartielles. The thin ‘metal plate’ (attached to other micro-components) was flexible, and due to my basic knowledge of flex systems, I understood that bending it backwards and forwards contributed to the collective soundscape/music performance. The first 5–15 minutes of this situation was enjoyable, including the novelty of the situation.”

“However, as time progressed, I remember being conscious that each of the other performers had laptops also, which helped them determine and adjust their own sensor instruments, according to the number feedbacks visible in the software environment. I however did not have a laptop, so I had no visual/numerical feedback on the movements I was making with the metal sheet.”

"This lack of feedback, in combination to little recognition/indication of my contribution to the whole (soundscape / dataflow) meant that the longer I was on stage, with an instrument I had never practiced with before, the more I felt disconnected to the performance of the sound."
"The flexible 'metal sheet' instrument – which I was let to believe _did_ contribute to the soundscape performance but was hard to recognize exactly how - only had a limited number of actions that could be applied with it. Without some form of satisfying sign which reflected action to sound, and that contribution to the actions-sounds of the other performers, it felt like I was on show to illustrate the lack of skill needed to be involved, rather than as a serious collaborator in the performance."
"As a newcomer to the experimental instruments designed by Koray Tahiroğlu and his collaborators, and especially when I became tired of flexing the metal sheet, I found myself watching them more, reverting back to my audience role, except from a 'backstage' position."

Andrew Paterson

29.02.2008
NEW YORK

Andrew Paterson was able to perform in a collaborative improvisation with the EMI Project metal plate instrument with his basic knowledge of bending flexible material. The easy use and control of EMI Project design strategies allowed Paterson to discover how the instrument works without difficulty. However, the *one-form to one-function* design strategy did not encourage him to investigate the usability of the instrument further. He said that there were a limited number of actions that could be performed with the instrument, which led him to take a less active role in the improvisation and he watched other performers as though a member of the audience.

After the second half of the improvisation, he could no longer recognize the sound of the metal plate instrument. It is possible that this is related to the overall sound output at that particular time of the improvisation; however, he expressed a need for a visual feedback mechanism, which could recognize individual instrument sounds within a complex sound structure. On the other hand, the improvisation began immediately when the Paterson took his place on stage, which meant doing a sound-check with his instrument was not possible. Introducing each performer and instrument independently and highlighting the versatility at the beginning the improvisation, could have drawn attention to the contributing sounds of each instrument. This might have given a better chance for the guest performer to understand how the instrument works, what he is doing with it and to recognize the sounds during each part of the improvisation. Based on his comments, a higher level of complexity of the instrument would have reduced boredom and kept him active in the performance (Settel and Lippe 2003). An appropriate degree of complexity for the instrument could be attained by altering the control structures on both the hardware and software parts.

The research process moved further with the study of possible implementations for experimental music controllers to explore alternative interaction possibilities. The development of control structures for interactive systems has also been a subject in the following phases of the research process.

6.

Developing ways to Control the Different Component and Manage Complexity in an Interactive Performance System

In order to create the sound synthesis modules and control strategies of the interactive performance systems described in this thesis had resulted in the need to develop ways of managing the complexity of interactive control (mapping) features.

In the first section of this chapter, the author briefly outlines his view on the control of multiple sound sources in an interactive tool. As a testbed towards this view, Cumhur Erkut and the author have continuously extended the functionalities of a basic library ClaPD[72] that meets the minimum requirements of the final system, albeit in a restricted application domain. ClaPD was written for an entirely different purpose, but it helped the project members to understand how to tackle the bigger challenge.

The author also introduces solutions to the problem of a better visualization strategy, and the dynamic creation of the control objects (clappers) in the ClaPD library. The solutions were, to a great extent, inspired by the implementations within the Pure Data community. Besides present-

72 ClaPD is released as a free software under the GNU Public License (GPL) and can be downloaded from http://www.acoustics.hut.fi/software/clapd ing an overview of the ClaPD, and the current solutions for the existing problems, the research focuses on how to use these ideas in real-time performance situations.

In the final phase of this research process, and after attending the eNTERFACE´07 summer workshop in Istanbul[73], the author focused on alternative uses of data for the control of audio-visual synthesis. During this four week workshop, and as part of the team on *Audiovisual Content Generation Controlled by Physiological Signals for Clinical and Artistic* Applications, the author worked with with researchers from the fields of human-computer interfaces and audiovisual synthesis in exploring multiple ways of mapping analyzed physiological signals to sound and image synthesis parameters in order to build biologically-driven musical instruments. Among the objectives of the workshop project was to control real-time sound and visual synthesis processes using physiological signals. Using different experimental prototypes, a reusable flexible framework for bio-musical applications that offers worthwhile perspective for future research was developed and validated.

At the end of the workshop, a live performance night was organized in order to introduce the biologically driven experimental musical instruments, and their practice in live performance. The author performed the piece *Improvisation for Live Bio-Signals* together with Selçuk Artut and Hannah Drayson during the performance night on Wednesday 8th of August 2007 at Boğaziçi Music Club in Istanbul.

In general, interaction is under-utilized in bio-music; an improved system can offer alternative design opportunities compared to a collection of instruments controlled by bio-signals in real-time. Working on biologically driven experimental musical instruments and studying an alternative use of data for the control of audio-visual synthesis in an interactive context led the author to work on an interactive performance system focusing on electrical bio-signals of humans as core musical material.

Together with Hannah Drayson and Cumhur Erkut, the author developed an Interactive Bio-music Improvisation System (IBIS), which is capable of rendering pre-recorded bio-signals under controlled situations, and allows two performers to interact with the computational representa-

73 http://www.cmpe.boun.edu.tr/enterface07/

tion of a third one in real-time. These capabilities afford a multitude of narratives. The last section of this chapter presents the author's bio-signal instrumentation and audiovisual synthesis strategies in detail and the novel computational representation of the *third state* in Interactive Bio-music Improvisation System (IBIS).

6.1 Control of Multiple Sound Sources

Originally released as a real-time electro-acoustic music environment, the application domain of Pure Data is being continuously expanded (Puckette 2007a). A meaningful introduction to Pure Data currently consists of sound, image, networking, and physical interaction modules[74]. Moreover, Pure Data is considered as an audio engine in many networked, distributed, interactive, and participatory audio-visual content creation and prototyping applications, including 3D graphical model creation and rendering and computer games (Kajastila et al. 2007, Farnell 2006).

An important characteristic of these applications is that their components communicate via control, rather than audio streams. The latter requires a higher bandwidth in networked applications, and are more prone to packet-losses and transmission errors. This distinction between control and audio streams enables long-awaited network-based collaboration (netpd 2008). Other possibilities that might be soon be realized in the Pure Data community include joint audio-video synthesis of large-scale environments and evolutionary music applications (Raghuvanshi and Lin 2006, Miranda and Biles 2007). These applications require dynamic handling of multiple instances of similar sound sources, and are characterized by fundamentally different cases from the current ones: *N* performers on *M* machines will need to interact with *P* patches that contain *Q*

74 The Pure Data Documentation Project aims to build a unified framework for documentation, tutorials, and workshops. The current modules in Pure Data are addressed in PDDP meetings. http://puredata.info/dev/pddp instances of S sound sources, which are controlled by C control streams and eventually converted to A audio-visual streams.

In order to manage this combinatorial complexity and to gain maximum benefit of the upcoming applications, recent studies focus on advanced control strategies and propose a dynamic mapping layer between control and audio-visual streams (Momeni and Henry 2006). The advantages of separating the audio and the control streams are well-known in physical model based sound synthesis (Farnell 2006, Henry 2004, Rocchesso and Fontana 2003). This approach can be extended by an additional layer that generates events in an hierarchical fashion. Such a three-layer system would manage multiple sound sources in interactive and participatory contexts, and would fully address the needs of the next-generation applications. It could also adapt to different application areas and scenarios. This is an ambitious project[75], but the author will thoroughly and systematically explore the possibilities in the long term.

Meanwhile, besides this top-down approach, it is also important to consider a bottom-up approach and continuously extend the functionalities of a basic library that meets the minimum requirements of the final system, albeit in a restricted application domain. ClaPD is such a library; written for an entirely different purpose, but it helps to understand how it might be possible to tackle the bigger challenge.

ClaPD is a Pure Data library for hand clapping synthesis and control (Peltola et al. 2007). The initial release of the ClaPD (rel-0.1) produced individual handclaps, or the asynchronous / synchronized applause of a group of clappers. In terms of the previous control layer discussion, the hierarchical event layer corresponds to the asynchronous / synchronized applause decision, the control layer determines the tempo and the hand configurations of individual clappers, and the synthesis layer is the actual audio calculation. Therefore, the potential of the ClaPD as a testbed for control of multiple sound sources in interactive and participatory contexts has been addressed earlier, where a prioritized task list for extension has been also deduced (Erkut 2006). This list includes a better visualization strategy, extended user control, generalization of the synthesis strategy, and the dynamic creation, connection, and disconnection of the clappers.

75 http://www.acoustics.hut.fi/~cerkut/temp/schema-sid/

Since then, Cumhur Erkut and the author have been implementing the required functionalities and use the ClaPD as a testbed for control of multiple sound sources in interactive and participatory contexts. Some of the required functionalities are readily available in the Pure Data community. In the sequel, this chapter refers to these externals and abstractions by their relative path in the pd-CVS repository[76].

6.1.1 Overview of ClaPD

The ClaPD currently contains low-level synthesis and higher-level control blocks, and primitive agents for event generation, which are fine-tuned by hand-clapping statistics. ClaPD can produce expressive, human-like synthetic applause of a single clapper with adjustable hand configuration, or asynchronous or synchronous applause of a clapper population. More than the single clapper mode of ClaPD, the main focus here is the second mode of ClaPD, which is illustrated in the screenshot of the patch Ensemble-GUI in Figure 6-1, where the clapper abstraction is expanded at the lower-right side of the figure. The clapper population is called *audience*, which consists of individual clappers. The clappers do not interact, but listen to a master clapper and adjust their clapping rates accordingly. Although technically possible, the hand-configuration control of the individual clappers of the *audience* is disabled due to the resulting control complexity.

Structure of ClaPD

ClaPD consists of a set of externals, abstractions, and main patches. The low-level synthesis block in ClaPD follows the excitation / resonator paradigm (Peltola et al. 2007). The external objects *noiseq~* and *twopz~* generate and shape the excitation signal, respectively, and *reson~* is the resonator. The parameters of these synthesis blocks are drawn randomly from a triangular distribution that is implemented as an abstraction (*trirand*). This allows a small variation between each clap. The parameters

76 http://pure-data.cvs.sourceforge.net/pure-data/externals/

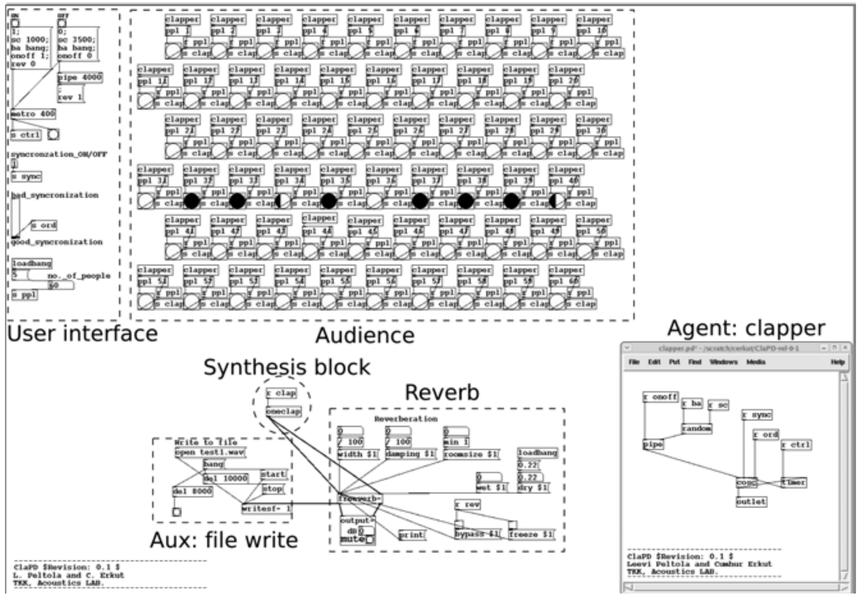


Figure 6–1: The audience patch of ClaPD (rel-0.1). The bangs connected to the clappers flash when they clap. At this instant, six clappers are fully synchronized, and two are catching up.

of the triangular distribution correspond to the hand configuration prototypes, and they are extracted from the analysis of recorded handclaps in an anechoic chamber (ibid). The abstraction *oneclap* accommodates all the other synthesis objects and provides the main synthesis block in the ClaPD; there is only a single synthesis block regardless of the number of clappers.

The abstraction *clapper* is the fundamental control entity in ClaPD; its state is the delta-time until its next clap in milliseconds, and its behavior is to update its own state. The clapping mode of the *audience* (asynchronous or synchronous) is user-controlled by a switch and perceived by the clapper.

In the synchronous mode, the clappers listen to the master clapper, which is a native Pure Data metro object that ticks with a fixed period around 440 ms. This imitates the period doubling of human clappers during synchronization (ibid). When the master claps, a clapper calculates its offset relative to the master and determines its behavior with the help

of the external object *cosc*. This control block is the most complex object in ClaPD; depending on the entrainment parameter of the *audience* and relative offset between the master and a clapper, it enforces the clapper to accelerate / decelerate. Moreover, when the mode is switched back to asynchronous, *cosc* decouples the clapper from the master and accelerates its state until a natural clapping rate – drawn from Tri(220,70) – is achieved. The detailed dynamics of *cosc* operation can be found in the referenced publication (ibid).

The remaining objects within the library are three main patches, the external *ppl* that controls the number of clappers within the *audience* and the abstraction *oneclapper* that generates the control stream in single clapper mode, which is not discussed here. One of the three main patches loads the required objects and provides a run-time interface to the user. The patch *SoloClapper* is a single clapper model, whereas the other two are the models of asynchronous / synchronous applause of an *audience*. Both ensemble models synthesize audio streams, only one of them (*Ensemble–GUI*) provides primitive visualization by flashing widgets as it is shown in Figure 6–1.

6.1.2 Use-cases of ClaPD

In the screenshot of the patch Ensemble–GUI in Figure 6–1, the clapper abstraction is expanded at the lower-right side of the figure. All the patches optionally include artificial reverberation to represent a listening environment via the Pure Data external library *freeverb~* by Olaf Matthes. Another purpose of the reverberation unit is to mask the transients due to the parameter updates of the synthesis object *oneclap*. The parameters of *freeverb~* can be controlled by the user, and its operation can be by-passed with a switch. The output of the reverberation can optionally be written to a file via an auxiliary block. The audio stream fed into *freeverb~* comes from the abstraction *oneclap*; the main synthesis block of the ClaPD. The user can set the hand configuration parameters for the entire *audience* by expanding this abstraction. The synthesis block receives the clapping events from individual clappers of the *audience*.

The clapping events are probed by a GUI widget connected to each clapper, it flashes when the clapper sends a clap event. The maximum number of clappers is fixed at 60, but the user is allowed to set it to a lower value using the interface block. Note that the simple visualization in ClaPD is not the most efficient one: with 60 clappers it uses half of the available CPU power on a Pentium 4 machine, whereas the audio calculations use only about %3. Without visualization, the patch Ensemble–NOGUI can accommodate a much larger *audience*.

By using the interface, the user can start and stop the applause, determine the asynchronous / synchronous mode, set the level of entrainment, and the number of people at run-time. Note that all these operations act on the *audience*, the user has no means to access the clapper states or to influence its behavior.

6.1.3 A Testbed: Problems and Solutions

With a modified version of the clapper abstraction (*myclapper*), each clapper is assigned to a pixel in the 2D grid of the *unauthorized / blinkenlights* external by Yves Degoyon, and flashes this pixel for 100 ms (adjustable) during the corresponding clap. This solution is not only CPU-friendly (about %6 for 60 clappers), it also provides a better visual description of the emerging patterns of synchronization within the *audience*. Moreover, the visualization can be turned on and off: the user interface (UI) sends a visualization flag that is received by each clapper. Therefore currently there is no need for separate main patches with and without the visualization.

Dynamic creation of clappers (constructor)

The *audience* originally has been constructed manually by creating 60 static copies of the clapper object, including their unique ppl number. Below 60 clappers, the number of people in the UI disables all the clappers whose ppl number are higher, but the unneeded clappers still persist on the patch. For more clappers, it required their creation by copying and pasting, editing their ppl number ID, and updating the number of people in the UI. Controlling the number of people just by using the UI, and creating the clappers dynamically have emerged as problems to be solved. There have been several ways to do that: pd-msg, constructor, nqpoly4, dyn~, and the dyn system (Grill 2004). Initially, the constructor abstraction has been the most useful tool for our purposes, but later Erkut and the author facilitated the native Pure Data internal messaging system for more efficient and direct dynamic creation of the clappers.

At the lowest level, the Pure Data system has built-in scripting facilities (ibid). As it is documented in the Pure Data extended version, it is possible to create and control Pure Data objects, modify them, load a patch or create a new one through messages that can be sent from another patch. Dynamic control for the internal events requires no GUI or manual intervention in edit mode.

Based on this lowest level native mechanism, the *constructor* abstraction has been tested for the ClaPD dynamic control system. It is developed by Ben Bogart and Cyrille Henry, and can create a 3D-matrix of abstractions (specified by the creation arguments) and connections among them (given as a list to the second inlet). The modified clapper abstraction was cloned as a 2D-matrix with the same amount of rows and columns as the blinkenlight pixel grid and a wrapper was created to pass the number of people to the creation arguments of the constructor and blinkenlight. Erkut and the author have not yet assigned spatial presence to the clappers, nor experimented with different interconnection strategies, although constructor would provide the required functionalities for these experiments.

The *nqpoly4* external by Steven Pickles (pix), which can take abstractions and link them together to make a polyphonic instrument, proved to be most useful for resource allocation when dynamically creating the audio objects .

Another possibility for internal events management in Pure Data is the *dyn~* external by Thomas Grill. Even though the *dyn~* external looks similar to the pd-msg description, it provides the advantages of better object and interconnection addressing. Finally, the dyn API seems to be the most comprehensive system that was encountered for dynamic object management (ibid).

In the last release of the ClaPD, the final dynamic patch was created by using the internal messaging system of Pure Data. Through a main patch, Erkut and the author distribute the clappers as a matrix, concurrently define the row and column values of the blinkenlights grid, and send them as a creation argument to the *audigen* (audience generator) abstraction object. Each clapper then receives a unique ID, together with a row and a column index to specify its appearance both in a subpatch and

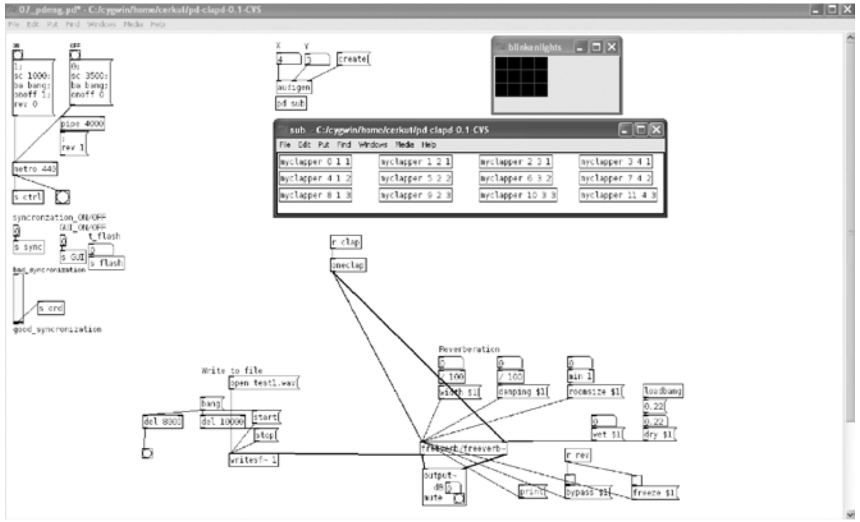


Figure 6–2: Dynamically-generated audience by using the internal messaging system of pd. The clappers in the subpatch are created by audiogen, and they concurrently define the blinkenlights grid.

in the blinkenlights grid; *myclapper* objects receive these values as creation arguments. An example of the resulting subpatch is illustrated in Figure 6–2.

6.1.4 Generalization of the Synthesis Strategy

As in the previous release of the ClaPD, each clapper sends a bang to the main synthesis block (*oneclap*, shown within a dashed circle in Figure 6–1) according to its own timing mechanism. Since the audio and event generators are decoupled, the clapping synthesis block can be replaced with any other sound generation block to generate other collective scenes (e.g.,, a crowd of people yelling, pack of dogs barking, or even some kind of harmonic musical material). The only requirement is to construct an abstraction that can be triggered with a bang. Optionally, a matched control block with a more advanced timing mechanism (e.g., locking to p/q*master, where *p and q* are integers) can be also constructed.

A related question is how to mix multiple synthesis models (e.g., mix a crowd of clapping with some people whistling). After the dynamic creation of the subpatch, it is possible to manually edit any clapper, and reroute its firing to another synthesis block. The steps involved in this operation are as follows:

1. Create another synthesis block; connect its input to a *receive* (for instance, [r whistle]) and its output to the *freeverb~*.
2. Open any of the *myclapper* abstractions in the dynamically-generated subpatch, update the *send* object connected to *cosc* (for instance, [s whistle]).
3. Optionally, insert a p/q ratio to alter the timer operation.
4. Optionally, change the [pixon $1 $2 (message to [pixel $1 $2 127 0 0 (for a red appearance of the corresponding object on the blinkenlights grid.
5. Save this abstraction with a different name (for instance, *mywhistler*).
6. Edit the name of the desired objects in the subpatch.

The created abstractions can then be used as a library; once such a library is available, only steps 1 and 6 would be required. Currently, we are extending the library of different sound generators. Automatization of this procedure is considered as a future work.

An example of mixing multiple synthesis models is illustrated in Figure 6–3, where the dynamically-generated subpatch of 12 clappers have been changed by the operations outlined above to 10 clappers and 2 whistlers.

Resource allocation (nqpoly4)

The separation of the audio and control streams has an obvious advantage when dealing with a high number of objects. To illustrate this advantage, Erkut and the author have conducted a simple experiment. Based on the example of the pd-msg documentation, *n* instances an oscillator and a single clapper (control and audio) have been created, and the CPU load on a P4 machine was measured both using the Pure Data tool and from the command line. The CPU load percentage was $0.2n$ in the first case, and $0.36n$ in the second. This means, it is possible to create at most 500 instances

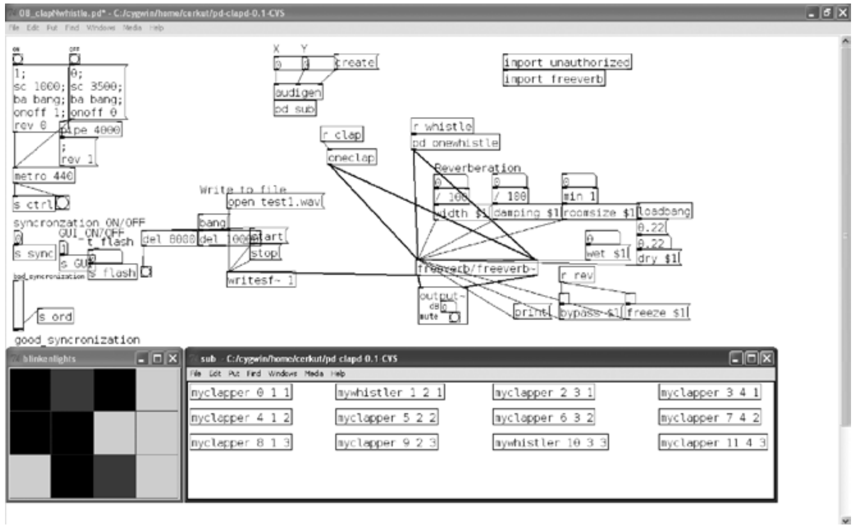


Figure 6–3: An example of mixing multiple synthesis models: 10 clappers and 2 whistlers.

of an oscillator, and 277 instances of the clapper object on that machine, if both audio and control streams are used. On the other hand, in the extreme case of a single audio object in ClaPD (*oneclap*), Erkut and the author created thousands of instances of the control-only clappers, but lost the flexibility of parametric control, and observed some transient effects when multiple clappers excited this single audio object. An optimum number of the audio objects is between these two extremes, and the second outlet of the *nqploy4* that outputs a bang when the audio object has finished playing and is ready to receive another trigger is a great tool for further experiments with generalization and resource allocation. In the case of multiple sound generators (e.g., clap and whistle), *nqploy4* should be utilized per generator.

6.1.5 Conclusion

ClaPD is a platform for controlling multiple clap sound objects in interactive contexts. The control structure in ClaPD currently relies on the one-to-one relation between each clapper and the master clapper; how-

ever, in the future it will rely on the event generation of each clapper, which will be controlled and manipulated by the events of the all other clappers. Each clapper will be thus an agent that listens and interacts with all the others, and the behavior of these agents will be controlled by the events of the other agents (Erkut 2006, Miranda and Biles 2007). With additional synthesis objects, ClaPD will be then a sound performance system, which can be used in various musical art events. Erkut and the author will implement more musical events to be explored by the agents during a performance in the future.

Performing live electronics in real-time constitutes a need for overall control of the performance system. The multi-agent control systems give the possibility to have an accompaniment system during a live performance. The dynamic event generation modules enrich the sound synthesis of the musical performance compared to predefined structures. Generative multi-agent modules are driven by improvisational acts of a human performer; however, their autonomous behavior is a benefit in terms of generative aspect of music events.

The agent-based control system in ClaPD can be used for two different control strategies. Performers can control each agent (clappers) individually or the control function can be on the master clap agent, which has an overall control on the events of the generated clappers. The current ClaPD architecture can be extended into a real-time music synthesis performance tool by mapping sound sources as agents instead on the clapper abstractions. Controlling single agent behavior or the master controller for multi-agent event generation can be turned into organizing sonic relationships over time in a real-time performance.

Considering mapping as the modification of the input according to the event changes in numerical ranges, Joseph Butch Rovan and his colleagues propose a three-layer distinction between mapping strategies: One-to-One, Convergent, or Divergent (Rovan et al. 1997).

- *One-to-One Mapping* : Each independent gestural output is assigned to one musical parameter, usually via a MIDI control message. This is the simplest mapping scheme, but usually the least expressive. It takes direct advantage of the MIDI controller architecture.
- *Divergent Mapping* : One gestural output is used to control more than one simultaneous musical parameter. Al-

though it may initially provide macro-level expressivity control, this approach nevertheless may prove limited when applied alone, as it does not allow access to internal (micro) features of the sound object.

- *Convergent Mapping* : In this case many gestures are coupled to produce one musical parameter. This scheme requires previous experience with the system in order to achieve effective control. Although harder to master, it proves far more expressive than the simpler unity mapping (ibid).

One-to-One mapping is one of the most focused mapping of control strategies in interactive systems. It involves more control parameters for each gesture input and the system gets more complex expressivity control features. Rovan and his colleagues propose convergent mapping as the most musical expressive form from the point of view of instrumental characteristics (ibid). However, the modification of the input and the resulting audio and visual synthesis can be more complex if the mapping system has more dynamic features.

Ali Momeni and Cyrille Henry (2006) propose dynamic independent mapping layers for control of audio and video synthesis, which allow expressive control of musical and visual control structures. Enriching the approach of mapping, they introduce dynamic, independent visual mapping layers. In their work Momeni and Henry introduce classic mapping layer as the modification for matching the outputs of a controller to the inputs of an audio/video synthesizer. Dynamic independent mapping is a generative system whose inputs and outputs are not specific to any particular controller or audio/video synthesizer (ibid). Their mapping strategy allows exploration and expressive control of a high dimensional parameter space using a low dimensional gestural controller. The system takes some input and produces a large number of output parameters. This process can be interpreted as a common goal for any dynamic mapping layer implementation. The multi agent system in the dynamic event generation module that is proposed in this chapter also consists of generating multi output parameter as the result of the agents interaction and the input parameters changes.

The control of multiple sound sources in interactive and participatory contexts will be required by the next-generation applications. The realization of these ideas will be based on the distinction between the events, control, and audio streams. While working in the long term to implement these functionalities in a top-down fashion, Erkut and the author are continuously extending the functionalities of the hand-clapping synthesizer ClaPD in the bottom-up direction. The current solutions were inspired by existing implementations provided by the PD-community, the development of a better visualization strategy, and the dynamic creation of the control objects (clappers).

In the future, the ideas found for the generalization of the synthesis strategy and resource allocation will be fully utilized. Meanwhile, reducing the dependencies to the other externals will be a guiding principle for the research.

The one-to-one relationship of a clapper and the master clapper have been the main subject so far; the research will focus on different interconnection strategies and the assignment of spatial presence to the clappers will be researched. The next step will be switching to extended user control by using Open Sound Control (OSC) protocol. Finally, a functional performance system that demonstrates the research view is yet another important future challenge.

The author presented ClaPD during the Pure Data Convention 2007, in Montreal, Canada.

6.2 Voluntary and Involuntary Use of Bio-Signal Data for the Control of Audio-Visual Synthesis in IBIS

Bio-music is an experimental music form that is based on sensor data obtained from living organisms. In this section, work focuses on electrical bio-signals of humans; on their acquisition, processing and feature extraction, and particularly on their usage in concurrent audio-visual synthesis within an interactive improvisation system.

The performing characteristics of bio-music make bio-signals an important and meaningful source of musical information both in composition and interactive improvisation. Many bio-music controllers have been used as computer interfaces for composition and performances (Knapp and Lusted 1990). Early pioneers, such as Alvin Lucier, Richard Teitelbaum, and David Rosenboom have produced important bio-music works, some of which are direct mappings of the performer's bio-signals onto musical structures (Emmerson 2007). In these works, interaction was rather limited; such works can be regarded as direct sonification of the biofeedback systems.

Rosenboom (1990) has systematically investigated the neurological interaction in order to extract musical features. In his work *On Being Visible,* he has developed a self-organizing, dynamic interactive electronic music system that constructs musical forms as a result of real-time analysis of the EEG parameters of two performers (ibid). In other words, his work provides an excellent example of how to interpret the interaction between two human performers in computational terms.

An interactive bio-music system can also be considered as an ecosystem that situates performers within an environment (Di Scipio 2003). This situation enables another mode of interaction; the *stigmergy,* that is; the indirect interaction between performers via the environment (Borgo 2005). In this interaction mode, one performer modifies the environment and the other responds to the modified environment rather than directly to the actions of the first performer. Such interactive systems can offer alternative interaction design opportunities rather than just a collection of instruments controlled by bio-signals in real-time.

In this section, the research introduces the *Interactive Bio-music Improvisation System (IBIS). IBIS* is an extension of the project members'[77] previous audiovisual bio-music implementations. Performances *Improvisation for Live Bio-Signals (2007)*[78] and *Time Series (2007)* involved the early modules of this system. The core novelty of IBIS lies in its capability to render the pre-recorded bio-signals and to allow the two performers to interact with the computational representation of a *third* one.

Besides its obvious bio-music orientation, IBIS also relates to other

77 IBIS is developed by Koray Tahiroğlu, Hannah Drayson and Cumhur Erkut.

78 Koray Tahiroğlu and Selçuk Artut performed the piece Improvisation for Live Bio-Signals together with Hannah Drayson (live visuals) at the eNTERFACE 07 workshop in Istanbul, Turkey on Wednesday, 10 August 2007.

contemporary themes in computer music, e.g., emotion-aware interaction, audience as partner, and networked and geographically displaced performance.

6.2.1 Bio-Music Instrumentation

This project and previous works by the project members have utilized general purpose biofeedback units which feature a range of different sensor types intended for various therapeutic applications. In addition to collecting signal, these units also amplify and perform analogue to digital conversion, allowing them to be interfaced with a computer. Appropriate software can then analyze the data and produce outputs for patient training or assessment. Typically systems are compatible with these sensor types:

A) Temperature ; most usually attached to the finger.
B) Respiration ; an elasticated harness worn around the chest which measures the motion of the breath via a strain sensor. The subject's rate and depth of breath can be inferred from the data collected.
C) Skin Conductance (Galvanic Skin Response). Skin conductance is a measure of the electrical impedance of the skin measure between two electrodes, most usually worn on the fingers of the non-dominant hand.
D) Blood Volume Pulse (BVP). BVP is recorded with a finger-tip sensor, which uses a process called photoplethysmography to measure blood pressure in the extremities.
E) Electromyogram (EMG). The electromyogram uses electrode applied to the skin to record the electrical potentials which stimulate movement in the underlying muscle.
F) Electrodcardiogram (ECG). This measurement reveals the muscular activity of the heart via its electrical activity.

Biofeedback is a therapy that allows patients to become aware of and regulate what were once considered the involuntary portions of the nervous system controlling such things as heart rate, blood pressure and body temperature. Biofeedback technology uses sensor based systems to 'feed back' information about the physiological function of the user's body, usually in the form of an auditory or visual stimuli, such as a changing musical tone or graphical display. By using these technologies the IBIS system manifests both the voluntary and involuntary activity of the performer's bodies. Through the biofeedback paradigm, it then allows performers to become aware of, and eventually modify, their own involuntary processes.

The software infrastructure for bio-signal acquisition and management during the improvisation uses an implementation of the Bio-Music Platform[79]. This platform is suitable for the communication of a wide range of data types in real time, between multiple machines and software. To achieve this, the Open Sound Control (OSC) protocol is employed, using a multicast server architecture. The Bio-Music Platform includes an OSC specified namespace intended for the flexible management of bio-signal data.

A Nexus-10 and a Nexus-4 physiological monitoring systems[80] make up the hardware signal acquisition setup. Combined, the two units provide a total of 12 channels for data acquisition, six channels suitable for EEG, EMG and ECG, and a further six for BVP, Skin conductance, Respiration and Skin Temperature. Both Nexus units use wireless communication to send sensor data to the manufacturer's API, which performs primary analysis of signals (e.g. artefact removal). A custom script is then used to read this processed data from a constantly updating .bin file within the application directory. It is then de-coded and converted into the OSC namespace, at which time it is sent over the local network via UDP Multicast.

The Bio-Music platform has been chosen in order to improve the real-time computational efficiency of IBIS. Bio-signal data acquired by multiple users can be processed, sent and received via the Bio-Music Platform within a local area network. This setup provides fast and direct

79 The Bio-Music Platform was developed at the eNTERFACE '07 Workshop on Multimodal Interfaces, hosted by Bogazici University, Istanbul. http://www.cmpe.boun.edu.tr/enterface07/

80 Nexus-10 and 4 are designed and manufactured by Mind Media BV. http://www.mindmedia.nl/

connections between diverse bio-signal sources and IBIS for real-time data processing.

Performers' machines connected to the network and receiving multicast data can apply it within a range of software. For this interactive system, Pure Data, Biotrace+[81] and Python have been chosen for further processing, audiovisual synthesis and control.

6.2.2 Visual Synthesis Strategies: Three Circles States

The visual synthesis for the improvisation uses a subsequent version of *Circles (2007)* a bio-signal visualization program created in Pure Data. The program processes raw bio-signals in real-time, applying them as variables in an audiovisual display generated by GEM (Graphical Environment for Multimedia)[82], a library for Pure Data.

Circles was originally developed for a performance at Boğaziçi University entitled *Time Series*; *an uncontrolled experiment (2007)*. During this performance data was collected using a Thought Technology ProComp Unit, developed for therapeutic biofeedback and research processes. This instrument was used by the performers to collect a number of bio-signal data modalities from a volunteer 'subject', which were then converted in real-time into the audiovisual display.

The visual output of the *Circles* Pure Data patch is a 3-dimensional sphere comprised of rotating disks. Each representing one channel of bio-signal data the display is modified by the live bio-signals, which are related to variables such as disc spin direction, size, color, speed and other render and graphical aspects. For example, during *Time Series (2007)*, raw amplitude signals were normalized and their value were calculated as a percentage of 360° and applied to the disc's angle of rotation. In the case of the ECG and Respiration signals, the semi-abstract representation of the data in the on screen activity can be perceived by the viewer as cor-

81 http://www.mindmedia.nl/english/biotrace.php

82 http://gem.puredata.info/

responding to the activity of the organs and systems monitored.

Program inputs can be varied so as to make use of a variety of signals. For *Time Series (2007)* blood volume pulse, temperature, respiration, and electrocardiogram were used. Even with simple mappings of the raw data, the display created by *Circles* makes apparent the relationships between the various instruments, illustrating to the viewer dynamic and relative change, between the sensor modalities and the subjects resulting bodily response.

A more advanced version of the program is employed for the visual synthesis section of the improvised performance, processing incoming live and pre-recorded bio-signal data and applying it as control data for the 3D visualization. Projected within the performance environment, the resulting visual output will contribute to the Stigmergic dynamic between performers and the resulting improvisation.

6.2.3 Audio Synthesis Strategies

Improvisation for Live Bio-Signals (2007)[83] is an improvisation for digital musical instruments controlled by the biological signals of two performers. Each performer wears a set of different bio-sensors which control the instruments during the improvisation. The audio synthesis strategies of IBIS were developed taking the sound modules of this earlier interactive performance system as a basis.

The audio synthesis strategies in IBIS consist of a number of audio modules, which are controlled by parameter mapping modules. The system responds to the bio-signal data received from the IBIS network, analyses the signals and maps them onto a number of musical textures.

Measures of Skin Conductance and an Electrocardiogram (ECG) are combined to control the digital musical instrument that creates dynamic rhythmic patterns. The rhythmic period of heart is mapped by detecting the peak level for each beat.

83 Koray Tahiroğlu and Selçuk Artut performed the piece Improvisation for Live Bio-Signals together with Hannah Drayson (live visuals) at the eNTERFACE 07 workshop in Istanbul, Turkey on Wednesday 10 August 2007.

The changing patterns of the heart's electrical activity also provides more possibilities to create a dynamic pattern with sound synthesis, however, the common sonic representation of heart beat and ECG monitoring sound responses is avoided intentionally. Instead, noise sound sources are combined together with glitchy sound samples in order to create a rhythmic pattern; where the heart beat structure can be still traced in the sonic texture. Periodic changes in the skin conductance sensor and interbeat variability of the performers showed the greatest usable variation for dynamic rhythmic patterns.

Each audio synthesis module in IBIS generates a class of sounds with multiple sonic gradations and variants. The parameter mapping techniques used in the audio synthesis modules rely on the extraction of information from the internal states of the performers and their interaction with the improvisation environment. The two main modules are described here.

The [freqModIBIS~] sound module is based on frequency modulation. Normalized raw data of the respiration rate determines the pitch, modulation points and amplitude values. Throughout various mapping strategies it is possible to generate alternative frequency modulations.

The instrument [polysynthIBIS~] applies parameter changes to the transformations of sampled sound materials, using them as a source for the synthesis of new sound output. In this sound module, the EMG measured raw data range of muscle responses determine the index of the wave-table. The instrument loads sound samples in advance to multiple arrays for use as a voice source for the instrument. The transformation of the sound uses a polyphonic synthesis patch with five different parameters. Pitch, amplitude, duration, the number of sound samples from the wavetable and starting point in milliseconds are all modified by variations in the parameter mapping.

6.2.4 Third State

Each performer's internal state control the audiovisual synthesis in the performance system; live bio-signals representing the real-time internal state are complemented by pre-recorded bio-signal data representing "frozen" internal states.

The real-time data controlling elements of the audiovisual output makes

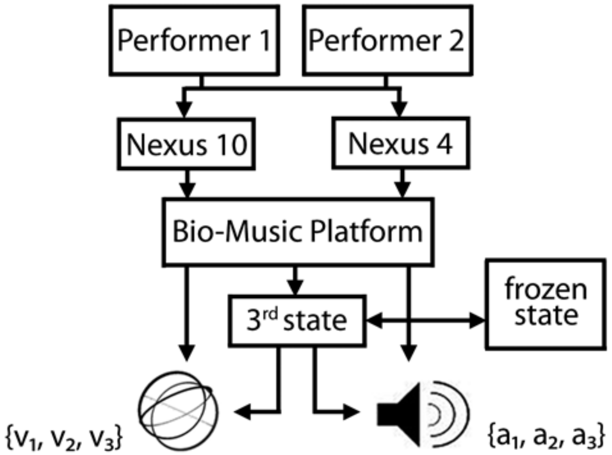


Figure 6–4: Block diagram of IBIS system.

detectable the mainly involuntary responses of the performer's sympathetic autonomic nervous system to the performance environment.

In contrast to the 'somatic' portion of the peripheral nervous system, which receives sensory information and controls skeletal muscle and *voluntary* movements, the autonomic ('self governing') nervous system is concerned with regulation of smooth muscle, cardiac muscle and glands. The sympathetic and parasympathetic autonomic nervous systems sub-divide this system. The sympathetic system is associated with activities that increase the expenditure of energy and levels of arousal, for instance, speeding the heart, raising blood sugar levels, erecting fur or hair, or creating goose bumps. It is the *involuntary* activity of this system that is revealed most prevalently by Skin Conductance, Electrocardiogram, Temperature and to Respiration sensing.

In addition to live physiological data, performers make use of additional pre-recorded data-sets (frozen data), which can be introduced in response to developments during the improvisation. These datasets represent a physiological history of responses to earlier recordings and improvisation activities. Their content draws upon the literature of physiological responses to musical, visual and auditory stimuli, such as the effects of respiratory feedback on emotion and the relationship between skin conductance and auditory stimuli (Philippot et al. 2002, Khalfa et al. 2002).

The interaction of the performance output and environment with the performer's results in feedback effects within the improvisation that are not limited to voluntary acts – such as introducing frozen state data, but also upon what are arguably *involuntary* modifications of the live-data through the responses of the performer's nervous systems. In this sense, the third state can be considered a combination of the voluntary and involuntary use of bio-signal data for the control of audio-visual synthesis open to real-time modification via the channels of biofeedback and performer control.

Improvisatory context

Musical improvisation is a process formed by interaction between musicians, based on an exchange of musical events and gestures, which flow in the moment of playing. Whether a performance where the collaboration is human-with-human or human-with-machine, the common characteristic of this activity is that it requires active participation within a linear time structure.

In an interactive system, a linear communication flow within the system develops an implicit feedback loop between the performer and the system through its audio-visual outputs. The output then influences the performer's decisions about their real-time interactions with the control data structures. Figure 6–4 shows the performance settings and block diagram of IBIS.

There is a closed loop feedback between the performer and an interactive performance system. However, during a real-time bio-music improvisation process another type of feedback loop can also be achieved through the acquisition of bio-signals. Sonic relations during a period of improvisation cause changes in the emotional arousal levels of the performer, and directly alter the bio-signal acquisition. IBIS uses bio-signals as the main source for the improvisation process.

Improvisation is based on exchanging musical events; however, the effects of audiovisual output on the acquisition of bio-signals have more weight on the progress of the improvisation in this system.

In the performance setting, the interaction between the real-time internal states of the performers creates another internal state, the third state, which generates its own channel for the resulting audio-visual outputs through bio-signal data of the frozen state. The indirect and the direct interaction modifies the interactive system output in alternative ways allowing the audience to better discern and identify the sonic and visual characteristics of each individual state in an IBIS performance.

The system can incorporate multiple performers real-time internal states and multiple frozen internal states creating numerous interaction channels for the improvisation process.

6.2.5 Conclusion

In IBIS, the project members have concentrated on the very act of interaction, which is typically under-utilized in bio-music. With a novel design strategy based on an abstract representation of the performers' physiological states (i.e., the third state), the project members have explicated the combination of the voluntary and involuntary use of bio-signal data for the control of audio-visual synthesis in real-time modification via the channels of biofeedback and performer control. The IBIS is thus capable of rendering pre-recorded bio-signals under controlled situations, and allows two performers to interact with the computational representation of a third one in real-time.

One-to-One mapping is the most common input control stream to a single continuous parameter at the output stream. According to Teresa Marrin and Rosalind Picard (1998) this method often yields a clear and useful result, but has limitations. In the *Conductor's Jacket* data-acquisition system in order to develop better mappings between the input gestures and the output audio stream, they collect and analyze data from musicians in real-time performance situations. *Conductor's Jacket* is a wearable array of sensors, which detects and records physiological changes related to muscle tension of the musician. Jacket as an interface is more than a metaphor, allows recording data with the way that the gesture is naturally performed (ibid). Marrin and Picard have been recording data in various events of seven conductors. The frozen states of these conductors have been analyzed and in the second part of their research they applied analyzed frozen states to build user-dependent models for real-time recognition of expressive gestures. These models have been used for mapping conducting gestures onto musical processes such as controlling music through beat, rhythm and tempo detection (Miranda and Wanderley 2006: 205).

Frozen states in IBIS consist of data-acquisition of gestures under various performance situations. Data could be recorded when someone is walking on the beach, traveling on a bus or under any circumstances in various environments. However it can also be recorded when performing actual musical activity and the recorded data of a musician could be a frozen state for a bio-music improvisation session with IBIS, which would build an interesting narrative for a collective musical improvisation.

The capabilities of the IBIS afford a multitude of narratives; exploring these narratives fully is the most important future task. These narratives can be used of in explanatory and conceptual models around the central theme of the living body akin to Emmerson's (2007) work. The project members demonstrated the components of the IBIS within a demo session during the ICMC-08 Conference.

7.

Conclusion

In this dissertation, using a practice-based methodology, the author addressed how new media and its artistic activities can be applied in a practice to explore new possibilities in music making. It is not possible to address all of the interesting directions that offer new possibilities to music making, given the scope of the methodology used, and considering the vastness of the field. Instead, the work has focused on selective aspects, as developed through the author's artistic works. The aim has been to bring together the methodologies of the research based on live-practice of art and new media technologies, and to develop interactive improvisation systems for further experiences of experimental music.

Computer music is interdisciplinary; therefore, there is a close connection with new media. Moreover, there has been a growing interest in new media to position music as a medium to offer new possibilities. The media laboratories in various institutions are conducting research on computer music and sound in general. Researchers and artists should understand the essential technical and artistic foundations of computer music in order to enrich potential research outcomes, and be a part of new musical developments. From this perspective, technical aspects may contribute some freedom in artistic creation and determine the artistic work. However computer art should not be limited to the possibilities a computer can propose. Instead, it should be the artist or researcher who pushes the limits of what a medium can offer.

The practice-based research method of this thesis is an approach used in the practice of art, which combines observations and questions that arising from the use of previously developed interactive systems. These elements of the method are used as anchor points that provide ideas for the further development of research as well as new concepts for artistic performances. The conceptualized theories developed for interactive systems and the performances presented in this dissertation represent a linear time structure of the research process. This structure can also be the criteria for measuring the success of this research based on the live-practice of art. How the conceptual ideas for the interactive system are constructed and what goals were achieved in comparison to the previous phases of the research can provide guidelines for the evaluation criteria. The main research questions of the thesis have been explored through the case studies and discussed in detail at the end of each chapter. Overall, by providing a sequence of examples, together with discussions about their development and implementation in the field through performances, the results of the thesis can be of use to artists and researchers in this field.

The use of improvisation as the mainstream of human musical interaction and the musical sphere of the performances seek to encourage a critical and performative view of the research. The musical activities and performances in this dissertation represent an attempt to introduce computer generated experimental music with its performance-centric assumptions rather than composer-centric ones. Improvisation happens in real-time and thus represents the features of the time it is created and performed unlike in recorded music.

In one way or another music is a part of life. Compared to other art disciplines, music is perhaps the most consumed. It is easy to imagine that in the current age not a single day can pass without one hearing at least one piece of music. Therefore, as a daily activity, listening can be extended into an active model of human musical interaction. Furthermore, it can turn into participation in a creative process. The advanced developments of technology have made it possible for people to be musically creative easily. Participation in the musical experience can turn into a collaborative activity by involving an audience in the process of making music. Involving an audience in the process of music making enhances the pleasure.

Interactive improvisation systems give more possibilities for exploring the improvisation process in the context of human machine interaction. The systems developed by the author during the research for this thesis can be viewed as an alternative to systems designed for experiencing conventional notions of musical structures because they give an opportunity to discover various possibilities for organizing sounds and developing new kinds of music.

The author determined the operation structures, autonomies, and interaction possibilities of the interactive performance systems. However, in a majority of the case studies in the dissertation the music making strategies were developed together with colleagues, guest performers and the audience. Based on the evaluations of the observations given in chapters 4 and 5, it should be clear that there is not only one type of musical instrument design strategy or one type of model for audience participation in music making. It is foreseen that, the advanced developments in computational tools will lead researchers to design alternative opportunities. Furthermore, in the future, as it is proposed in chapter 5, the role of tacit knowledge in performance participation could and should be developed further. Introducing the sonic structure of experimental musical instruments to the audience or guest performers before the actual performance or during an introductory section of the performance is one possible way to do this.

Considering the computational power of the interactive systems during the real-time sound processing, the interactive performance systems depicted in this thesis have worked with reasonably low computational processing systems. In the future, research can also focus on developing these systems with more up-to-date computation tools in terms of real-time sound processing efficiency.

One of the primary contributions of research based on the live-practice of art in general is that for each disciplines involved, the research process resulted in increased awareness of the artistic possibilities. Thus the dissertation has presented new information on interdisciplinary collaboration in the form of strategies developed for creating interactive performance systems, the observations of their performance features and conceptual theories. This will hopefully be useful to artists and as well as researchers in this field.

The research ended up concentrating on human musical interaction and developing interactive improvisation systems for experiencing new ways of making music. The systems developed by the author should not be seen a complete answer to the problems of interactive performance systems in the field. The dissertation proposes alternative approaches towards experiencing experimental music.

There are many opportunities for developing interactive systems. An indefinite amount of interactive performance systems can be developed and compared on how representative their conceptual ideas and applications are in new music making fields.

The physical limitations of traditional musical instruments that have been used together with interactive systems could have also be reduced by using advanced computational techniques. In these kinds of systems, the boundaries of limited communication protocol features between musical instruments and interactive systems, such as MIDI standards can be avoided by using advanced protocol utilities. Furthermore, the sonic palette of traditional instruments can be altered into various directions to experience alternative sonic structures.

By developing extensive models of data integration for musical structures, the musical approach to sonification used in this research process could also be extended. Direct mapping strategies can be broaden by involving interactive sonification mapping strategies, which have been discussed in chapter 3. Interactive systems developed in the future may offer more designs for involving the audience in the music making process. Experimental musical instruments with *easy to use, easy to control* design features can lead audience participation in the act of creation with alternative interactivity opportunities and the process may turn into a novel musical experience. Research will continue exploring the development of new sensing technologies, which will certainly alter the design characteristics of the experimental musical instruments.

In the future, research will almost certainly focus on finding alternative interaction possibilities for experimental music instruments as well as dynamic control structures. In this context, practice-based research methods will also be useful for future developments. Interactive improvisation systems will most likely offer a more interdisciplinary and successful future in making music.

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