

# **Music of the Spheres**

From Prototyping to  
Product Realization

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<b>Abstract</b>  <p>Music of the Spheres allows multiple users of all ages to play and interact simultaneously. The interactive environment consists of a tabletop projection screen and external speakers that present dynamic multimedia when producing music and sounds. Users can interact with the system using different geometric shaped blocks as tangible interfaces.</p> <p>The written part reflects the background research, prototyping and realization outcomes to existing interaction design, prototyping and embodied design paradigms. I interpret the outcomes from a sound designer's point of view. In the Music of the Spheres project I have collaborated with professionals from different design fields. I have had the possibility to learn and share my knowledge with industrial designers, carpenters, glass masters, pedagogues, historians and electronic engineers. In this way, I hope this thesis contributes to the cross-disciplinary design discussion in the field of interactive sound design.</p> <p>In addition, design solutions related to building a low-cost audiovisual multi-touch environment are presented. By familiarizing oneself with this thesis, the reader can expect to gain a good understanding of employing one tested approach for building a functional multi-touch environment.</p>	
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# 1 Introduction

In fall 2008 Executive Manager Maija Meretniemi from Kindergarten Museum Helsinki contacted Aalto University School of Art and Design, Media Lab Head of Sound in New Media program Antti Ikonen. Meretniemi's initial plan was to ask Media Lab sound students to collaborate with the design team of the museum. In December 2009 Antti Ikonen presented Meretniemi's idea to the Sound in New Media 2008 students. The museum wanted to have a sound design for their new permanent exhibition. Ikonen kindly asked me to take the role of a project manager and a sound designer. At the beginning of the project, the core sound design team consisted of Media Lab students Ilkka Olander and Jari Suominen. During the course of time Industrial Design student Daniel Vester and Media Lab student Anna Salmi joined the team.

As a result of the project four sound installations were developed for the museum. The project started in January 2009 and the final version of the last installation was delivered in January 15, 2010. One of the installations, The Music of the Spheres, is Matti Luhtala's, the author's, MA in Sound in New Media Master's Thesis to Aalto University School of Art and Design Media Lab. The Music of the Spheres has been done in collaboration with Daniel Vester and Anna Salmi. In the project I acted as a concept designer, electronics designer, interaction designer, sound designer, technical hardware designer and a product manager. Vester was in charge of physical installation 3D renderings, technical building drawings and materials. Vester also built the supporting construction mainly by himself. Anna Salmi provided the graphics and the visual style for the installation. Salmi also gave her insights on the interaction design as well as on the work with the users.

## 1.1 Origin of Music of the Spheres

I encountered Music of the Spheres term first time at the time when I was doing background research on the pedagogical model of the kindergarten. Music of the Spheres was assimilated to its original idea. In the pedagogical context the concept of Music of the Spheres symbolizes kindergarten as a place for teaching recognition and appreciation of harmony in nature with the help of a radical and a highly spiritual system of abstract-design. Through the idea it was possible

to teach the mathematically generated logic of an underlying creation system [Brosterman, 1997, p. 12]. By a closer examination, the term with its interesting story of origin seemed an appropriate name for our installation.

In December 17, 2009 at the Media Lab Demo Day Andrea Botero Cabrera and Koray Tahiroglu introduced me to the story of the “Music of the Spheres”<sup>1</sup>. At the latter part of the project, I found out that Fröbel had actually borrowed the term from Pythagoras. It was also interesting to find out that I had, without knowing, used Pythagoras’s fundamental musical intervals and mathematical formulas to map my sounds and to control dynamic visuals programmatically.

The roots of the sound theory of Music of the Spheres are located in Greek. Mathematician and astronomer Pythagoras is frequently credited for creating the concept. The story behind the Music of the Spheres takes place in sixth century BC. According to a myth, Pythagoras experienced an eureka moment when hearing the noise produced by hammers of different weights bashing metal anvils. A hammer with a certain weight would produce a frequency twice as long as a hammer half the mass of the first. In musical terms sound is an octave lower. [Young, 2003, p. 74]

Pythagoras continued experimenting with a stretched string attached to a monochord. Dividing the string halfway in a ratio 1:2, it sounds a perfect octave. Moving the string in a ratio 3:2, the two segments sound together in a perfect fifth and so on. Western scaling system, used still today has its Pythagorean roots. Scientific historian Thomas Levenson has stated, “From the sounds of a monochord, The Pythagoreans deduced a universe” [Young, 2003, p. 72]. By his statement Levenson refers to the Pythagoras Music of the Spheres concept.

## 1.2 Personal motivation

I have played with traditional step and time line sequencers from early 90’s. Somehow they raised great expectations in me but at the end left me feeling slightly disappointed. Especially, I experienced timeline-controlled tools as limiting my creativity and freedom. Based on my experiences, I wrote the following sentence in a curriculum vita in year 2005.

*“-- I would like to create new kinds of sound design tools for audiovisual artists. --”*

---

<sup>1</sup> Personal discussion, 17 December, 2009 with Andrea Botero Cabrera and Koray Tahiroglu

This idea sparked me to apply to Media Lab. Through my previous education; I had gained professional experience in traditional media sound projects, such as composing music and designing sounds for films and animations. Nevertheless, I felt novice designing and creating interactive media content. When I started studying at the Media Lab I wanted to adopt the skills for employing new media tools. In particular, my aim was to improve my experience in programming sounds and visuals and to apply those skills to prototyping techniques and theories.

At the time the Kindergarten project was introduced, my thesis idea was bubbling under. I was pondering an idea for creating innovative audiovisual tools. I was also very interested in physical computing and tangible interaction possibilities. My motivation working with children originates from a personal history of designing and creating educational music and sound related new media projects for them. Productions have offered me great insights and possibilities to enhance my problem solving skills. I think creating content for such a demanding target group is always a challenge. In addition to being interested in designing for children I have a curiosity for designing interactive content to public spaces. Museum environments have given me enormous pleasure to work with. In these projects I have had a chance to experiment and search for my designer identity.

In the first kick-off meeting at the Kindergarten museum I was introduced to Friedrich Fröbel's educational ideas and his life long educational work, Fröbel's blocks. Those simple blocks made an impact on me. The over 200-year old toy had amused children and tickled their endless imagination in various play situations over centuries. Fröbel's educational ideas are explained in more detail in chapter 2.1.1.



## 2 Thesis goals

In this thesis I focus on the Music of the Spheres project. I use the abbreviation MOTS when referring to the production and installation. The thesis consists of two parts, the production part of the MOTS and the written thesis. The production consists of designing and realizing the installation as well as managing the project. In the written part I go through the background research, conducted user studies, techniques employed in working with users, key questions and the description of the tangible user interface prototype development process. Finally the realization of the MOTS concept is outlined and its implementation phases are explained.

I reflect the background research, prototyping and realization outcomes to existing interaction design, prototyping and embodied design paradigms. I see sound design as my strongest design skill. For this reason, I have chosen to interpret the outcomes from a sound designer's point of view. In the MOTS project I have collaborated with professionals from different design fields. I have had the possibility to learn and share my knowledge with industrial designers, carpenters, glass masters, pedagogues, historians and electronic engineers. In this way, I hope this thesis contributes to the cross-disciplinary design discussion in the field of interactive sound design.

The installation is targeted mainly for children in a specific museum environment. I present my findings primarily in the light of designing for children's museum context but to a certain extent argue that they can be extended to the interactive sound design field also in a wider perspective. The thesis project has been my learning experience to develop an understanding of the hands-on prototyping techniques as well as to study and develop my personal user-centered design skills. Motivation for this is the developing of my academic research expertise and a hope of contributing to the currently active interactive prototyping and interaction design discussion in the fields of interactive sound design and art.

Finally, design solutions related to building a low-cost audiovisual multi-touch environment are presented. Our solution is not the only proper alternative for building a multi-touch environment. However, by familiarizing oneself with this thesis, the reader can expect to gain a good understanding of employing one tested approach for building a functional multi-touch environment.

## 2.1 Starting point for the design

Fröbel's blocks and his educational ideas have been the primary source of my inspiration. In addition, Wassily Kandinsky's Color and Shape theory has influenced the design of MOTS. During the project I have also been inspired of many works created by digital media artists and researchers.

An idea of turning the old toy to a new updated digital version was introduced as part of the installation concept proposals to the museum. Starting point for creating the MOTS concept was to re-design the original Fröbel's blocks into the digital medium, to an expressive and dynamic audiovisual interactive environment. At the beginning of the project I envisioned developing a playful interaction system with six degrees of freedom. The system would allow users to play and interact with the interactive blocks. They would continuously send computed information of their distance to other blocks, moving direction, acceleration, rotation, angle, leaning side and most importantly height. The collected data would be turned into rich multimedia content.

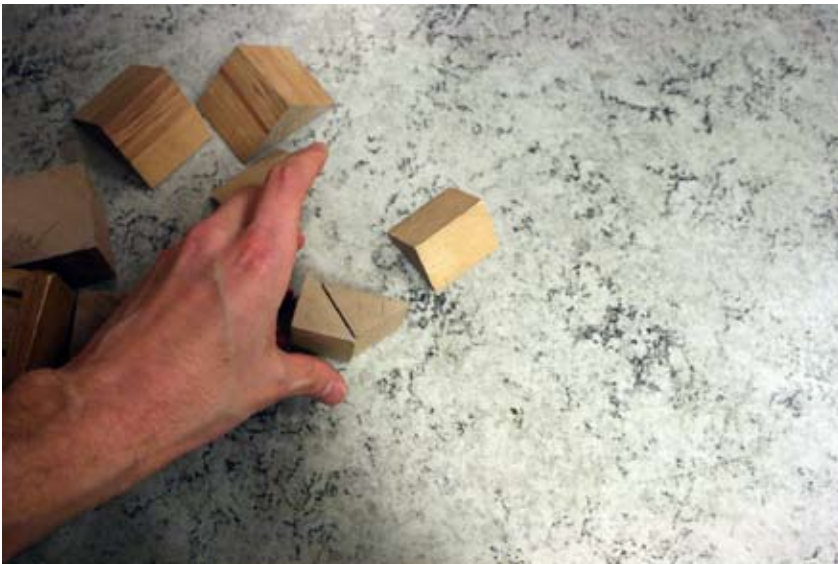
The concept of the MOTS was presented to the museum-working group using a concept video made by reactIVision developers team describing the system and the user experience. The video was proof of concept for the museum design team and they decided to support the idea of the MOTS.



**Figure 1. Getting inspired: Reactable software.**

### **2.1.1 Fröbel's blocks**

The basis of the MOTS lays in Friedrich Fröbel's educational ideas [Brosterman, 1997, p. 22]. Fröbel [1782 – 1852] was a German pedagogue and a philosopher. He became known as the inventor of the kindergarten and as the designer of the educational play materials called Fröbel's gifts, which included a series of geometric building and pattern activity blocks. Original blocks are made of wood and they come in different sizes [see Figure 2]. The blocks are not only used for playing but for introducing the children to the interesting world of geometrics. In Fröbel's times children constructed pre-drawn pattern designs on papers. These exercises were thought to teach recognition of harmony in nature and to teach how the world is constructed in the mathematically generated logic [Brosterman, 1997, p. 12].



**Figure 2. Benchmarking: Original Fröbel's blocks.**

Fröbel's initial idea was to create a concept that would support a child's learning in different developmental phases. Kindergarten offered a suitable environment for children. Their activities such as play were supported with a wide range of educational tools. Activities in the kindergarten included singing, dancing and gardening and self-directed play with the Fröbel's gifts. Fröbel also introduced the

concept of “free work” and established the “game” as the typical form that life took in childhood, and he also emphasized the game’s educational worth.

### ***2.1.2 Color and shape theory***

In summer 2009 I visited Germany, Dessau. During the stay I visited the Bauhaus school and the Bauhaus exhibition. The time for the visit was favorable because of the 90-years anniversary of the Bauhaus school. The Bauhaus ideology enthused me. Walter Gropius, the first director of the Bauhaus school, had a vision of unifying the visual arts, sculpture and architecture with performing arts of theater, dance and music [Bauhaus-Archiv Berlin 2009, p. 16]. The Bauhaus school curriculum allowed an artist to seek one’s artistic identity over various art forms during studies. The visit to the exhibition was exciting and in a way it relieved me. Since then I have allowed myself to think about sound in a wider perspective and I have tried not to lock myself down into one expression channel. Nowadays, I try to expand my design thinking towards other interesting forms of interactive media and think of new ways of using sound.

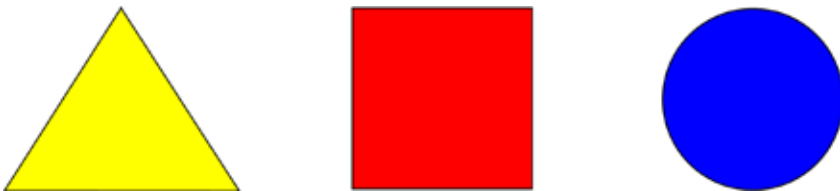
The Bauhaus exhibition showed a connection between Fröbel’s ideology and the Bauhaus school. Probably the most referred connection between Fröbel and Bauhaus is Wassily Kandinsky, a Russian painter, and art theorist (1866 – 13 December 1944). Fröbel’s ideas and kindergarten movement had quickly spread across Europe, America and Japan. Fröbel’s gifts and occupations had gained reputation and became a pervasive “visual language” of elementary forms and basic colors. Kandinsky was educated in the period of the greatest influence of the kindergarten. It is known that Kandinsky as well as Frank Lloyd Wright and Le Corbusier were educated according to Fröbel’s methods.

Kandinsky lectured on the topics of art and architecture at the Bauhaus school from 1922 until in 1933. Kandinsky has once stated that the Fröbel’s blocks affected his theoretical thinking and work as an artist. I see that Kandinsky’s art works, especially from his period of point and line technique, can be seen as a trace of the kindergarten impact [see Figure 3].



**Figure 3. Wassily Kandinsky: Composition VIII.**

Kandinsky proposed his Color and Shape theory in 1923. Kandinsky's idea was to create a universal correspondence between the three elementary shapes and the three primary colors (see Figure 4). According to the theory, each shape and color has its unique meaning and character. The dynamic triangle is inherently yellow, the static square is intrinsically red and the serene circle is naturally blue (Lupton, 1991, p. 3). These three forms and colors served as my primary source of inspiration for creating visual and sound form language for the MOTS



**Figure 4. Color and Shape theory: three basic shapes and colors.**

### 3 Fröbel's blocks as a basis for interaction design

Interaction could be defined as the exchange of information between two or more active participants or users. A party of the interaction can be another human that we communicate with or a computer application that we utilize. An example of an interactive system could be an automated payment system or an audio edit program. The writer and game designer Chris Crawford describes interaction as “an iterative process of listening, thinking, and speaking between two or more actors” [Noble, 2009, p. 5]. From the interaction design perspective, I see Fröbel's blocks as an interaction tool that enables communication among users as Crawford suggests.

Mitchel Resnick, the director of the Lifelong Kindergarten group at the MIT



Media Lab, has divided learning through playing into five phases (see Figure 5). Playing situation with the blocks enables children to imagine, create, play, share and reflect. In my mind Crawford's three key concepts of interaction include the iterative five steps of play presented by Resnick. The playing situation requires interaction feedback loop to encourage children to start playing freely.

**Figure 5. Mitchel Resnick: kindergarten approach to learning.**

I argue that these two principles extend to any interaction tool design. Undeniably the Fröbel's blocks offer a good starting point for designing new kinds of audiovisual interaction devices. For me the most important interaction design question during the MOTS project has been, how can new technologies be integrated to design, free expression and play. In the following subchapters I go through some interaction paradigms and reflect on their relevance from the point of view of the project. Last, I introduce my sources of inspiration for designing the MOTS.

## 3.1 Traditional interaction

Computers and interaction devices have changed only little in the last 60 years. Douglas Engelbart changed the way computers worked, from specialized machinery that only a trained scientist could use, to a user-friendly tool that almost anyone can utilize. Engelbart introduced his first mouse prototype in 1963. Engelbart's idea of inspiring people and giving them freedom to realize their dreams still carries on. [Engelbart Institute, 2008]

The fundamental use properties of personal computers have changed dramatically over the past thirty years. The device itself, often still a square shaped box standing on the table has changed very little. Sitting by the computer ties us out of our natural environment. Finger clickable mouse and two-hand-operated keyboard constrains creativity and freedom of interaction in many ways. Undoubtedly, traditional interaction tools get the job done but not always with the desired results.

Preserving interaction freedom of the Fröbel's blocks was essential when choosing and developing an interaction platform for the MOTS. In my opinion clickable mouse, keyboard and the desktop metaphor with graphical interfaces did not support the MOTS design goals. Interaction possibilities provided by the mouse and its frustrating constraints affect the human-computer interaction. Furthermore, the mouse influences on how people communicate with each other even in a more holistic sense. Eminently, the mouse interaction offers only a few possibilities to combine digital and physical world artifacts. One of the problems of mouse interaction is the number of users on a screen that it limits. The traditional mouse interaction is meant only for single user operation of machines.

The teacher and new media artist Dan O'Sullivan focuses on physical computing topics in his work as an artist. I think O'Sullivan successfully describes how traditional mouse-operated computer perceives the user (see figure 6).



**Figure 6. Dan O’Sullivan: How computer sees us.**

O’Sullivan points out, how the personal computer user has a relatively big finger compared to the rest of the body parts. It is noteworthy that the strange looking creature does not have a mouth, hands or the rest of the body [Sullivan,2004, p. xviii]. Certainly the image is a caricature but it is illustrative of the traditional means of interacting with computers. In my mind the creature should not represent the potential MOTS user.

### 3.2 Attempts towards seamless interaction

Ubiquitous computing seeks an answer to the question of how to provide better interaction between humans and technology. Mark Weiser is said to be the father of ubiquitous computing. He has envisioned ubiquitous computing as a technology embedded in the physical environment, providing useful services without disturbing the natural flow of human activities. [Oulasvirta et al, 2003, p. 2]

At early 1990’s Weiser worked at the Xerox’s Palo Alto Research Center [PARC]. He proposed a research program called “Ubiquitous Computing”. Weiser saw that the development and diffusion of general-purpose computers, and in particular PC’s had resulted in a focus of computers rather than of serving the users needs and tasks that s/he needed to accomplish. The critical movement was to see ubiquitous computing contextual based. The traditional interactive PC computers focuses on what the user does. Ubiquitous Computing research instead seeks to find ways of how the system could explore who the user is, when and where they are acting on and so on. [Ourish, 2001, p. 28, p. 39]



Mark Weiser and his colleagues were also behind one of the first tangible interface concepts. Digital Desk was developed in the early 90's. The Digital Desk augmented the space with unconventional components allowing the user to interact with physical objects and electronic documents. Since Weiser's Digital Desk project, the tangible interaction has grown into an emerging field of human-computer interaction that links the digital and the physical worlds by embedding computation in physical artifacts and environments. However, not much has changed from Weiser's attempts to make a difference to the existing interaction paradigms between humans and technology. I think that we still use modern personal computers and generalized interaction tools in a too limited way.

### ***3.2.1 Physical computing and prototyping***

Physical computing prototyping has gained reputation over the last years, in particular, amongst experimental sound and visual interaction fields. I see this movement as an extension to Weiser's ubiquitous computing ideas from the 1990's. However, nowadays technology is a lot cheaper, technology is easier to access and more information available for developing and building complex devices. Modern time offers good opportunities for designers to seek more proper ways for interaction. Rapid prototyping tools such as Arduino, Basic Stamp and Make Kit platforms allows developers to create ubiquitous computing prototypes relatively easily. Probably Arduino is nowadays the most common because of its relatively easy programming syntax and widely active open source sharing community. Arduino offers an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive design artifacts [Arduino, 2010]. With the help of these prototyping tools, designers and artists can create their own physical interaction controllers for performance and every day gadgets. Often these concepts and prototypes seek an answer to the question, how to improve the interaction between human and a computer.

### 3.3 Sources of inspiration for designing interaction

As my source of inspiration for the MOTS interaction design I present two works, Tangible Geospace and Perceptive Pixel's multi-touch interfaces. To me they represent works that have significantly contributed to the research discussion in their respective fields. They share an idea of searching new ways of human-computer interaction and fading technology to the background. These two criteria were also the driving ideas for me in the MOTS production. In addition, I wanted to promote the possibility for users to freely and intuitively explore the system.

#### ***3.3.1 Tangible interaction***

Hiroshi Ishii and Brygg Ullmer from the MIT Media Laboratory, Tangible Media Group have researched ubiquitous environments, tangible interaction and multi-user interaction in the "Tangible Bits" research project. Tangible Geospace is part of their work and it seeks to find new ways of multi-user and tangible interaction. The starting point for Ishii's and Ullmer's research is an understanding that people are almost constantly "wired" so that they can be here [physical space] and there [cyberspace] simultaneously.

Tangible Geospace uses physical models of landmarks of MIT's campus area. These objects are MIT's Great Dome and the Media Lab building. Physical objects, also called phicons, allow the user to manipulate 2D and 3D graphical maps of the MIT campus (see figure 7). By grasping a small physical model of the Great Dome and placing it onto the desk's surface, a two-dimensional map of MIT campus appears on the desk surface beneath the object, with the location of the Dome on the map bound to the physical location of the Dome phicon (Ishii et al, 1997, p. 5).



**Figure 7. Tangible Geospace: Scaling and Rotation Device with embedded mechanical constraints.**

### **3.3.2 Multi-touch interaction**

Existing multi-touch research has opened new possibilities for multi-user interaction design and advanced computer power usage. Academic research groups and corporate companies have studied multi-user environments and their advantages. Recently open source communities have also developed their versions of multi-touch environments.

Jeff Hans is the inventor of Perceptive Pixel's graphical multi-touch interfaces. Hans is also a consulting research scientist for NYU's Department of Computer Science. Hans introduced his multi-touch environment in 1996. Hans public reputation gained the same year when he presented his findings and multi-touch prototype in TED Talk [Ted, 2006]. His presentation handled cheap, scalable multi-touch and pressure-sensitive computer screen interface that enabled multi-user interaction and point-and-click interaction [see figure 8].



**Figure 8. Jeff Hans: Perspective Pixel's multi-touch wall.**

At the time of writing this thesis, Apple's iPhone, iPad, iPod, Microsoft Surface and a great number of other new touch-based interfaces exist. In addition to the recent developments in the commercial world multi-touch interaction has established itself as an area of research in the academia. The fundamentals of designing and structuring interactions using gestures might not change. Most of the current multi-touch systems use gestures that have been commonly agreed upon. The essentials cover two-finger expanding or contracting, turning two fingers to rotate and tapping to select.

## 4 Background research

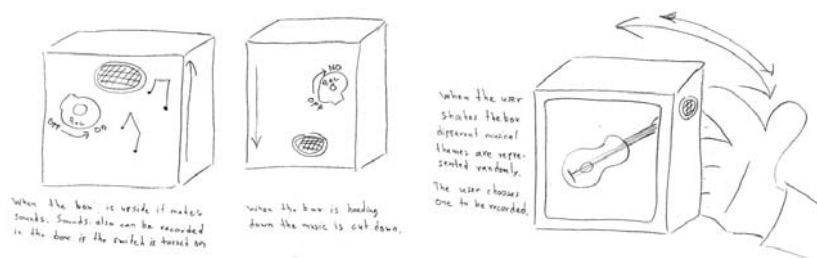
The MOTS project started in January 2009. From January to May 2009 research and design phase was in progress. The focus at that time was on studying users and exploring interactive prototyping technologies. Most of the design and research work was done in Interactive prototyping 2009 and Design Research course modules held at the Aalto University School of Art and Design, Units of Industrial Design and Media Lab.

The MOTS interface prototype development consists of three design phases. 1. Sketching ideas. 2. Observing children. 3. Tune Your Mute Workshop – Getting inspired through working with peers. These protocols will be described in more detail in the following paragraphs. A prototype for the interface was created based on the collected feedback. Description of the process and outcomes are explained in chapter 5.

Multi-touch table, technology and their possibilities were not introduced during the courses and were not part of the tangible interface prototyping. However, potential for combining tangible interfaces and a multi-touch table was discussed during the course modules.

### 4.1 Sketching ideas

In the beginning of the project 25 ideas were sketched on paper. Those included different variations of the MOTS instrument. From all these five of the most interesting ones were placed on wall. Through personal discussions with the course lecturer Professor Turkka Keinonen and my student peers the most feasible idea was chosen for the future development (see Figure 9).



**Figure 9. Sketching ideas: tilting and shaking the box.**

## 4.2 Observing children

Observation situation was organized in March 2009. The aim was to achieve an understanding from the special target group, its needs, behaviors and activities. The observation was organized in a living room environment with three children of ages 5, 6 and 7 years old. The observations lasted for one and a half hours. At first, Fröbel's blocks of two sizes were introduced to the children. Second, the blocks were offered for free playing for them. During the play the observer asked questions from the children. For example "what would you like to add to this play now" and "please, explain what are you doing with the blocks next". Below is a list of what the children said and did.

### **Children said:**

- It is fun to have many sizes and shapes of blocks.
- I would like to have more colors.
- I would like to paint.
- I am now making a wardrobe for the king's underwear.

### **Children did:**

- Singing word game.
- Misusing the blocks.

### **4.2.1 Observation outcomes**

The first observation session revealed that children's way of playing with the blocks extends to three dimensions. Constructions tend to develop to the horizontal and vertical directions. For example at the beginning of the play the children built shapes very systematically on the ground level. As the play went on, constructions began to rise in height. After 20 minutes of playing, children started to reinvent and develop new ways of using the blocks. Instead of piling the blocks systematically, children placed them in a more random order and layered them more prone [see Figure 10].



**Figure 10. Observing children: misusing the blocks.**

From a technical point of view this kind of interaction behavior sets a challenge on how the blocks can communicate with each other when they are placed chaotically and layered randomly. Simple on-off interaction mechanisms are easy to develop. The complexity level increases when the aim is to develop advanced interactions. The studies also revealed that the children's way of interacting is not very detailed and pedantic. This information seems useful for designing clear interaction feedback systems and tangible interface blocks.

## 4.3 Tune Your Mute workshop

The Tune You Mute workshop was organized in April 2009 for getting an understanding of the future ways for sound manipulation and music creation. The primary goal was to gather information for designing an aesthetically fun and tempting physical interface as well as for finding new music instrument functionality. The secondary goal was to create new ways of interaction between multiple users through silent collaboration. The outcomes were expected to give inspiration to the MOTS concept design and to shed light on how the design peers work.

### **Tune Your Mute workshop keywords**

- Conversational design practice.
- Collaborative inquiry.
- Evoking strange and unfamiliar design ideas.

#### **4.3.1 Framework**

Tune Your Mute is an adaptation from the Silent Game practice [Habrahen, 1987]. Silent game is a design game practice that enables direct involvement of designers shaping future design artifacts. The practice is more commonly used by architects in early design phases when sketching new ideas. Two players play the game. One party arranges few objects on a board and the other party continues the arrangement by adding and tries to be true to the patterns implied by what the first player did. The players are not allowed to talk. One player creates at a time. Other two interpret happenings and write notes of the game.

The Tune Your Mute workshop included four persons. Three designers from different backgrounds were invited to the workshop [a composer & sound designer, a system architect and an industrial designer]. This kind of a group of professionals was gathered in a wish to get a cross-disciplinary point of view on the topic. The fourth person documented the event with a video camera and an audio recorder. The actual playtime lasted for one hour. After the play short discussion followed.

At the beginning of the session the workshop leader introduced the workshop idea to the participants. The Tune Your Mute game players were asked to design and create a music instrument for children. The only given advice was that the instrument needs an interface and it should make sounds. After the given guidelines, different sound props were given to the participators. Props included some sound instruments, Foley materials, Lego blocks, clay, papers and pens.

#### **4.3.2 Tune Your Mute outcomes**

Tune Your Mute workshop was an experiment after the observation of the children. Adaptation from the silent game practice offered a good possibility to test a cross-disciplinary design practice. Also the use of a silent environment in

the field of sound and music instrument design was consciously planned in order to gain surprising and inspiring ideas.

Tune Your Mute workshop offered interesting results. My expression is that speechless environment affected to design decisions. It set participants free from descriptive words, which might guide a designer towards familiar and safe design decisions. At first participants found out the given task demanding. Two of the participants stated in their written reports that they did not know where to start. I believe this is because of unfamiliar communication situation. Sound designer and industrial designer participants expressed their thoughts as following.

### ***Sound Designer***

*“--It is getting complex, should try to expand sound possibilities..--”*

*“--Construction base, no sound possibilities, sound is imprisoned, no way of playing.--”*

### ***Industrial Designer***

*“--Not easy, what is expected?--”*

*“--Could not see what is happening.--”*

*“--Limited choices.--”*

As the session went on, the participants started to find collective understanding. The props worked as a communication channel between members. Slowly the participants started to explore with shapes and interaction possibilities. One of the participants expressed design progress as following.

### ***Media designer and system architect***

*“--Construction has stability problem -> Participant gave up -> I will fix it -> next one replicates and improves it.--”*

During the workshop, participants focused on creating interaction rules rather than sounds. I think participants professional backgrounds affected to design decisions and chosen props and design decisions. Mainly the used props consisted of tangible and formable objects such as Lego blocks and modeling wax. Offered music instruments were not used so actively. Perhaps the participants might felt embarrassment and refused to play with sound instruments.

From the point of view of music instrument interaction building the workshop offered interesting results. Especially, when examining characteristics of the interaction and interface proposals in the created prototype artifacts [see figures 11 and 12].





**Figure 11. Tune Your Mute workshop outcomes: instrument and explanations of interaction methods.**



**Figure 12. Tune Your Mute workshop outcomes: individual component – interface and sound signal flow.**

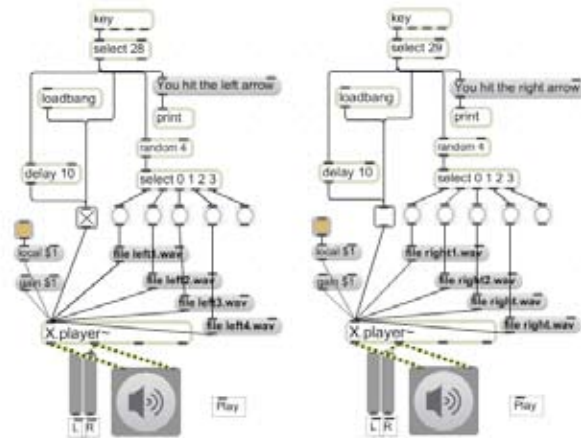
On the other hand, the workshop did not offer too much information for sound aesthetic design. I believe that, the Tune Your Mute practice could also be used for designing creative and new kinds of sounds. To achieve different results, I need to rethink used sound props in more detail. Perhaps designing personal Tune Your Mute vocabulary could be experienced. It also worth to consider arranging the workshop with more sound oriented people and underline the need for creating sound interface and audible output.

## 4.4 Wizard of OZ workshop

Wizard of OZ workshop was organized at kindergarten Auringonkukka in Viikki in early May 2009. The aim was to achieve understanding of children playing behavior in larger groups, attitude towards original Fröbel's blocks and test developed demo concept with children. 12 children participated in the workshop. Additionally two persons organized the workshop. Other led the workshop and other worked as a Wizard. 12 children were divided in to four groups. Tested persons were 5 to 7 year old. Workshop lasted three hours.

### **4.4.1 Framework**

In the workshop the Wizard of OZ methodology was used. The Wizard triggered music and sounds according how children played and organized the blocks in different shapes and patterns. In the testing setting Wizard wasn't hidden behind curtain but he was feign to write with his computer. Assumption was that adding sounds would awaken children's imagination and affect their immersion state. The Wizard operated sounds with custom-made MaxMsp audio patches (see Figure 13). The patch sounds were divided in four themes: up, down, left and right. Used sounds were indexed to computer's corresponding arrow buttons.



**Figure 13. Custom Wizard of Oz patch: Sound themes for the left and right arrow.**

The Wizard’s task was to follow playing situation and deploy triggering sound related to children’s playing direction. When an arrow button was triggered, the sampler chose randomly one of the four sounds. The sounds consisted of few seconds lasting sound effects and one background music. All in all, the patch contained seventeen sounds. The sounds for the each theme were chosen based on their pitch, note progression, overall tonality or mood. For example, when the direction of building with the blocks was up, the Wizard favored up-theme sounds (see Table 1).

Sound Theme – Up	Sound Description
Sample 1	Digital trophy sound (like glittering stars on sky)
Sample 2	Voice over artist saying hip hip heh!
Sample 3	Up progressing glockenspiel and flute melody
Sample 4	Rhythmic synthetic bass sound (goofy whaka whaka filter)

**Table 1. Wizard of OZ sound patch: sound descriptions of up-sound theme.**

The workshop situation contained pre and post inquiries. Lutz Gegner, a student from Taik Industrial Design department had scoped testing method for the Interactive prototyping course groups. In this way Gegner collected data from the user tests for his MA thesis research part. The Wizard of OZ workshop inquiry part was an adaptation of Gegner's proposed design methodology. The study structure was same as in Gegner's proposed testing situation. Original idea of the pre and post questionnaires were simplified. Only 7 questions were asked in each round. This was done with two polar questions and asking children to place happy face stickers on paper.

### **Workshop phases**

1. Present the user scenario. [see appendix 1]
2. Hand the Pre-Use questionnaire to the users. [see appendix 2]
3. Let the users interact with the product.
4. Hand the Post-use questionnaire to the users.

### ***4.4.2 Wizard of OZ outcomes***

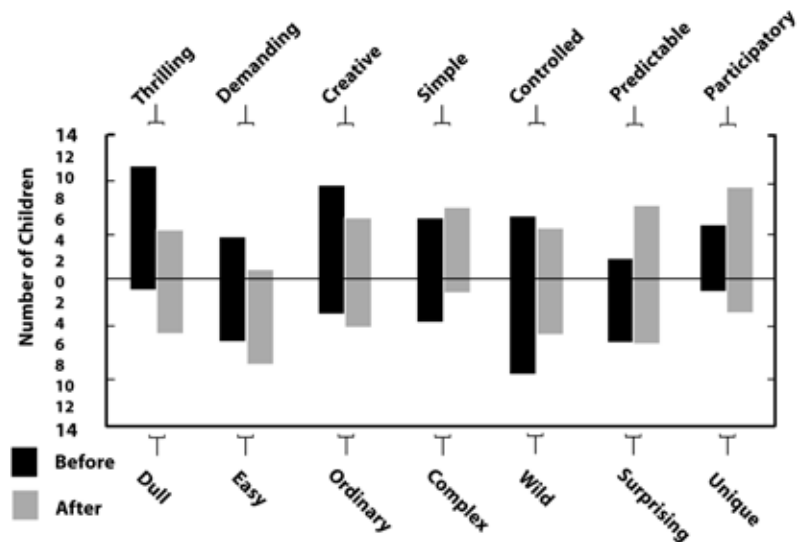
My original idea was to test an interactive prototype with children. Testing situation needed to be altered due to the MOTS production design phase and special target group. At the time of the arranged workshop, I did not have robust working version of the prototype. Instead the original Fröbel's blocks were used. Wizard of OZ method was chosen to simulate lack of real-time interaction. The setting was reliable and children accepted an idea that the blocks are interactive and channel for the sounds. During the workshop any of the children did not doubt whether the OZ was causing the sounds.

Children found out the sounds interesting and stimulating experience. During the workshop few children started to imitate particular sounds by mouth. This kind of feedback information could be used when designing final sounds. For example by doing a detailed study of similar tones and harmonic characters that the children felt amusing. According to director of Auringonkukka one boy was really exited of the sounds. The boy had mentioned afterwards to the director, that he felt like being in a game. Further inquiry proved that he liked the sounds that made "bombing" effect.

Randomly played sounds caused interesting confusion among children. This happened when children expected a particular sound to output but the feedback was unexpected. At first one could think that random interaction could lead to frustration. However, children were able to disregard the situation and continue searching the meaning behind the play. I believe this happened because children perhaps did not have a ready made mental model for unseen tested playing environment. This kind of knowledge sets a good ground for unforeseen digital interactive installation design.

The Wizard of OZ user study session revealed what kinds of qualifications are expected from the tangible instrument interface targeted for children. During the testing I found out that physical interface needs to be robust. This was demonstrated during the Wizard of Oz testing. We tested three groups. Four children were in an each group. First and third group focused on to play constructively. The second group was more unmanageable. In the group were two twin boys. They practically throw Fröbel's blocks against walls, each other and other participants as well. It's children behavior and nature to play in very rough manner. Children run, jump and rave during playing. Creating a well-designed structure and choosing right kind of building materials and are must to make the system to uphold. In addition, secure restrictions need to be fulfilled to protect children.

During the workshop pre and post questions were asked from the children. The goal was to get understanding of expectations of the pre and post play situation. Individual answers were counted and collected (see Table 2).



**Table 2. Wizard of OZ enquiry: before and after answers.**

The table is divided in two axes. Number of the children is presented on the vertical axis. Seven polarized question pairs are described on the horizontal axis. The black and grey colored bars represent results of pre and post questions. The original question paper had seven answer options to choose. Almost all the answers were end of the polarized question parallel. For this reason only the most extreme end answers are chosen for evaluating.

Results prove that the playing situation was expected to be more thrilling than it was. Children found out the play easier than thought in advance and the play did not offer so much freedom or creativity than thought in advance. The word pair Unique-Participatory is interesting. It shows that the children expected the play to be more single person situation. To me the result tells that the blocks, music and the whole context supported sharing and collaborative playing situation.

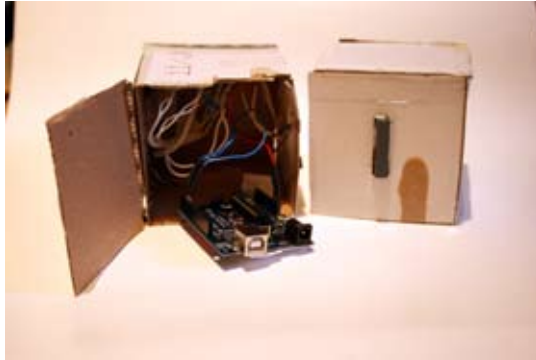
Interpreting children's answers it is likely that the play situation did not offer too much new ways of playing. Anyhow, this was expected result. Presented user scenario was created future playing blocks in mind. Visual style and story behind it probably made the children to believe that there is more to expect. The collected results are valuable. They encourage me to develop the MOTS concept further. Children's answers also remind that the content needs to fill certain requirements. I think that the original blocks offer plenty of playing possibilities. The audio content needs to make the difference. If the play does not offer enough freedom and creativity children get bored and might direct their attention towards more interesting topics.

## 5 Building the first prototype

The prototype development started after the background research observation phase. Regarding the Tune Your Mute workshop, it was organized in the early stage of the prototyping phase. The goal was to create an interactive and functional prototype. My main focus was in trying to develop fluid human-computer interaction combined to an aesthetically pleasing sound output. Design for the interface layout was not included in the prototype development. Only the three basic physical shapes were introduced in order to find out how the size of the blocks and their shape functioned in real life conditions. I decided to postpone the final visual and object design towards the end of the production roadmap as it is explained in Chapter 7 on product realization.

### 5.1 Experimenting with physical computing

The first version of the MOTS prototype consisted of two kinds of physical interface models: dummy and technology blocks (see Figure 14). The blocks embedded with technology had an Arduino Duemilanove microcontroller board, magnet switches and an energy supplier inside. The so-called dummy blocks had magnets inside. Their purpose was to trigger magnet switch sensors placed inside the technology blocks. The data was sent onwards to the computer for data analysis. For building the first prototype version, the following technologies were explored. Hardware: Arduino Duemilanove microcontroller board. Software: Arduino IDE (Integrated Development Environment), Processing IDE, MaxMsp and magnet switches (sensors).

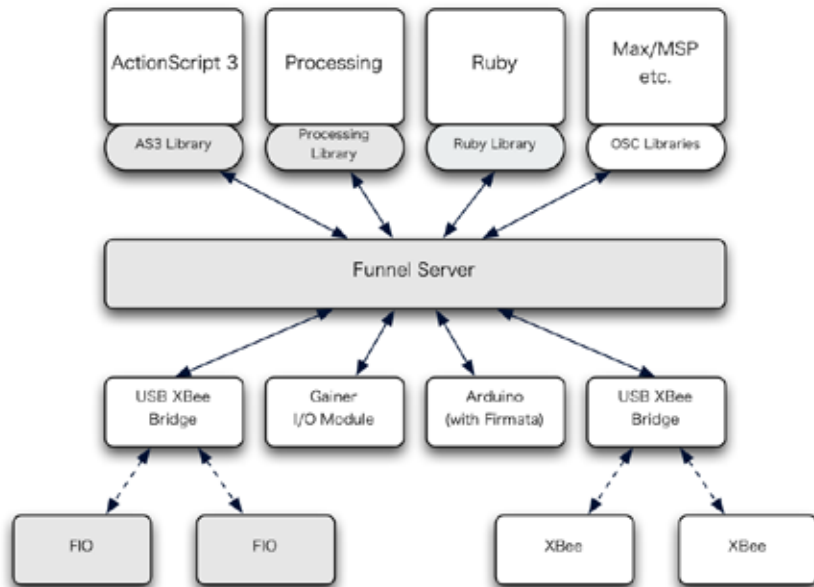


**Figure 14. The first paper prototype version and embedded Arduino system: smart technology and its counterpart with magnet switches.**

In an enhanced version of the prototype I replaced magnet switch sensors with hall sensors. The advantage of the hall sensors was that they could detect analog values between 0 and 1023. The interval is determined by the Arduino's ADC [analog to digital converter] of 10 bits. Magnet switches send and receive on and off messages. The reason for experimenting with the hall sensor technology was the need to measure distance and uneven encounter between two or more blocks. This kind of interaction was considered to give more room to creative audiovisual manipulation. The presented scenario allows four different interaction modes: 1. All resistors connected, 2. Resistor A connected, 3. Resistor B connected, and 4. No resistors connected. By choosing different resistors to individual blocks and modes, numerous connection scenarios could be achieved [see Appendix 3]. An Excel chart was created for choosing desired resistors [see appendix 4].

An enhanced prototyping version exploited Arduino based Funnel I/O board [Funnel, 2010] and XBee [Digi, 2009] using Zigbee wireless technology protocol. The Zigbee protocol enables the creation of radio networks between individual Zigbee units. Zigbee protocol was chosen because of its availability and easy configuration between Arduino board and Zigbee. Funnel I/O board was chosen because of its small size and compatibility with the Zigbee radio chips. The funnel developers have also included a Funnel server handle data transferring between Funnel I/O and supported programs [see Figure 15].





**Figure 15. Funnel: Funnel system.**

## 5.2 Prototyping outcomes

During the prototyping phase I created two working prototypes. The hands-on research work revealed that adding interactivity to the basic primary shaped blocks affects the playing situation. The paper prototype models embedded with electronics allowed me to experiment with tangible interaction. Based on the collected feedback, I argue that interactivity and sound output produces a multi-sensory feedback system. During the Interactive Prototyping course Professor Turkka Keinonen expressed his concern about creating a seamless interaction flow.<sup>2</sup>

*“How can you achieve the same freedom of play that the original Fröbel’s blocks enable?”<sup>1</sup> – Professor Turkka Keinonen*

<sup>2</sup> Personal discussion with Turkka Keinonen, Spring 2009

I think Keinonen made a good point. To achieve a fluent dynamic interaction is a difficult task to implement. The simple Fröbel's blocks allow children to manipulate individual pieces expressively. The children can create their own magical universe without extra interactive layers. I still think adding interactivity to the Blocks is desirable. In this way, sharing content with others becomes possible. For example, reorganizing the playing situation and inviting children from other locations via Internet to collaborate would become possible.

During the prototyping phase the two most important learning experiences for me was to discover the complexity of creating interaction to physical interfaces. Also designing an iterative interactive experience seemed a great challenge. To achieve these the system interaction must work seamlessly. Not to forget, that when adding a sound interface and a sound output, the listening experience should not be disturbed in anyway. If the sounds have undesired digital distortions the immersion vanishes, no matter how good the interaction is.

The Research outcomes from user-centered design studies and the prototyping outcomes helped me to narrow down possibilities and to focus on developing the final concept of the MOTS. The ambitious ideas of combining a reactIVision based camera tracking and Fröbel's blocks embedded with Arduino and sensors were abandoned. After the critical learning phases I chose an established reactIVision framework as the main technical environment. This approach limited me to focus on creating interaction on the horizontal axis instead of aiming for the six degrees of freedom.

### **Note!**

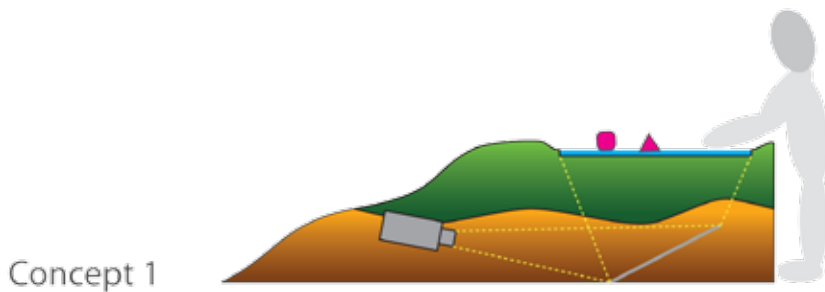
*Finally I would like to mention a warning word. It is not a good idea to take electronics with you to an airplane. I did, got busted at airport and lost my 2-month hardware work when returning back from England. Unclosed Arduino and attached wires might look suspicious to package inspector.*

## 6 Concept

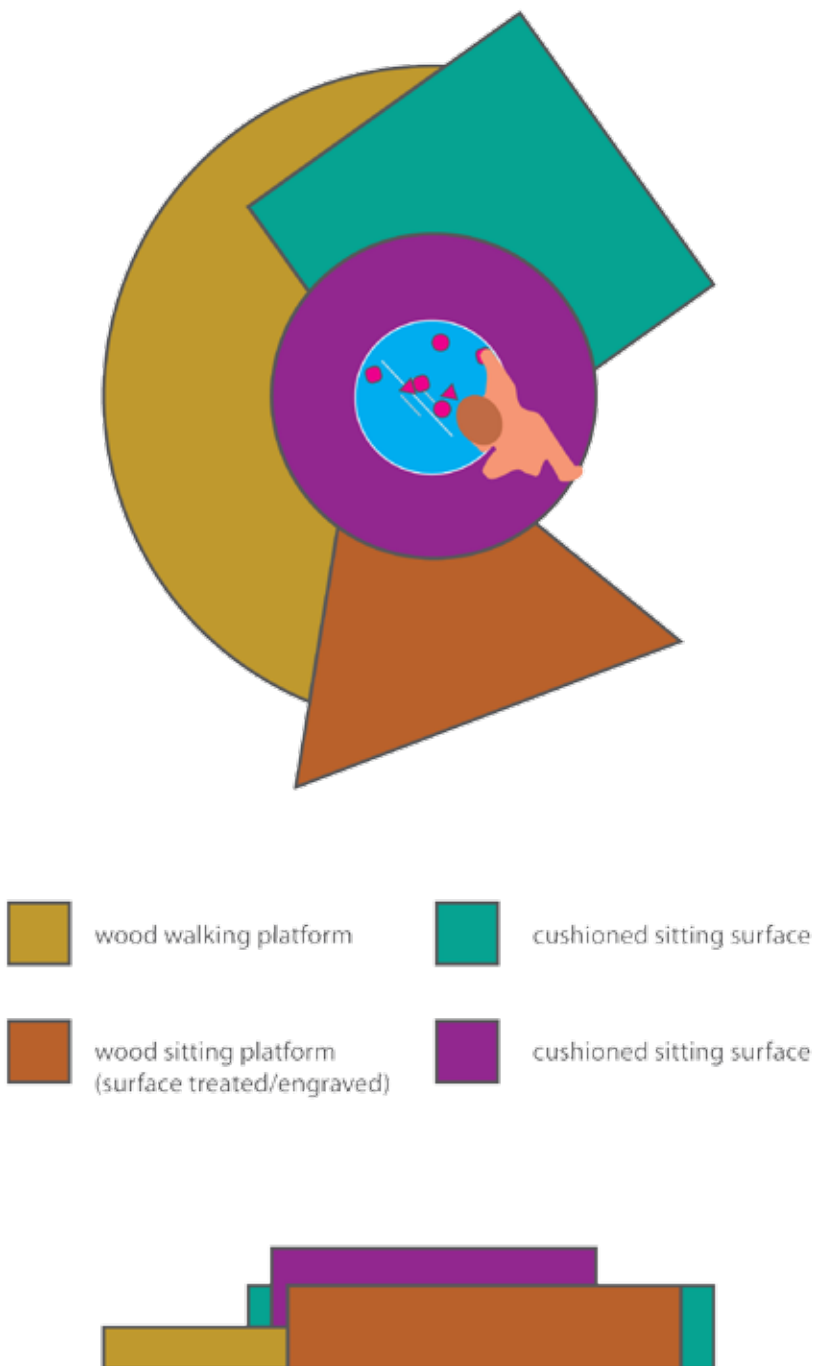
The MOTS allows multiple users of all ages to play and interact simultaneously. The interactive play environment consists of a tabletop projection screen and external speakers that present dynamic multimedia when producing music, sounds and visuals. Users can interact with the system using different geometric shaped blocks as tangible interfaces.

The metaphor for the interaction in the MOTS is closely related to the act of gardening and growing flowers. Using the tangible objects users can create kaleidoscopic geometric shaped flowers and explore poly-rhythmic sound patterns with different musical scales. While playing with the MOTS the users aim is to take care for and nourish the garden in order for the plants and the music to grow.

The MOTS design is aesthetically fun, friendly and easy to approach. The shape takes inspiration from an artist palette, where instead of mixing paints, the user is creating colorful visuals and sounds. The MOTS can be implemented both indoors and outdoors. The environment allows for people of all ages and sizes to sit, kneel or stand near the interactive surface. The cushioned surface also allows children to lie close to the interactive surface. The MOTS takes into consideration that the interaction between a multi interactive platform and mobile computers could allow for a wide possibility of future concepts.



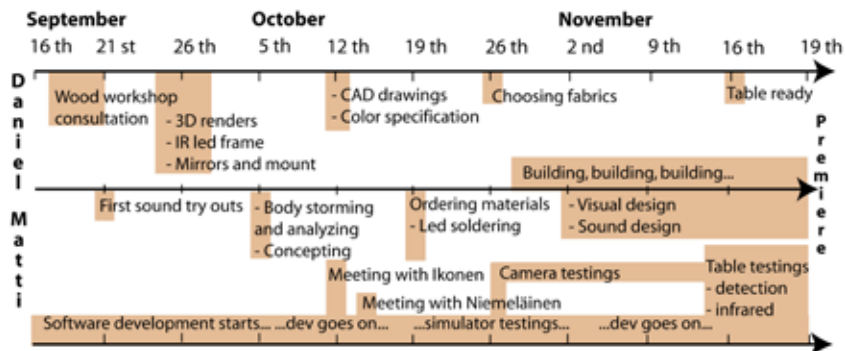
**Figure 16. Table proposal 1: early concepts.**



**Figure 17. Table proposal 2: early concepts.**

## 7 Product realization

MOTS design and realization process lasted from September 16, 2009 to November 19, 2009. Realization part of the design process was divided in two phases. Production tracks are physical construction and content design [see Figures 18 and 19]. Daniel Vester was responsible of designing and building the physical table structure and three chairs. I was in charge of content design, programming and product management.



**Figure 18. MOTS product management: timetable.**



**Figure 19. Product management: timetables and hands-on work.**

## 7.1 Physical construction

### 7.1.1 Table and chairs

Final decisions on materials were based on a detailed study of museum environment. Durability and safety issues as well as aesthetic requirements needed to take into account. Initial idea was to achieve mountain like structure that the users could climb on and kneel around it [see Figures 16 & 17]. The physical construction consists of table and three chairs. Table has a height of 55 centimeter and the chairs have a height of 35 centimeters. Supporting structures are designed to take weight of a child and take hard impacts [see Figure 20]. Tail Wood workshop master Martin Hackenberg expressed well the requirements of the installation.<sup>3</sup>

*“The table needs to tolerate flock of elephants rumbling on it”.*

— Martin Hackenberg



**Figure 20. MOTS physical construction: supporting structures.**

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<sup>3</sup> Personal discussion with Martin Hackenberg, Fall 2009

### **7.1.2 Surface materials**

To make the environment comfortable, an idea to cover the whole table and chairs with soft foam and fabrics was introduced. Finally we decided to cover only the top with soft material and fabric. Reason for this was that covered soft walls could act as misleading affordance inviting children to push against cushioned walls. Furthermore, covering the whole table with fabric might have led to a stuffy aesthetic feeling. Final outer walls were covered with polished veneer. Tabletop is covered with soft foam and black fireproof material. The fabric is produced to last over 40000 frictions and it is suitable for public environments. The chairs are covered with two colors, Caribbean blue and Cyan red [see figure 21].

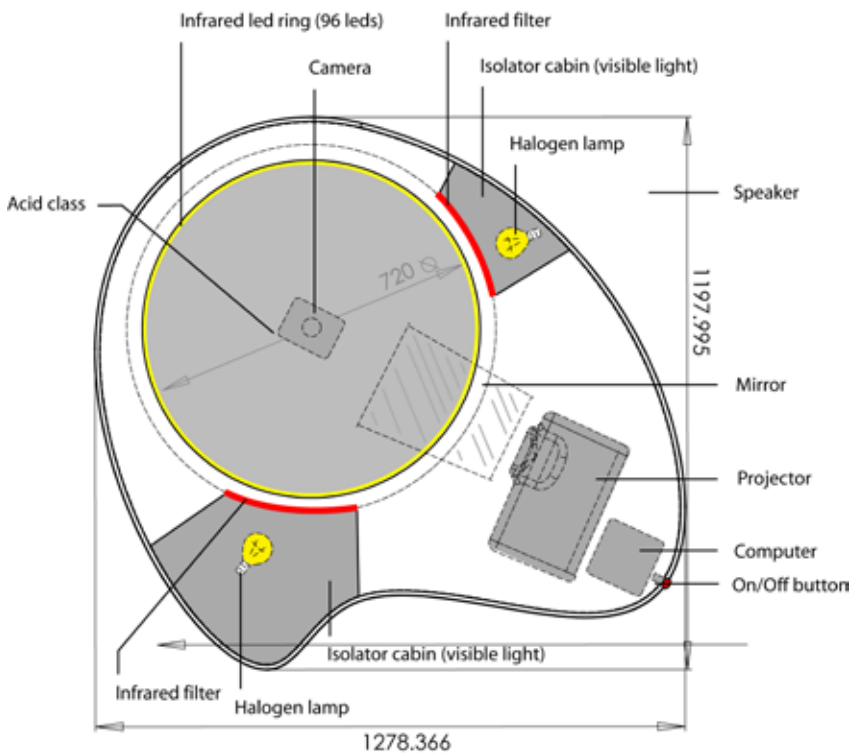


**Figure 21. Visiting fabric store: proposed fabrics and colors.**

Black surface material was chosen because of its good contrast against projection screen. Black color around projection screen continues as a circle frame. In this way separation between screen and seating area is clearer and projected image looks brighter. Black material was also chosen because of its long lasting durability. The chosen colors for chairs were thought to bring up the desired playful feeling.

## 7.2 Hardware system design

The hardware system is enclosed inside the MOTS construction. By removing the table's top lid technical parts can be easily operated. The placement of the technical parts is represented in the following descriptive drawing [see Figure 22]. For more detailed list of the components and expenses, please see Appendix 5.



**Figure 22. MOTS: hardware system from above.**



### ***7.2.1 Infrared cabins and camera detection***

I found out achieving good camera detection as the most critical part of the hardware development. To meet the desired lighting conditions for accurate camera detection a lot of testing was required. In order to make suitable lighting environment for tracking tangible objects, we used Diffused Illumination Infrared Technique [Diffused Illumination, 2009]. Media Artist Merja Nieminen was developing a multi-touch based system for her series of “Tilassa” performances. Luckily both of our projects were rolling at the same time and we were able to help each other. Nieminen kindly borrowed two commercial ready-made infrared lights for us to test. After few successful tryouts, we were able to achieve accurate tracking.

Nieminen proposed to us that creating an own infrared light could be possible.<sup>4</sup> After a small survey we found out that normal halogen light has enough infrared light for our needs.<sup>4</sup> The light needed a proper infrared filter in front of it to filter out the normal light. For this kind of setup we designed two enclosed cabins between inner and outer walls. Inside a cabin a halogen light was set. A web camera was put inside a separate closed case. In front of the camera lens we attached an infrared filter [see Figure 23].



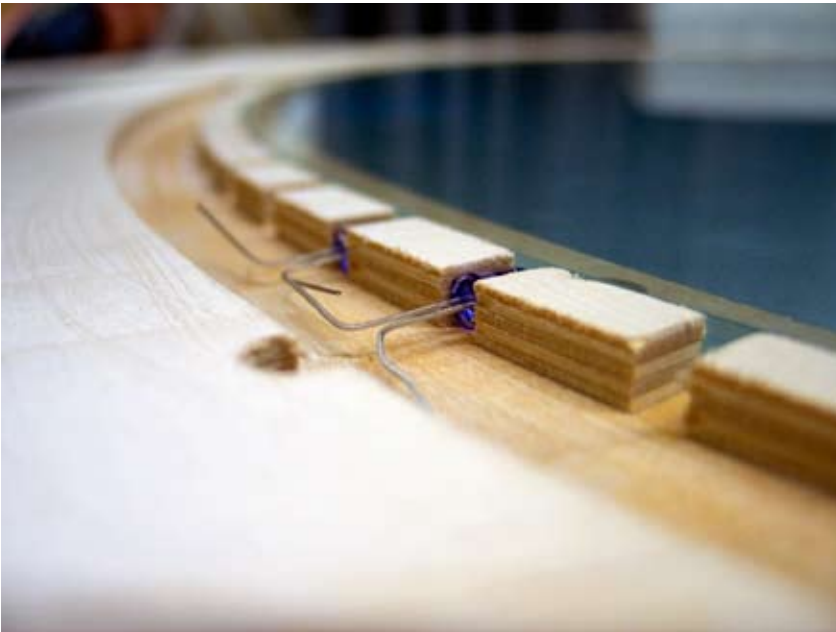
**Figure 23. Inner table structure: infra led cabin.**

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<sup>4</sup> Personal discussion with Merja Nieminen, November 17 2009

### **7.2.2 Infrared led clusters**

At the beginning of the project the idea was to use blob detection together with the marker recognition. However, the current MOTS version utilizes only marker tracking mechanism, and the table is designed for deploying a multi-touch functionality for extending interaction possibilities. This is done with a special FTIR (Frustrated Total Internal Reflection) infrared lighting technique (FTIR, 2009). Table's carrying structure contains a lid that was carved with a special CNC machine (see Figure 24).



**Figure 24. Carved led ring: placement of IR leds (FTIR technique).**

Table's circumference is 235,61 centimeters. The lid has 96 led spots. In each spot a led is set. 96 led lights are divided in 12 clusters. 8 led lights are in one cluster (see Figure 25). This design choice was chosen to avoid possible malfunctions in case of burning led or wiring problems. In this way only one cluster turns off if problems occur. Seeking a fault led from 8 alternatives is easier than from 96.

**Power supply voltage (V): 12**

**LED voltage drop (V): 1.378**

**LED current rating (mA): 31**

**Number of LEDs: 8**

**Output:**



**Figure 25. Infra led cluster: wiring diagram.**

Distance between two led lights is 2.45 centimeters. The distance was found out to be suitable distance to achieve enough lighting to enable blob detection. Certainly it would be better to have more led lights and place them closer. However, this would cause cumulative heating effect. If temperature rises over a certain heat threshold, it will kill the led lights.

### ***7.2.3 Projector mounting and calibration***

Projector mounting system was designed to allow adjusting projectors height in vertical direction and rotation around its axis (see Figure 26). These functions allowed operating with the projector freely when searching a proper image quality. A mirror and camera were put on fixed positions inside the structure.



**Figure 26. Projector mounting system: two decrees of freedom.**

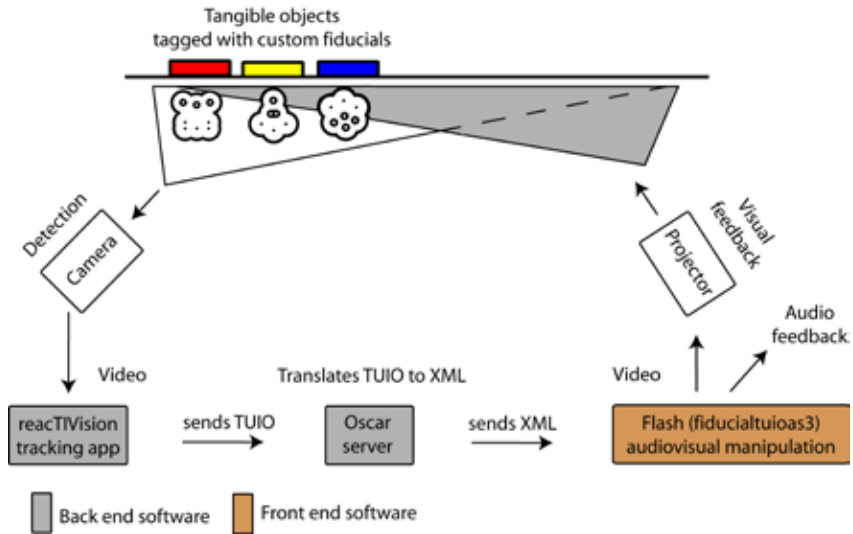
I found out the calibration phase very demanding. A lot of hands-on work was needed before the final hardware settings were found. Four components, projector, mirror, camera and projection surface need to be perfectly in sync to make the system work. For example, making small-scale changes in the projector, might lead to large keystone problem in projected image. In our project we used mirror reflection technique to expand the projected image size. This solution was used because of the target group's ergonomic needs. Direct projection would be desired whenever it is possible. That would allow easier calibration, avoiding shadow images and hot spots caused by uneven projector light.

## 7.3 Software system design

In this part I describe the MOTS software development progress. I try to explain why and how I end up to software design decisions that I made during the process. I want to underline the fact that my current expertise and focus of this thesis is not in programming, as traditional software developer perceives it. I think of myself primarily as a designer who understands programming principles and is capable of realizing functional interactive programs.

For me as a sound designer programming feels like a natural extension to composing. I feel comfortable working with programming languages after learning several years to play music and analytical listening. I see programming as an art form and programming languages as useful artistic tools. What really fascinate me in music and programming is their typological hierarchical structures and endless capabilities to create unseen and inexperienced artifacts.

The MOTS environment consists of two kinds of applications, back and front end. Referring to back end applications, I mean reactIVision, Oscar, fiducialas3 applications and automated start-up and shutdown applications. Applications are open source versions and have been developed by other people or by larger communities. My role as a designer was to find information of and ways to make the applications function together. Most of my programming work was done in the front end, on the more noticeable side of programming. Below is presented the software architecture flow chart (see Figure 27). It explains the MOTS's software architecture flow between front and back end applications.



**Figure 27. MOTS software system: software signal flow.**

### 7.3.1 *reactIVision*

reactIVision has been developed by Martin Kaltenbrunner and Ross Bencina at the Music Technology Group at the Universitat Pompeu Fabra in Barcelona, Spain. I chose the reactIVision software for camera detecting software. It is flexible open source, cross-platform computer vision framework for the fast and robust tracking of fiducial markers attached onto physical objects. It is also capable for multi-touch finger tracking, a function that we might introduce in the future. Technically speaking, reactIVision sends TUIO messages via UDP port 3333 to any TUIO enabled client application. reactIVision people have also developed a simulator for simple interaction testing. Benefit of the simulator is that the developer can use it for testing in personal computer environment. This was very useful when making small-scale changes in the MOTS software. It also allowed me to continue developing at the time when we did not have the table ready.

### **7.3.2 Oscar**

Oscar server is needed for parsing TUIO signals sent from reactTIVision. The Oscar is standalone application written in Cocoa and Python. According to Oscar developers, the application receives data from an UDP socket (which is the OSC/TUIO transmission protocol), translates it to XML-based messages that Flash can understand and forwards them via a TCP socket to all the Flash app clients connected (both on the local machine and/or on the network). This conversion procedure is needed to make reactTIVision's TUIO data compatible with Flash's XML socket data. The purpose of above mentioned procedure is to make Flash based applications communicate with other OSC (and TUIO) enabled devices and applications in the same network (Cionini, 2009).

### **7.3.3 Flash – *fiducialtuoas3***

To bridge reactTIVision and Flash I exploited open source *fiducialtuoas3* library. *Fiducialtuoas3* is a framework developed by Johannes Luderschmidt. It is an open source library that handles needed XML socket data sent from Oscar. The framework is easy to modify and use to develop creative content on it. The framework allows using both multi-touch and fiducial support. (Luderschmidt, 2010).

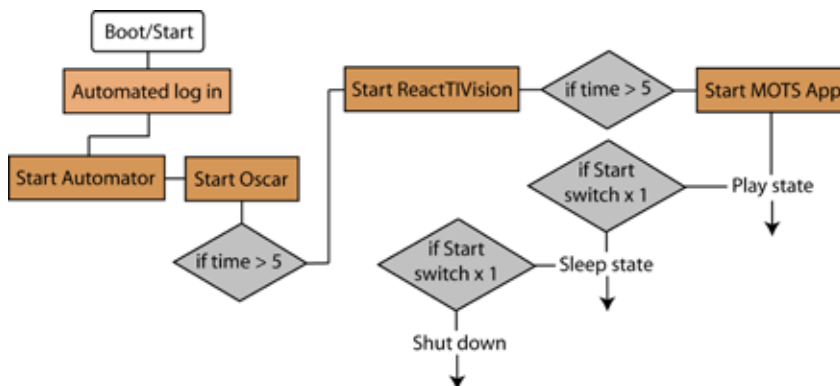
### **7.3.4 MOTS application**

For developing the MOTS application, I used Adobe Flash and Flex development environments. The programming language was pure Actionscript 3 (read AS 3). At the beginning of the project in January I did not have much of an experience of programming. My first approach to programming was with Processing. It is an open source programming language and environment that offers easy approach to programming (Processing, 2009). I found it good for learning how to program images, animation, and interactions. By doing programming exercises and reading manuals I was able to learn basics of programming syntax and idea behind object-oriented programming.

The MOTS application utilizes of several open source libraries. They are used for sound and visual manipulations. Programming wise, the MOTS application is designed in object oriented way (read OOP). In particular, the application tries to exploit encapsulation design pattern. In the context of OOP, encapsulation is often called as a “Black Box”, meaning that the one can do something with it but can not see how it functions [Sanders, 2007, p. 15]. The MOTS application design includes a main class and subclasses. The main class’s functionality is to instantiate all the other subclasses such as marker recognition, visual and sound and effects classes. I chose this orientation because keeping the objects and their functionalities in the separate classes helps to remain the application structure clear.

### 7.3.5 Automated start-up

A user-friendly start-up and shutdown functionalities for the MOTS were needed for the museum staff. An easy to use system reduces unnecessary workload from them. We fulfilled these requirements by creating an automated start-up/shut-down system [see figure 28].



**Figure 28. MOTS start-up/shut-down system: software signal flow.**

The MOTS system user sees the start-up and shut-down procedure as described below.

### **Turning on the system**

1. Turn on the system: press once the start-up button.
2. Turn the projector on via remote control.

### **Turning off the system**

3. Shut-down the system: press two times the start-up/shut-down button.
4. Turn the projector off via remote control.

Apple Automator application was used to create a program for opening all the applications at start-up. Shutdown system was more complicated to create. The Applications of the MOTS override OS automated shutdown. For this reason a roundabout for the shutdown was necessary. To shutdown the system properly I used the Sleep Watcher application to detect the state of the system. If the system was awake and the user pressed the button, the system went to sleep. When the user pressed the button the second time, Shell-script told Finder to shutdown all running applications and finally OS to turn off. The created solution is a gentle way of shutting down the system. The weak point of the created procedure is that all possible unsaved modifications in the programs are lost.

## **7.4 Sound design**

The starting point for the MOTS was to create a new kind of audiovisual instrument of an old Fröbel toy. The MOTS concept was also supposed to support free experimentation, enabling a dialogue through the use of tangible blocks and a dynamic visual form language. Tangible interaction blocks and projection screen interface are primary components that are presented for the user. The music and sounds were supposed to index and underline visible content and tangible blocks states. All three components, the visible, the tangible and the audible were to be clearly interconnected. The primary task of the three components was to



support the most important aspects of the concept, communication and playing together.

I think these ideas set high requirements for creating audio content for the MOTS. The created music and the sounds were expected to support the visual composition and the interaction process. Sounds were to be designed in a manner to promote play. Nevertheless, focus was considered to be in free experimentation rather than in achieving something predetermined. To fulfill the sound requirements I divided the sound design process into three phases: 1. Getting inspired, 2. Pre-sound design and 3. Creating sounds.

### **7.4.1 Sound design inspiration**

As a source of inspiration for sound design I used two works. They both utilize multi-touch technology. With the MOTS they also share an idea of allowing the users to produce sounds and visuals through free experimentation.

#### **Shape Color and Sound**

The Shape Color and Sound by Penesta Dika and Tomor Elezkurtai is designed on reactIVision framework. Their work was presented for the first time at Ars Electronica Festival in 2006. According to the authors, the Shape Color and Sound enables multi-touch and tangible interaction. Dika and Elezkur explain that the work is about creating sound images and visible sound simultaneously through tangible shapes/objects. Their concept is based on three main topics. [Dika, 2006]

1. The color-circle of Johannes Itten.
2. Twelve-tone-technique of Arnold Schönberg.
3. Elementary geometrical shapes of Euclidean Geometry.

#### **Bloom**

*“Bloom is an endless music machine, a music box for the 21st century. You can play it, and you can watch it play itself.” – Brian Eno*

The Bloom software is developed by an ambient music pioneer Brian Eno and a musician and software designer Peter Chilvers. According to the creators, the Bloom explores an uncharted territory in the realm of software applications for the iPhone and the iPod touch. The Bloom is a combination of a musical instrument, composition and an artwork. Multi-touch based interaction allows the user to create elaborate patterns, unique melodies and accompanying visualizations by simply tapping the screen. In addition the Bloom has 12 different mood settings for different color and sound variations. [Generative music, 2009]

### ***7.4.2 Sketching mapping strategies***

In this part I explain the mapping strategies that I used to bring the conceptualized sounds and the interactions together. I use the mapping word as a synonym to pre-sound design. Pre-sound design is a more commonly used term in the more traditional sound design fields (ex. film sound design). By using the both terms I refer to a production phase in which the sound designer makes a list of sounds, descriptive time line visuals, comparison charts, sound aesthetic descriptions, emotional curves and possibly sonic sketches.

Sound design in the field of new media has borrowed pre-sound design practices from the more traditional and established sound design fields. However, the requirements for pre-sound design in the field of new media are different. I think that mapping is a more descriptive term when talking about interactive media productions. With the term interactive I describe a production where sounds are designed to meet the needs arising from interaction between a physical machine or software and human.

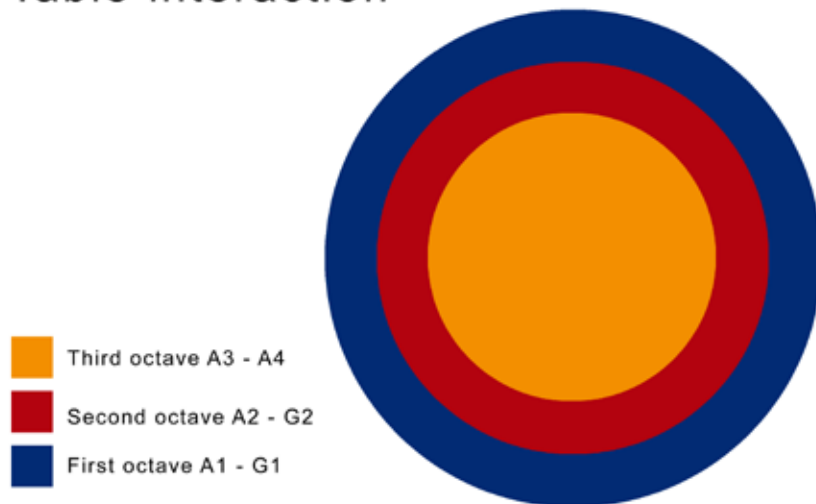
To me the process of mapping sounds in the context of new media includes techniques such as creating small code snippets, drawing up universal mark-up language charts (UML), file name lists and other descriptive materials in order to communicate between software and hardware designers. By using design practices from traditional and new media sound fields, the new media sound

designer is capable of presenting ideas understandably for other designers and professionals coming from different fields. I approached mapping by sketching descriptive visuals of interaction phases. I go through them in three phases: 1. Object move, 2. Object rotation and 3. Object collision.

### **Object move**

The interaction surface is divided into three round areas. The outer circle area is for low octave sounds, the middle area is for middle octave sounds and the innermost layer is for high octave sounds. (see Figure 29).

## **Table interaction**



**Figure 29. Mapping strategies: dividing the table into three areas / octaves.**

Within three octaves users are able to progress in notes from the lowest to the highest by moving a tangible object between the outer circle and the exact center point. An idea was also to allow users to change scales. To avoid conflicting scales and chaotically sounding results the MOTS was thought to benefit from modal scales (see Figure 30). Modal scale forms of an ordered series of intervals, applied only to the 7 specific diatonic scales (using only the seven tones of the scale without chromatic alterations) that follow the tonic note. (Kontunen, 1990)



**Figure 30. The eight musical modes: modal scales.**

From the interaction design point of view users are able to experiment note progressions within three different modal modes by moving a tangible block towards and away from the center point. In this way, the users can play music from the same 21 pre-chosen notes within three octaves. Only tonic, in other words the first note of the scale changes. For example when a user moves the block from the outer circle towards the center circle, the keynote C changes to D and E and so on.

### Object rotation

The rotational mapping strategy was created in order to achieve a wide range of sound and visual expressions. Rotation is also very a natural and an established way of interaction. If a user rotates a tangible object towards right, a visual flower object grows and more leafs appear around the previous layers. If the user rotates the object towards the left, a visual flower shrinks and the most outer leafs disappear. The smallest shape is the simplest. When the leaves grow, secondary colors and more complex shapes are added. The same principle applies to the complexity of melodies, timbre variations and advanced bar measures. For example, the rhythms could be progressing from 2/2 to 5/4 and to more exotic timing variations. Ideas of the correspondence between interaction, sounds and visuals are elaborated in Table 3.

Phase 1	Phase 2
<p>Object Rotation</p>	<p>Object Rotation</p>

**Table 3. Mapping strategies: description of sound behavior in rotation.**

Each flower leaf has its individual sound font or sample. Each leaf play sounds actively one after another looping through all the leaves. Alternatively random functionality can be added instead of just looping. Nevertheless, more than one layer of leafs in each flower can play simultaneously for creating polyrhythmic patterns. However, sounds and poly-rhythmic patterns need to be clear and simple enough. Otherwise a result might lead to a non-meaningful sound output.

## Object collision

The third sound interaction idea is Object collision. When two tangible objects collide or visual objects overlap the flower visual and sound behavior changes. Overlapping leaf colors are mixed and sound on them is muted. Alternatively sound volume can rise or new sounds could be introduced (see Figure 31).

### Object Collision



**Figure 31. Mapping sounds: collision functionality.**

### 7.4.3 Designing sound qualities

I approached designing the sound qualities by using Kandinsky's Color and Shape theory. First, I created a list of comparison words between the Kandinsky's proposed shapes and designed sound qualities (see Table 4).

<b>Color and Shape Theory</b>	<b>Sound Quality</b>
Dynamic triangle	Distorted, Harsh, Pointy
Static square	Systematic, Safe, Harsh, Precise
Serene circle	Soft

**Table 4. Comparison table: Kandisky's shapes vrs. sound qualities.**

To me this kind of approach to sound design is natural. I think describing the sound qualities in written form is crucial in the mapping phase. It is similar to sonic sketching when sounds are produced by vocally. Both practices help designer to build up an idea of the first version. In later development states descriptive words could be helpful when referring to the original idea and searching for certain sound.

#### **7.4.4 First sound tryouts**

I started my sound design testing with MaxMsp program. An initial idea was to combine Flash and MaxMsp programs. MaxMsp would be used to control the sounds and Flash to control the visuals. For the sounds I exploited Real Time Composition Library by Karlheinz Essl [Essl, 2010]. The library is developed for algorithmic composition. First version of the MOTS utilized the modal scale ideas presented earlier in this chapter.

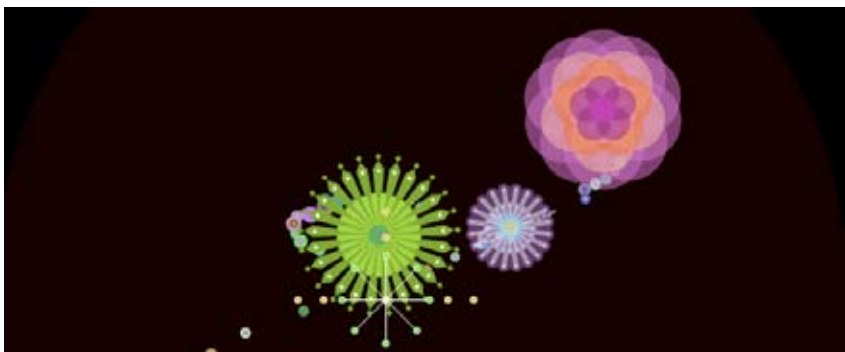
Through careful experimenting with the two programs problems started to occur when combining too many applications together. I experienced undesired latency issues when combining Flash and MaxMsp. MaxMsp patches tended to crash randomly without obvious reasons. When using MaxMsp or Flash alone I did not encounter these problems. Finally I chose to work only in Flash environment. Freedom of generative sound creation was lost. On the other hand, benefits of using only one program were remarkable. First, I was able to cut down latency times. Second, development work in one programming environment was easier than spreading variables, objects and libraries in two different programs. The most important aspect for my decision was that the installation is used daily perhaps next ten years. Due to nature of the installation, it was critical to create reliable and smooth running system by making sure that the program is simple enough not to crash.

After the switch from MaxMsp to Flash environment all sounds needed to be made with pre-recorded samples. At the time of writing, Flash based generative sound engines existed but they were not utilized during the development. Reason for this is Adobe Flash Player's poor ability to produce computational sounds. Yet, dynamic sound manipulations are handled via computational filtering. As a framework for building the MOTS application, I used an open source Bloom AS 3 developed by Seth Sandler [Sandler, 2008]. The application is ported from the Eno's Iphone application.

### **7.4.5 Final sound design version**

As a source of inspiration for designing the sounds I used bell-sounding tones from the Bloom software. After the careful analytic listening I was able to create similar sounding clear and shiny characteristics that while playing together make pleasant and calming effect. The main idea of the created sound qualities is that the user can concentrate listening on them or participate in collaborative composition process.

The sound samples include 22 individual samples. The samples of the MOTS are 22 diatonic notes progressing from A1 to A4. Users can create the sounds by placing the tangible objects on the table. When two of the tangible objects confront distance and time threshold a note is produced (explained in detail in the Interaction design chapter 7.5.). The note is represented with visual flower that continues pulsating together with sound between pre-determined time intervals [see Figure 32].



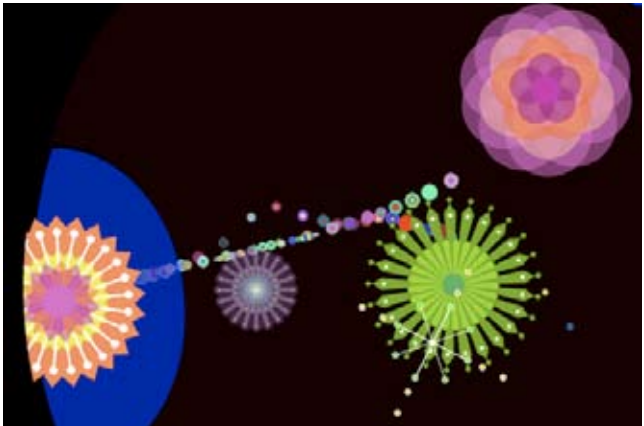
**Figure 32. Playing notes: two interface objects and one note object.**

The notes and the corresponding visual flowers are triggered programmatically according to their calculated position on the table. This functionality was created mapping pre-recorded samples to tables 22 round segments. Programming realization is represented on below [see Table 6].

Description	Code
Variables to hold calculated distance between center and an tangible object	<pre>var dx = stageCenter - flower. xPosition; var dy = stageCenter - flower. yPosition;</pre>
Divide the table to 22 round segments [three octaves]	<pre>var dist = Math.sqrt(dx * dx + dy * dy); dist = Math.round(dist) / 2.5; for (var i:int = 0; i &lt; 22; i++) {</pre>
Track the object's position on the table and play the corresponding note	<pre>if (flower.xPos &gt; (i * dist) &amp;&amp; flower. xPos &lt; (i * dist) + dist    flower.y &gt; (i * dist) &amp;&amp; flower.y &lt; (i * dist) + dist){   playNote(i); } }</pre>

**Table 5. Programming sounds: dividing table into 22 notes segments.**

The changing distance between two or more of the blocks is presented with visual flower seeds and bird sounds. This aesthetic design decision supports the gardening metaphor. From the interaction point of view the two media elements together support users to create new flowers and sounds [see Figure 33].



**Figure 33. Distance between blocks: the flowers and seeds.**



## 7.5 Interaction design

The starting point for the interaction design was in Fröbel's pedagogical ideas. The Fröbel's gifts and occupations were his most important contribution to the field of pedagogy. His approach to learning also included the act of gardening flowers. During the production I chose the gardening as the metaphor for the MOTS interaction design. The final interaction design concept was developed after the detailed studies of children's' interaction with Fröbel's blocks and the possibilities of multi-touch interaction possibilities and constraints. In this section I explain an iterative Bodystorming interaction design practice that was used to clarify the interaction design goals. Finally I introduce the resulting interaction design of the MOTS application.

### **7.5.1 Bodystorming**

Bodystorming technique was used to gather information on how users might interact with a system. The purpose was to gain an understanding for designing the content and the software system. Burns et al coined the term Bodystorming while designing a computer workstation for a hairdresser. In their conclusions Burns et al found out that "by designing in an enactive way, they were able to build an increased empathy for the people that they had identified as the users"[Oulasvirta et al, 2003, p.2].

Bodystorming practice was chosen because it permitted immediate feedback for generated design ideas, and could provide a more accurate understanding of the contextual factors. The idea of arranging the small-scale session was to see the existing content and interaction ideas from a new perspective, through the eyes of the users. According to researchers Oulasvirta, Kurvinen and Kankainen, the practice is very useful for getting information quickly, directly and with less effort on reading documents of the actual interaction environment [Oulasvirta et al, 2003, p.1].

The Bodystorming session included one person interacting with a non-interactive table. Two sessions were organized, each circa 20 minutes long. During

the session the “bodystormer” explained freely to a camera what was happening in each state of interaction. The “bodystormer” used different colored markers and original Fröbel’s blocks in order to help the explanation (see figure 34). After the sessions the film was analyzed and ideas were written down in a textual narrative. Furthermore, drawings and interaction flows were developed further.

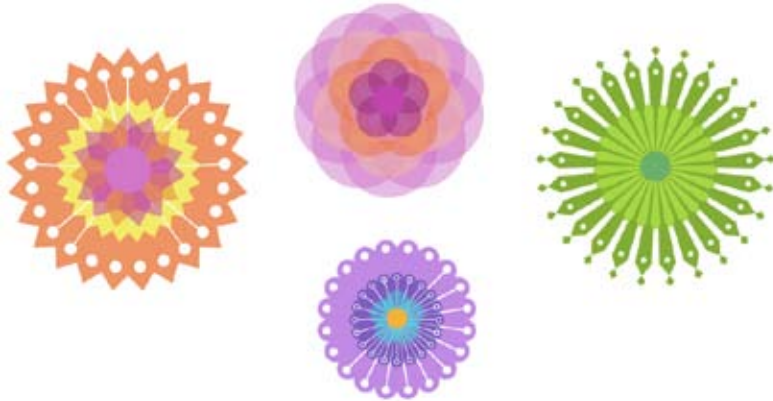


**Figure 34. Bodystorming: talking aloud and sketching interaction.**

The Bodystorming practice was a useful experience in that it helped me to understand the nature of interaction in the MOTS environment. By including the original Fröbel’s blocks and other concrete materials I was able to concretize my ideas in a rapid manner. I found out that arranging the design session in a context resembling the actual use context helped me to look the interaction situation from the users, in this case the child’s, point of view. The practice also allowed me to look at the interaction idea from a different angle. During the session additional interaction metaphors were conceptualized. For example an underwater metaphor was one of those that I came up with. However, the gardening theme appeared more fascinating and was chosen for realization.

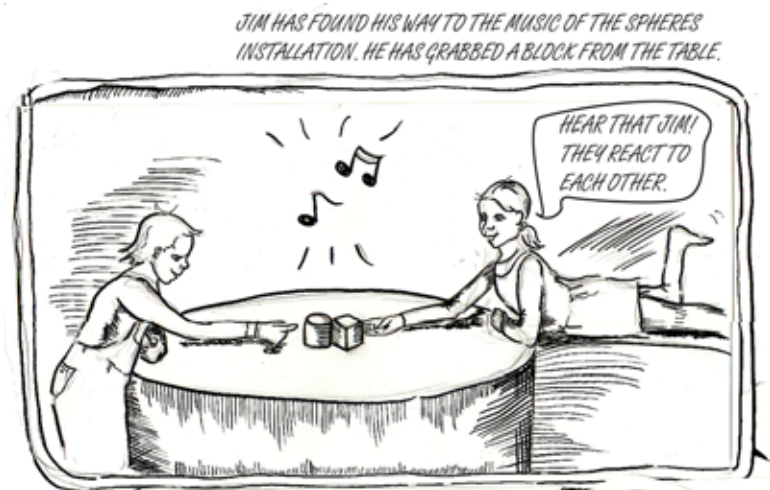
## ***7.5.2 Resulting interaction design***

The interaction metaphor of the MOTS is closely related to the act of gardening and growing flowers. Using the tangible objects users are able to create kaleidoscopic geometrically shaped flowers (see Figure 35) and to explore the polyrhythmic sound patterns with different musical scales.



**Figure 35. Interaction Design: MOTS flower objects.**

In the Figure 35 there are three larger flower objects and one smaller note object. The larger flower objects are individual flowers that are mapped to the geometric shaped tangible objects. The leftmost flower is for rectangle object, the top middle flower is for the round object and the rightmost is for the triangle object. When the table is on idle state the flowers are in their nests. When a block is grasped and put on the table, a corresponding flower travels under the tangible block. When the user moves the block the flower follows it with a spring effect. As soon as two or more of the blocks are on the table flower visuals and sounds can be produced. By facing the tangible objects together on the screen users can create smaller flowers that produce sounds (see Figure 36 and appendix 6).



**Figure 36. Interaction design: creating flowers and sounds.**

The collaborative creation process of the garden is represented with sounds and visuals. The blocks coming close enough to each other produce seeds that meet in the middle point of the two blocks. After a certain time a flower note is produced. The created flowers live as long as the users remove them with the tangible block. The idea of this feature is that the interaction supports collaborative creation and allows a single user to control, which sound flowers can be removed.

## 7.6 Interface design

The MOTS interface system is developed on reactIVision framework. It was chosen because it offers an open source, cross-platform computer vision framework for fast and robust tracking of fiducial markers (Kaltenbrunner, N/A). ReactIVision is also used in various art and design projects that have been proven to work in real life situations. The MOTS interface consists of a glass surface, tangible blocks and a sound system.

### **7.6.1 Screen**

The MOTS environment uses a bottom-up projection technique. It means that the projected image is screened on the vertically set screen. For the screening purpose we used acid glass with a 75 centimeters diameter. The other side of the glass is manipulated and the other is bright. The edges of the glass are polished. Polishing is needed to allow the infrared light to access the lateral interior part of the glass when using FTIR technique as explained in the chapter 7.2.2. Soon after the MOTS was delivered to the museum, I found out that the wooden blocks cause small scratches on the glass surface. This might be because of tiny dust particles between the blocks and the surface. We removed this problem by adding felt pieces under the blocks.

### **7.6.2 Tangible blocks**

Three tangible block shapes were chosen based on the three primary shapes that Kandinsky proposed in his Color and Shape theory. According to his theory, each

shape and color has its unique meaning and character. The dynamic triangle is inherently yellow, the static square is intrinsically red and the serene circle is naturally blue [Lupton et al 1991, p. 3]. Blocks are made of wood. Original Fröbel's Blocks are also made of birch wood and they are natural wood color. The wooden material was chosen because of its durability. In the Wizard of OZ workshop we found out that the children were playing with the blocks in a rough manner. Based on that knowledge we decided to use a long lasting material. We also wanted to work with a material that looked and felt warm. Wood has a type of quality that it looks nice after several years. Scratched and beaten-up surface does not matter so much in wood compared to plastic for example. The wooden blocks also give a good contrast to the colorful flower objects projected on screen. If they were colored, the projected feedback could suffer.

During the project Lecturer Rasmus Vuori from Media Lab questioned if the block provides an interaction itself or is it a tool for interaction.<sup>5</sup> Vuori's point led me to think the interaction more critically. The blocks are interaction tools and the projected visual material on surface as well as the produced sounds act as the interaction channel. I see this because the block itself does not present any kind of digital feedback.

### 7.6.3 Markers

reactIVision framework comes with specially designed markers. reactIVision offers three different marker versions. Currently the fastest recognition is achieved with Amoeba fiducial sets [see figure 37].

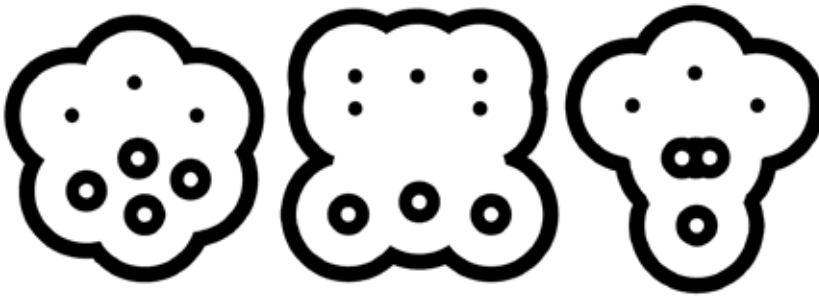


**Figure 37. reactIVision fiducials: Amoeba fiducials 0, 1 and 2.**

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<sup>5</sup> Personal discussion with Rasmus Vuori, 27 January 2010 and 24 February 2010

Markers have individual pattern shapes. Based on the pattern, camera recognizes the fiducial and its index number. With this unique information developers can build something meaningful on the client software side (ex. move visuals or alter sounds). An alternative way of using fiducials is to create a set of self-made fiducials. This is made possible by using software called Fid.Gen. It is a general-purpose generator for designing and tailoring custom fiducial markers to be used in reactIVision based projects (Fidgen, 2009). The software offers numerous parameters to adjust the size and complexity of the markers. We created a set of three custom made markers for our blocks (see Figure 38).

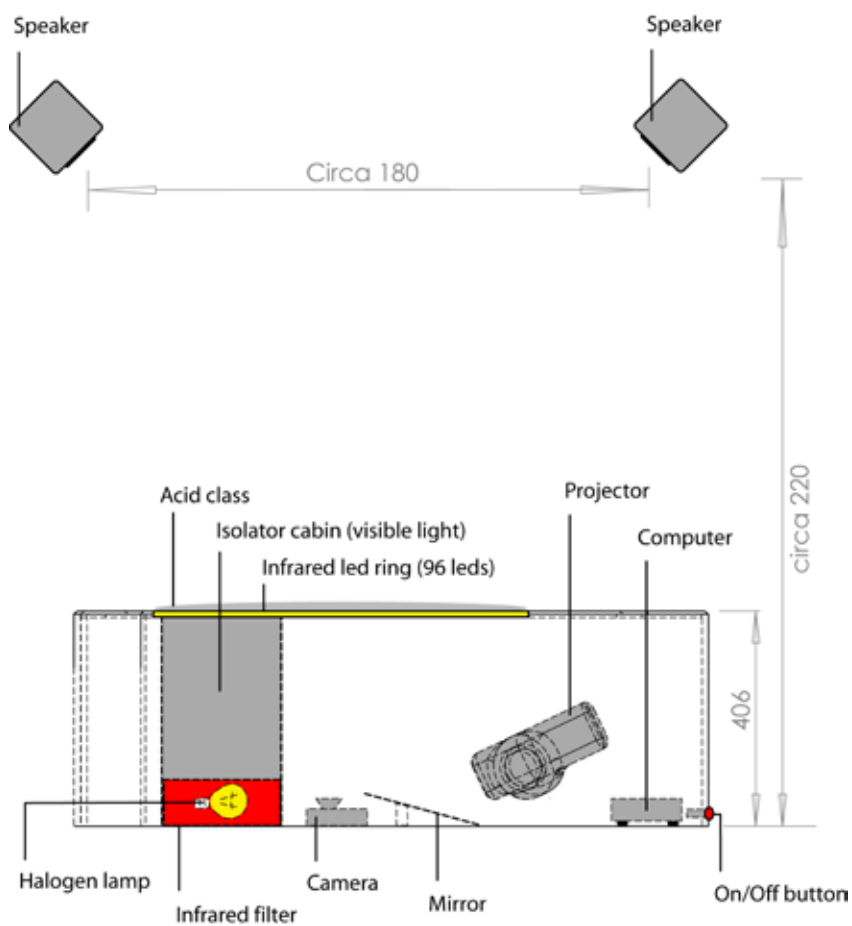


**Figure 38. Markers for recognition: Fid.Gen designed markers.**

The reason for choosing to create a set of our own markers was because I felt that the ready-made markers lack of a look and feel appropriate for children. Their size is also quite large and we found out that the Amoeba shape is hard to fit in circle and triangular shaped blocks.

#### **7.6.4 Sound system**

The sound system consists of two ceiling mounted active speakers and a computer for sending audio. The speakers can produce sounds from 55 Hz to 20 kHz. They are angled to circa 45 degrees and face down to the MOTS surface. Placement of the MOTS speakers and the screen form a triangular shape (see Figure 39). This kind of a setup creates a desired listening environment. The stereo sound produced by the speakers can be heard unbiased all over the table. The surrounding environment of the MOTS is open to other rooms of the museum. This causes some sound leaking. This was considered when designing sounds for The MOTS. The produced sounds form a pleasant sounding melody structures filling the museum acoustic environment pleasantly.



**Figure 39. MOTS: sound system.**

## 8 User testing

The prototype system of the MOTS has allowed for interesting and stimulating user experiences to emerge. Through three user-testing situations I have been able to collect feedback from the users. In the following subchapters I go through some findings from the tests.

### 8.1 Premiere night

The premiere night was arranged in November 14, 2009. The night was exiting for us because it was the first public presentation of the MOTS. During the evening visitors had a chance to play with the system. The diameter size of the first demo blocks was circa 15 centimeters. During the night it was found out that the children lifted them with two hands [see Figure 40].



**Figure 40. Tangible blocks: first version.**



After gaining this insight we decided to reduce the diameter of the blocks to circa 12 centimeters. According to later user test results, the children are able to hold them in their hands and to manipulate them on the surface by rotating, dragging, pushing and sliding. [see Figure 41].



**Figure 41. User testing: children operating tangible interfaces.**

During the premiere night I found out that the MOTS program was not reliable. The program was created with the MaxMsp and Adobe Flash programs. During the night the MaxMsp patch failed to work several times. Based on this feedback the development environment was switched to the Flash. However the user feedback of creating sounds and visuals was encouraging. For example one child was very surprised of being able to create a visual objects and sounds on screen. This action was followed by a discussion between the child and her mother as to how 'things' such as flowers are created on an everyday basis. The interaction promotes the play environment as being educational and fun at the same time.

## 8.2 Beta version

The beta version test was the first official user-testing situation. It was arranged on 8 and 9 December 2009. The testing situation was organized at the Kindergarten Museum with 22 children of 6 years of age. Testing group consisted of a workshop leader and an assistant. For the tests a new Flash based application was developed and two different programs were tested during these days. On the first day the program consisted of experimenting with the so-called "big eaters" that tried to eat flowers that had been created. The second version did not contain the "big eaters". The arranged testing situations were divided in two parts in order to get a better understanding of the interaction between the users and the realized system. A hypothesis was that after the tests the concept in general could be improved. At first the workshop leader introduced the system to the children. After a short discussion, children played with the system in groups of 3 and 4. During the play children were asked to teach how the system works. The playing time for each group was circa 15 minutes. The workshop was video recorded with two cameras.

### **The first day outcomes**

The first day proved that the children focus mainly on the monsters or the big eaters. The nature of the interaction during the first day seemed to be far from the original MOTS concept. The children did not perceive the idea of creating sounds and new visuals in the form of flowers. Instead they were fascinated about trying to destroy the monsters and the play was more self-centered. The content on the screen affected also moving the blocks. The children acted hectically and moved the tangible objects fast. This kind of behavior downgraded the sampling ratio between the camera and the markers and affected the interaction flow. The result was a poor visual presentation and the sounds were not triggered. The children also tended to compete by hitting each other's blocks, which produced some noise. From the technological point of view I was happy to notice that the new Flash based application worked as we had planned.

## **The second day outcomes**

The second day testing situation proved that the children acted more calmly after the monsters were taken off. The application version used during the second day guided the children to collaborate and to create sounds and visuals in a more constructive manner. During the play the children eagerly tried to understand what they were supposed to do. As if they were thinking it as a game with a preset structure. From the free play point of view it is interesting that the children started to invent their own rules to the play. For example one girl said during the play that creating colors and sounds is wonderful! When asking her to explain what she meant she continued as follows.

*“-- I am now turning off these colors. On and off with my other block. I can create other colors with the other colored blocks. --“*

In reality the system was not equipped with such functionality. I think it was an interesting finding that the created system allowed such an imaginary approach to the play. Perhaps I will include functionality described by the girl to the system in a later version. After the session a staff member from the museum mentioned that a girl group had danced according the music created by the playing children. I think this kind of information is useful to know. It is a proof that the sounds and created sound patterns are suitable also for the museum environment in general. All in all, the second day results are closer to the original MOTS concept than the first day results.

## **8.3 Release version testing**

The release version test was arranged on March 1, 2009 at the Kindergarten Museum. 12 children of 5 and 6 years of age participated to the testing. During the testing a new version of the MOTS application was tested. To the new version sounds and visual world had been updated. The interaction design was also enhanced based on the achieved understanding from the previous user studies. The structure of the session was free observation and the event was organized in the real museum visit context. The group of children toured the museum and at the end stage of the visit the children played with the system. The playing situation was filmed.

During the testing situation I was able to gain understanding how the children perceive the system. The children tend to think that they are meant to achieve something. In many points of the MOTS testing situations, especially boys said that they are playing a game and they talked about getting to another level. To me this kind of behavior is a sign of pre-learned mental model and could be a sign of transferring the model from the world of video games. On the other hand, it can be a sign of a pressure to achieve something. Anyhow, this is just my personal opinion and not in the scope of this thesis.



**Figure 42. User testing at the Kindergarten Museum: planting flowers.**

## 9 Conclusions

To me the MOTS project offered a great learning experience. Reflecting on the time that the project started, I think my designer identity has created more branches. I feel that my roots are still strongly based in sound design but I have also found my courage to look towards new directions. Nowadays, I orient myself more holistically towards sound design. During the project I have had a chance to collaborate with designers and researchers from different fields. They are all my teachers.

My starting point was to turn an old toy into a new interactive play environment. The process included five phases. 1. Background research, 2. Prototype testing, 3. Evaluating, 4. Concepting and 5. Producing the final product. The emphasis was strongly in the background research. The nature of the productions as a large-scale required detailed research on the target user group and the technology. One of the biggest challenges of this project was to design and produce a long lasting and aesthetically pleasing installation.

The timetable of the project allowed me to experiment with different design materials and practices. Over the production time I strengthened my personal design skills by experimenting in unfamiliar design arenas and used different user-centered design approaches. Some of them were more experimental than others and perhaps served more the author's learning than the goals of the production. However, I feel that all the phases were needed in order to fulfill the requirements of the production.

The MOTS idea morphed constantly during the process. I started with a simple blocks made out of paper and embedded with technology. Then the design combined a multi-touch table system and embedded tangible cubes. An ambitious idea of combining two technologies and creating a six degrees of freedom solution was not fully realized. However, the information gathered during the tangible interaction phase revealed useful information of existing prototyping technologies and their possible usages. Combining interactive physical elements explored in this project and existing open source multi-touch systems such as ReactIVision it is possible to gain results for creating new kinds of expressive 3D audiovisual interface systems. The initially designed interaction and sound design concepts were partly realized. In the future in the MOTS design track we take into consideration implementing the missing features. Connecting the MOTS

system to the network would open great possibilities for future research and concepts.

Often new media design productions require multidisciplinary design teams. I personally believe this is the design direction of the future for creating new ideas and professionally produced art and design artifacts. I also think that sound in new media design has a responsibility to reflect sounds as design elements that make a difference to our socio-cultural environment. In complex productions such as the MOTS a sound in new media design can act as a bridge between the different design knowledge from many fields. At its best the production team can achieve a shared understanding and produce new, meaningful and perhaps unseen design experiences that can improve the quality of many peoples' life.

# References

## Publications

BAUHAUS-ARCHIV BERLIN, 2009, Bauhaus a conceptual model, Hatje Cantz, Ostfildern, Berlin.

BROSTERMAN, N, 1997 , "Inventing Kindergarten", Incorporated, New York.

DOURISH P, 2001, Where the Action is, The Foundations of Embodied Interaction, The MIT Press, London.

HABRAKEN, N, 1987, Concept Design Games, MIT Department of Architecture, Cambridge.

KONTUNEN, J, 1990, Musiikin hielet 1, Perustiedot, WSOY, Juva.

LUPTON, E and Miler J. A, 1991, the abc's of triangle, square and sphere, the bauhaus and design theory, Princeton Architectural Press, New York.

NOBLE, J, 2009, Programming Interactivity, A Designers guide to Processing, Arduino and openFrameworks, O'reilly.

O'SULLIVAN, D and Igoe, T, 2004, Physical Computing, Sensing and Controlling the Physical World with Computers, Thomson Course Technology, Boston.

SANDERS, W & Cumararatunge, C, 2007, ActionScript 3.0 Design Patterns, O'Reilly, California.

YOUNG, R, 2003, Undercurrents, The Hidden Wiring of Modern Music, Slapping Pythagoras, The Battle for the Music of the Spheres article, Continuum, New York.

## Articles

ISHII, H and Ullmer, B, 1997, Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, MIT Media Laboratory, Tangible Media Group, Cambridge

OULASVIRTA, A, Kurvinen, E and Kankainen, T, 2003, Understanding contexts by being there: case studies in bodystorming, Springer-Verlag London Limited 2003, London.

## Online references

ARDUINO, Web site, <http://www.arduino.cc>, [read March 15 2010].

DIFFUSED ILLUMINATION, Web site, [http://wiki.nuigroup.com/Diffused\\_Illumination](http://wiki.nuigroup.com/Diffused_Illumination), [read March 5 2010].

DIGI/XBEE, Web site, <http://www.digi.com/products/wireless/point-multipoint/>, [read 15 March, 2010].

DIKA, P, Web site, <http://www.infinet.at/penestadika/>, [read March 6, 2010].

ESSL, K, Web site, <http://www.essl.at/works/rtc.html>, [read March 6, 2010].

FTIR, Web site, <http://wiki.nuigroup.com/FTIR>, [read March 5, 2010].

FUNNEL, Web site, <http://www.funnel.cc/>, [read March 15, 2010].

FIDGEN, Web site, <http://code.google.com/p/fidgen/>, [read March 15, 2010].

GENERATIVE MUSIC, Web site, <http://www.generativemusic.com/>, [read March 6, 2010].

LUDERSCHMIDT, J, Web site, <http://code.google.com/p/fiducialtuioas3/>, [read March 6, 2010].

CIONINI, F, Web site, <http://www.todo.to.it/blog/oscar/>, [read March 6, 2010].

KALTEBRUNNER, M / reactIVision, Web site, <http://reactivision.sourceforge.net>, [read January 23, 2010].

DOUG ENGELBART INSTITUTE, Web site, <http://www.doungengelbart.org/firsts/mouse.html>, [read March 15, 2010].

SANDLER, S, Web site, <http://sethsandler.com/audiotouch/bloom-generative-music-application/>, [read March 6, 2010].

HABRAKEN, N., J, [http://www.habraken.com/html/concept\\_design\\_games.htm](http://www.habraken.com/html/concept_design_games.htm), [read January 22, 2010].

PROCESSING, Web site, <http://processing.org/>, [read March 6, 2010].

TED TALK, Web site, [http://www.ted.com/talks/jeff\\_han\\_demos\\_his\\_breakthroughtouchscreen.html](http://www.ted.com/talks/jeff_han_demos_his_breakthroughtouchscreen.html), [read March 15, 2010].



WEISER, M, Web site, The Computer for the 21st Century, <http://nano.xerox.com/hypertext/weiser/SciAmDraft3.html>, [read February 3, 2010].

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# Appendix



Appendix 1 (drawings by Anna Salmi).

## Music of the Spheres

Interactive Prototyping Course, Spring 2009



**Matti Luhtala**  
Helsinki, 7.5.2009

Pete the Spring is playing with his new blocks. With those he can build amazing shapes and patterns.





If Pete moves or rubs individual blocks against each other they start making simple sounds.

Soon Pete discovers that he can create several unique sound collages attaching more blocks together. Now the blocks act like an music instrument.



Pete's friend Minttu the Nut is visiting Pete. She shouts at the door: "Look Pete what I have with with me". Minttu has her own blocks as well.

Pete presents proudly his buildings. "Look how tall it is. Nice that you are here. Now can play together with more blocks.



Pete and Minttu share their blocks. Together they can create even very complex visual and sound shapes and patterns.

Appendix 2. Pre-Use questionnaire to the users (Modified from Lutz Gegner's version).

**Nimi/Name:**

**Ikä/Age:**

Työlsä/Dull

Jännittävä/Thrilling

☐

☐

☐

☐

☐

Helppo/Easy

Vaativa/Demanding

☐

☐

☐

☐

☐

Tavallinen/Ordinary

Luova/Creative

☐

☐

☐

☐

☐

Monimutkainen/  
Complex

Yksinkertainen/  
Simple

☐

☐

☐

☐

☐

Vallaton/Wild

Hallittu/Controlled

☐

☐

☐

☐

☐

Viihtyvä/Interesting/  
Surprising

Ennalta odotettava/  
Predictable

☐

☐

☐

☐

☐

Yksilöllinen/  
Unique

Mukaanottava/  
Participatory

☐

☐

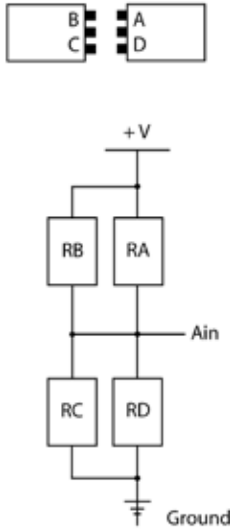
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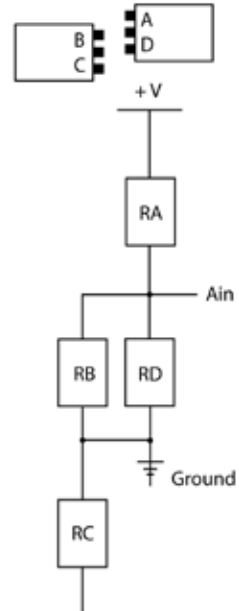
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Appendix 3. Connecting resistors schematics: [Design: Jussi Mikkonen and Matti Luhtala].

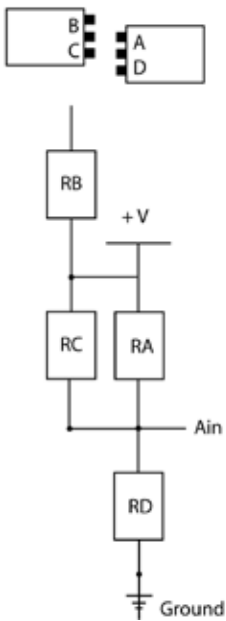
**Scene 1 (All resistors connected)**



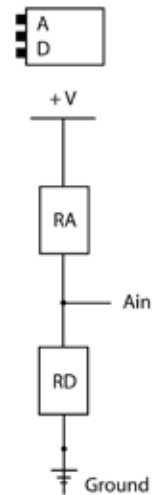
**Scene 2 (resistor C not connected)**



**Scene 3 (resistor B not connected)**



**Scene 4 (resistors A and D connected)**



Appendix 4. Choosing resistors chart: [Design: Jussi Mikkonen and Matti Luhtala].

	Side 1	Side 2	Side 3	Side 4
Ra	4700	4700	10000	10000
Rb	10000	4700	22000	21341
Rc	4700	10000	6800	22000
Rd	6800	4700	22000	200000
+V	5	5	5	5
Vref	5	5	5	5
resolution	10	10	10	10

-----

Rylä = Ra  Rb =	3197.28	2350	6875	6809.29
Rala = Rc  Rd =	2779.13	3197.28	5194.44	19819.82

Rb  Rd =	4047.62	2350	11000	19283.37
Ra  Rc =	2350	3197.28	4047.62	6875

-----

Scene 1

All resistors con'd

Vain	2.33	2.88	2.15	3.72
Analog value	475.71	589.63	440.28	761.41

-----

Scene 2

Rc not connected

Vain	2.69	3.33	2.38	1.71
Analog value	549.65	682	487.14	349.35

-----

Scene 3

Rb not connected

Vain	1.28	2.02	0.78	0.17
Analog value	262.74	414.17	158.97	34.00

-----

Not connected

Only Ra and Rd

Vain	2.96	2.5	3.44	4.76
Analog value	604.90	511.5	703.31	974.29

Appendix 5. List of technical related components and cost estimate



<b>List of components (prices in the year 2009)</b>	<b>Price</b>
Class: 75 cm diameter (acid class)	120,00 €
Infra leds: OSRAM SFH485 (880nm), 1.5 v 100 (mA)	69,00 €
Camera: Unibrain Fire-I (Fire-i™ Digital Board Camera)	100,00 €
Lens Unibrain (80.95°wide, without infrared filter)	20,00 €
Projector: Optoma EH5255T	1190,00 €
Mirror: Regular mirror (front side mirror would be desired)	30,00 €
Infrared filter: INSTRUMENT PLASTICS (filtering 50 nm to 2000 nm)	100,00 €
Halogen lamps: Two Ikea lamps with 28 Watt bulbs	20,00 €
Computer: Apple Mini, 2 GHz Intel Core 2 Duo, 2 GB 667 MHz RAM	575,00 €
Speakers: M-Audio, Studiophile BX5a	350,00 €
Ceiling mount: K&M 24195 Wall & Ceiling Bracket	100,00 €
Supporting structures: Wood and veneer	250,00 €
Foam: 2 cm thick	80,00 €
Fabrics	120,00 €
Additional components: Ventilator, electric wires, audio cables	100,00 €
<b>Total</b>	<b>3224,00 €</b>

Appendix 6. MOTS interaction - user scenario (drawing and story by Anna Salmi).

