Design and Evaluation of Interactive Musical Fruit

Cumhur Erkut, Stefania Serafin, Jonas Fehr, Henrique M.R. Fernandes Figueira, Theis B. Hansen, Nicholas J. Kirwan, and Mariam R. Zakarian
Aalborg University Copenhagen, Medialogy
A.C. Meyers Vænge 15
DK-2450 Copenhagen SV, Denmark
+45 9940 258
{cer,sts}@create.aau.dk, {jfehr,hferna,tbha,nkirwa,mrza}13@student.aau.dk

ABSTRACT
In this paper we describe the design and evaluation of a novel, tangible user interface for interaction with sound, to be implemented in a museum setting. Our work-in-progress is part of a larger concept for an installation prioritizing a collaborative, explorative, multimodal experience. Focus has been centered on novice children, in order to accommodate all potential users of the museum, and to minimize the risk of excluding users based on skill or previous musical know-how. We have developed four instances of a multimodal device for interacting with sounds via a tangible interface, and called them Interactive Musical Fruits (IMFs). The IMF consists of an embedded processing system, which can detect its orientation. Qualitative testing with children has been performed, to better evaluate the current design state. Positive feedback from the test subjects upholds the validity and the potential of the IMF as an interface in a museum context. However, further research is required to improve the interactive and collaborative aspects of the device, as well as the aural and visual properties of the IMF.

Categories and Subject Descriptors
H.5.2 Information Interfaces and Presentation (e.g., HCI): User Interfaces – *evaluation/methodology, interaction styles, user-centered design.* K.3.0 Computers and Education: General.

General Terms
Performance, Design, Experimentation, Security, Human Factors.

Keywords
Tangible and embodied interaction, musical instrument, IMU.

1. INTRODUCTION
We present our ongoing work on an interactive musical installation, which aims to provide the visitors an experience of making music together, without necessarily having musical skills or expertise. Our framework builds upon a *tree metaphor*, and consists at the moment of four tangible interfaces (*fruits*) that are connected to a central unit (*trunk,* used for synchronization) via *branches.*

IDC'14, June 17-20, 2014, Aarhus, Denmark.

http://dx.doi.org/10.1145/2593968.2610451

The concept, created for The Danish Music Museum in Copenhagen, is illustrated on Fig. 1. The museum is in the process of moving to a new facility where a dedicated room will be used for new musical initiatives. In a brief, they expressed an interest in including users from all age groups. The museum as a setting comes with certain inherent constraints, such as the development of immediately understandable and intuitive designs, as one cannot expect the visitors to spend any considerable amount of time on learning to use a new interface. Prior knowledge of music cannot be assumed as a prerequisite; novices (e.g. children) have to be catered for. Finally, the museum emphasizes the following learning goal: all current and past musical instruments, however sophisticated or advanced in form and function, consist of elementary interactions initiated by human action. This is a strong call for us to revisit *embodied interaction* and *action-sound* relations as background material and design inspiration.

The rest of our contribution is as follows. After providing a brief background on the concepts outlined above, we describe our design process in Section 3, together with the implementation of both hardware and software. The next section focuses on testing, Section 5 presents a discussion of the results, and we conclude the paper in Section 6.

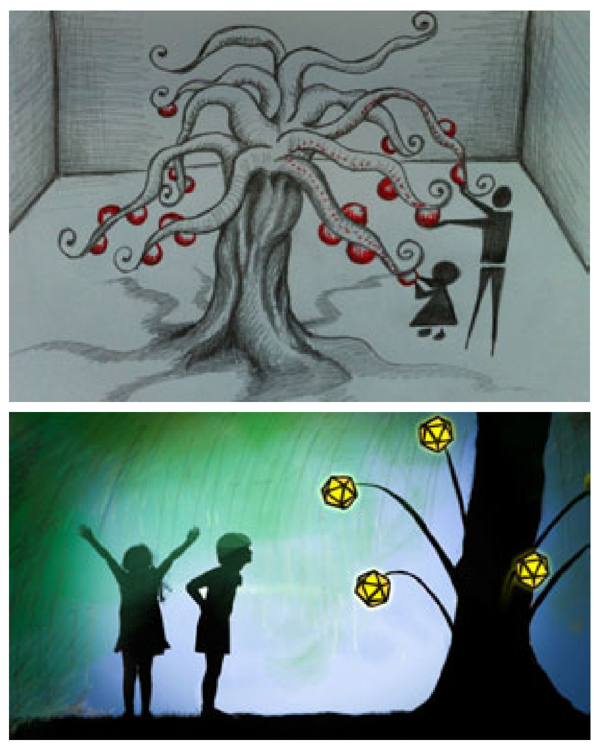

Figure 1. Our concept. © Mariam R. Zakarian, 2013.

2. BACKGROUND

In [3], a comparative overview of several contemporary, collaborative interface designs related to music-making for novices is provided. Felts & Lyon update this line of work annually in their "Gentle Introduction to NIME" tutorial series; the interested reader is referred to their tutorials for extensive references on easy user interfaces for music and interactive sound installations. Many of the conclusions, in particular those relating to collaborative interfaces, have been very relevant to our work. For instance, an interface that is *novel to all users* is beneficial in ensuring that users with different musical abilities can have the same starting point [3]. Similarly, *identical interfaces* for all users make it possible to quickly comprehend other user's input, once one has understood the use of one's own device. This is a way of shifting focus from the single interface to collaboration, and making it possible to learn from each other as well.

One way of creating an explorative, collaborative musical interface is to focus on a tangible design [4], which provides good opportunities for discovery and participation among users. Bakker and her colleagues [2] note that physical objects, unlike purely virtual ones, can help facilitate bridging the gap between the abstract and the concrete for children, e.g. as is the case when working with an abacus to learn math. Tangible interfaces can provide rich sensorimotor engagement and ease of understanding, which can in turn enhance the experience of music and stimulate discovery and participation [2]. In their investigation of using embodied metaphors in design, Bakker et al. note that even small children (of age four) are capable of understanding musical expressions such as volume and tempo, their vocabulary however is too restricted to articulate what they hear. One way to alleviate this problem is to avoid using language in exploration, and to allow children to explain via movement [2].

Besides embodied metaphors, the IDC community identifies a need for a wide set of expertise in building technologies with innovative forms of interaction [1], and emphasizes that breadth of expertise is key in building interactive technologies, which are tied to different content areas including music composition [1]. One such area is *sketching in hardware* by using modular, reconfigurable systems originating from the domain of designing and evaluating digital musical instruments [5, 6].

3. DESIGN AND IMPLEMENTATION

Our early ideas on design and implementation are presented in a short video at http://www.youtube.com/watch?v=-dJyK_y2CUg. Here, we provide an overview and update.

3.1 Physical Design

The main concept of the design is an interactive installation in the shape of a tree. Interactive musical fruits (IMFs) with individually assigned sounds are the interfaces, with which the guests of the museum can interact. The resulting soundscape contains a central background theme, on top of which the sounds of individual fruits are layered.

The fruits are essentially tangible interfaces containing a degree of abstraction, which are easily created through rapid prototyping, and are physically identical. We have gravitated towards an interface, which is free from musical associations. A spherical shape can be related to the shape of many different fruits, so we have adapted this shape for the prototype design. Both the *dodecahedron* and *icosahedron* were considered as simple abstractions of the sphere, as both can be unfolded into a two-dimensional plane. However, the *icosahedron* has more naturally connected edges, making it structurally more stable and more practical for rapid prototyping with the laser cutter. Prototypes were used to test the structure and gave a beneficial insight into how to encapsulate the electronic components in the fruits.

Suspending the fruits was a central part of the development of the interface. There was the need for attaching the prototype to a reference point, as the sensors inside the fruit deliver information about the interface's orientation. Through mounting the fruit to a fixed point it was possible to use the orientation to calculate the position in a two dimensional space. For a quick solution, we chose to use installation tubes for electrical wiring as a support mechanism for the prototype. The flexible properties of the tubes make it possible to move the fruit in space while also serving as a transport channel for the cable.

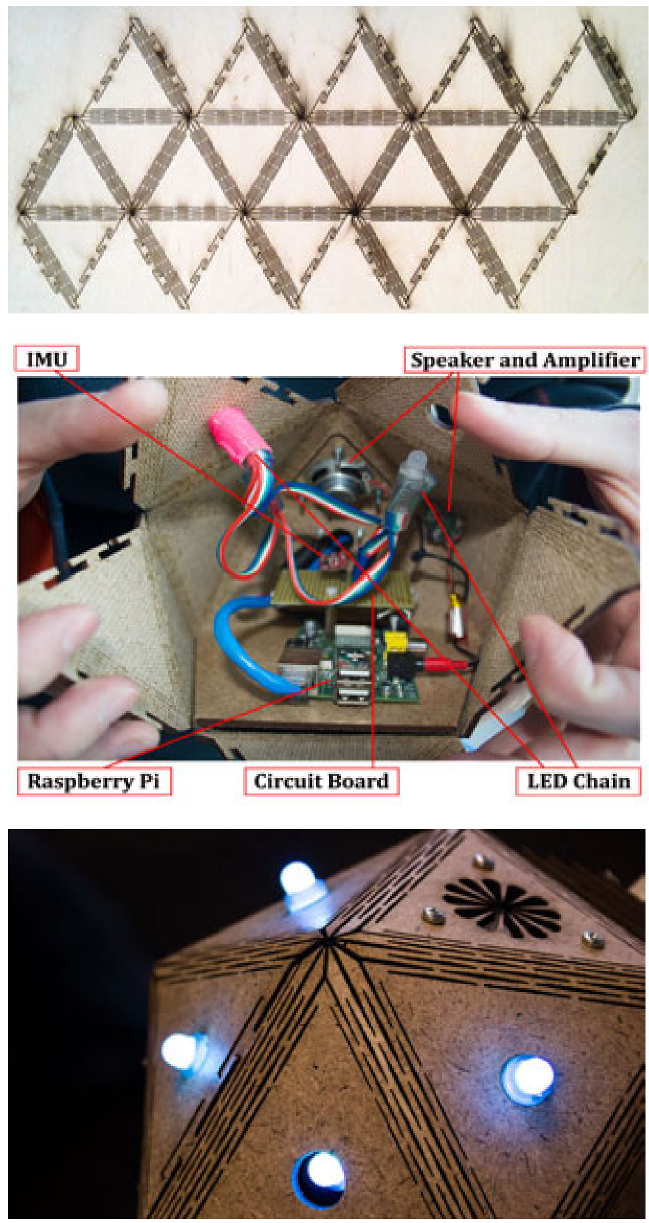

Figure 2. (Top) The icosahedron on planar plywood for laser cutting. (Middle) Inserting electronics. (Bottom) The 3D prototype. Photographs © Mariam R. Zakarian, 2013.

3.2 Implementation

Each fruit contains embedded sound synthesis and processing, which is controlled through movement. At the core of the system is a Raspberry Pi, a compact computer (Fig. 2, middle). Connected to this is an MPU-9150 *inertial measurement unit* (IMU), which collects orientation data. Visual feedback is provided by an addressable, multi-color LED chain. Audio feedback is provided by a small amplifier and speaker with a stereo 3.5mm jack input. Finally, the circuit board enables both the IMU and the LED chain to be physically integrated into the system. With the electronic components in place, the sides of the prototype are hinged together, and the result is illustrated on Fig. 2 (bottom).

3.3 Interaction and sound design

To encourage explorative gestures with the interface, we have decided to use its orientation data on two axes. This solution makes it possible to comprehend that moving the fruit to the same point will result in the same sound. Choosing left-right and up-down movements limit the parameters and the possible gestures in the IMF. This restricted control, however, contributes to making the interface more straightforward, accessible and easy to understand as far as *multimodal feedback* is concerned. More dynamic and compound gestures, considering acceleration and speed of the movement, can also be integrated into the interface in the future.

Three different sound generators were used in an attempt to implement easy-to-learn and limited control interfaces: i) a *granular synthesizer*, allowing the user to play very complex sounds using simple control implementations, ii) a sample looper, where movements control the playback speed and the volume of the sound, and iii) a plucked string simulation where the amount of played notes is randomly chosen from a pentatonic scale. Table 1 presents how the 2D actions are mapped to control, and eventually to auditory feedback.

The main sound generation and manipulation is facilitated by Pure Data (PD). Input from the IMU is received, scaled and routed to sound-generating and light-controlling parts of the program. Open Sound Control (OSC) protocol for remote messages is also supported.

Table 1. Action-control-sound mappings

Synth	Left/right	Up/down	Complexity
Granular	Playhead position	Playhead jumps	Intermediate
Sampler	Speed/Pitch Change	Volume	Low
String	Range and physical damping	Note density and feedback	High

4. TESTING

In a preliminary test, 14 participants from our university provided material for us to discover common gestures, which could be connected to musical attributes such as volume, pitch, tempo, rhythmic patterns, and timbre. The participants were videotaped while exploring the prototypes within a think-aloud protocol (examples available at http://www.youtube.com/watch?v=-dJyK_y2CUg). The exploration and comments differed a lot, therefore intuitive gestures were difficult to discern. The clearest indication of a gesture-sound mapping was the up and down movement related to volume change. While we have used this mapping in our next test, it is also likely that the flexible support tubes were more suggestive of vertical motion than horizontal, and have influenced the way the participants moved the IMF.

Our next test was with children about 12 years of age, considering our focus on novice users. Our test centered on the following questions: i) How do children *interact with and respond to our prototype*? ii) Do they interact with the prototype as *we expected* or will they show us new ways for further development? iii) How do they react on different sounds? Is abstract design a constraint?

8 children from a local school were recruited for testing. The children were presented with a short introduction to the project in two testing areas: A large room and an adjacent, smaller room. Audio was recorded from both testing areas. During testing, the gestures of the children were observed as they interacted with the prototype. They were then interviewed by the design team members. Finally, they were invited to free play with the interfaces. The free play is depicted on Fig. 3.

Figure 3. Free play after tests.

In interviews, additional questions were sometimes necessary to gauge how much the child comprehended, and because of this, the challenge during the interviews was finding the balance between stimulating the individual to answer, while at the same time avoiding influencing the answer. The interviews were conducted in the native language of the children.

The questions can be divided into three groups. The first block aimed at judging the child's musical knowledge and preference as well as getting more confident and familiar with each other. The second block aimed to assess if the child can comprehend what is being controlled and if they can describe what they hear. The focus of the test was to understand how the test subjects interact and play with the prototype. Finally, the last block was regarding the user’s overall impression of the prototype. Each child was asked which sound synthesizers he/she preferred and was encouraged to suggest changes for further development.

5. RESULTS

Almost all the children said they listen to pop music, some mentioning specific artists. Some reported musical skills, but none of them an interest in making music. Four out of the eight participants stated that they play or have played an instrument casually. Our observations suggest that prior knowledge of music is not needed for interacting with the fruit, and even with more advanced musical knowledge no difference in interaction was observed.

Most of the children were careful while interacting with the prototype in the beginning, but after encouragement they became less inhibited and moved it more confidently. A gentle, tapping motion was observed frequently, as when playing with a basketball. As they tapped the prototype, it bounced and returned by the elastic force of the branch. The children rarely took the fruit in both hands to move it in space, in order to scan for specific sounds. Some of them moved the prototype to extreme positions after being asked to investigate how it works. The majority of the time, the prototype was in continuous movement. The changing sound did not seem to provoke different gestures without different movements being requested by the interviewers.

5.1 Action-sound

All the children discovered that moving the prototype up and down had an effect on the sound. It is not possible to conclude from the test results if the children were able to understand if the sideways movements also influenced the sound, as they had to specifically be requested to perform this movement before they consciously did. Referring to Table 1, for the granular synthesizer it was not possible for the children to comprehend the mapping of gesture to sound, but several recognized that moving the fruit to the same place resulted in the same sound. Almost all the children were able to detect the speed change in the sampler. Only a few mentioned the volume as well. The third synthesizer seemed more straightforward and almost everybody recognized changes in the temporal density. Two users also mentioned the difference in sound related to moving the fruit side to side. Two of the children were reproducing specific sounds as an aid to explain the function.

5.2 Sound associations

All the participants except one mentioned a string instrument for the third synthesizer, and more than half of them associated it with a guitar. The other two patches resulted in a greater variety of answers. The granular synthesizer produced descriptions such as a parakeet, robot, an alarm clock, electronic or alien-sounds. One of the children described the sounds using a metaphor indicating playing conditions: boring and funny. The sampler (with playback speed changes) was often described with the sound's mechanics, for instance, sounding like it is being slowed down or sped up. Similar sounds were used as description, such as an airplane sound or an accident in a movie. The abstract association with a dream was also mentioned.

Describing an abstract sound is a difficult task, even for musically trained adults. Therefore, our test subjects often could not answer related questions verbally. However, some explained by direct vocalization. This is similar to what has been reported in [2].

5.3 Preferences

There were differences in sound preferences; some preferred the sampler and some the string synthesizer. Similarly, a large variance was observed in how the prototype was perceived in both shape and look. Several associations included special balls (ball/cube with corners), something from space (meteor, flying saucer), ornament, or just a specially folded box. None of the children mentioned the expected fruit. This matches our intention to keep the shape as abstract as possible.

5.4 Free play

The children displayed a clear interest in trying the prototype out of their own free will, long after the test. During this free play, it was observed that more than one child could play with the prototype at the same time. Some children used it to tease others, by holding the prototype over their heads and out of reach, as they tried to jump and grab it. Others used it as a football, bouncing it between them. One child mentioned that it could be fun to use the prototype as a swing you could sit on. It was also mentioned that the prototype is fun even without sound. The suggestions we have gathered provide us with insight that could be accommodated in future iterations.

6. CONCLUSIONS

In the pursuit of designing a musical installation for a museum, we have developed a tangible user interface for sound exploration. Starting from concept generation, we have aimed for an engaging interface that is abstract enough to invite both novices and experienced musicians. Key aspects we have addressed in design and implementation include *modularity*, *mobility*, *versatility* and *customizability*, as well as setting the *basic framework for the development of a collaborative system*. While it is true that collaboration is not investigated here and seems incidental to the reported results, our focus on the identical interfaces motivated us to investigate our design space on one interface before many. We hope that the short video at http://www.youtube.com/watch?v=-dJyK_y2CUg helps explaining our design rationale.

The overall positive response from the children during the user testing confirms that our design is progressing in the right direction. Clearly, there are aspects that need further work, especially regarding interaction. Further research is required to provide novices with a more straightforward and easy-to-use interface, as well as tailoring its use towards an explorative experience. Whether this experience is related more to sound or music is debatable; but following E. Varèse's definition of music as organized sound, we believe that exploring the relation between action, sound, and music is a relevant domain of inquiry, given the pedagogical goals of our brief. We are more interested in how the children construct this relation than what the interface does or how the sound models work. Yet, since sound is integral to our design, it will also be a major focus of further development. Likewise, the development and implementation of visuals and the actual tree interface will be concentrated on. As noted during testing, participants found the IMF interesting and stated that they would use it in a museum setting. This is a promising tendency and the concept will be developed and refined in the near future.

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