Sculpton : a malleable tangible object for musical expression

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TEI 2013, February 10-13, 2013, Barcelona, Spain
ACM

Abstract
This paper presents the actual stage of implementation of a new type of malleable tangible object for musical expression. *Sculpton* is an autonomous sonic object which uses the metaphor of sound sculpting for connecting physical information in digital audio. By manipulating the object the user can literally sculpt the sound through a real-time sound synthesis which reverberates the object structure. This project explores a novel approach compared to previous work and research around the topic of sound sculpting: user gestures is not externally sensed but within the artifact itself. *Sculpton* is an attempt for the development of a new kind of embodied musical instruments which combine multidimensional control, tangible and malleable characteristics with an organic handling. We will briefly describe the research, our framework and the actual state of the experimental prototypes.

Keywords
Tangible interfaces, interactive sound synthesis, embodiment, embedded sensors, malleable object.

ACM Classification Keywords
H5.2. User Interfaces, J.5. Arts and Humanities, Music, I.1.3. Computing Methodologies, Languages and Systems, Special-purpose hardware.

Introduction

The use of two-handed gestures is a common way to manipulate objects within our everyday environment. Tangible interfaces are a challenging framework for thinking and imagining how one can merge digital bits and physical atoms not only for controlling and manipulate digital processes and media but also to create new structures, such as within music. New digital, hybrid electroacoustic instruments and interfaces are an important experimentation field to apply these principles within tangible interaction. The increasing availability of embedded interactions, intelligent materials and the spread of interest in rapid prototyping such as 3D printing, forces us to think and push the idea of tangible interfaces beyond the reference of the surface and embrace the totality of the whole shape, volume, materiality and structure of an artifact. We introduce the development and the prototype of an autonomous tangible artifact for sound sculpting [5]. Within our concept shaping sound is an equivalent of physically shaping an object. This musical and sonic expression is made through the use of real-time sound synthesis through the form of a three dimensional organically shaped object which can be handled and modified by the user. This artifact combines many input attributes of conventional tangible interfaces (such as pressure sensitivity, etc.) with multidimensional control. The importance of building an interface that allows whole-hand interaction led us to the development of a malleable touch interface which combines a deformable object hull with an internal adaptable structure as digital representation for the generation and control of sound synthesis. In this paper we are going to document the current state and prototype design of such a malleable interface.

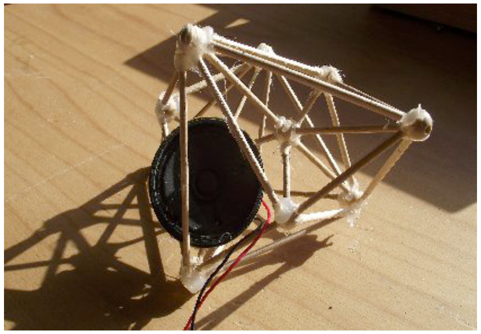

figure 1. Visualization of the concept

Framework

If we think about some actions and gestures which characterize our culture and expression, it's easy to understand how the hands are one of the most sensitive and articulated part of our body. Imagine a person who kneads bread: the movement of the hands and fingers create the most basic food for many cultures. But let's focus on the examples of sculpting and musical expression. Sculpting developed several techniques which involves the use of both hands – often without any additional tool - for modeling physical matter. For example in claying, where the shape of the final object made of material with low stiffness is often changed by placing the object on a flat surface and applying forces with the fingers of both hands [4]. In musical communication the use of hands is the basis for playing every kind of traditional musical instrument, clapping the bare hands or holding and shaking maracas are some perfect examples of the most common actions, while other more sophisticated instruments involve complex gestures and the intimate caressing of physical artifacts to produce sound and music. In this project we are proposing a new malleable touch interface, which combines the metaphor of claying for modeling real-time sound synthesis in a new type of digitally idiophone.

Sculpting

We started from the idea that malleable surfaces are the most expressive and promising metaphor for the development of new and dynamic tangible musical interfaces. If we simply compare the use of a single wooden block and a piece of plasticine, it is simple to observe that the human hand can transfer and reinforce the expressiveness trough more degrees of freedom comparing a malleable with a solid artifact. Especially this kind of surfaces are more suitable for a whole-hand interaction that involves both hands at the same time. With the term that we defined above as claying we refer to an action that transfer the bodily forces onto deformable matter or objects for modifying their shape. The idea of sculpting -going from a starting shape to another physical state- is the central concept that we have employed for achieving our musical objectives.

Interface characteristic

The challenge of this work is to create an autonomous object equipped with internal sensors, which should allow a user or musician to:

- hold and grasp and manipulate the object with both hands and fingers from each side (top, bottom, laterals);
- apply forces, such as pressure, to allow squeezing, stretching and other deformations;

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- stand-alone usage or within the constraints of other interactive surfaces or artifacts.

The interaction with the object will be intuitively improved by the dynamic binding to a creative and musical process. Every force and action applied to the object is reflected in real time digital sound synthesis through a virtual structure, which acts as a bridge where a sonic structure reverberates within the physical nature of an object.

Design space

There are two main topics for the development of this project: the tangible interaction and the sound design, which are inter-connected through a virtual model. These two layers are related though the interaction between the hands and the malleable object, that results in a reverberation of the internal object structure. Therefore this malleable tangible interface is based on three basic relation, which explain the main interaction concepts:

- external manipulation - internal behaviour;
- physical and sonic excitation – relaxation;
- spatial actuation – temporal response.

The idea of modeling synthesized sound in real time through a the sculpting of a malleable object, not only requires research in appropriate technology and materials, but also the development of mapping strategies between an organic control interface and its sonic expression.

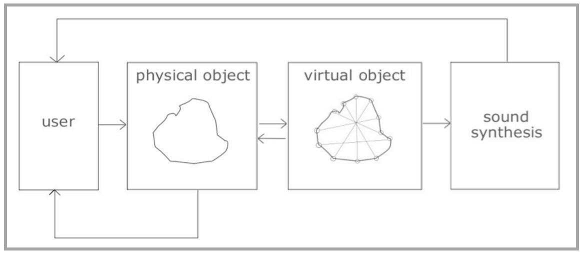

figure 2. Scheme of the interactions

Object design

The composer Alvin Lucier [3] describes the approach that some musicians used to compose their music by thinking about the instruments, and then building the actual musical instruments for their compositions. Lucier thinks about instruments that embody a representation of the composition itself within their internal structure. For this work we plan to create a structure that involves the best possible precision of movement, while the physical design should also be easy to implement, build and expand. In that case the modularity of the different elements is an important issue. We are working on a new type of a digital instrument characterized by a malleable tangible interface, where the sound expression is based on the actual object structure. The challenge of our project is to link the physical and the digital domain through a set of independent relations defined by our design space. The most important approach to the problem is to define the internal structure and the external shape of that object. Normally the structure of these objects is rigid and hardly modifiable, only some dedicated parts such as the strings, keys or a drum skin are designed to receive an external excitation by the user.

Modularity and physical Spring-mass

Modularity is a key concept for the structure and technical development of our malleable object. This idea not only embraces the structural design but also how can embody and connect digital elements within physical components. The “Triangles” by Gorbet and Orth [1] represent a key reference in the area of tangible interfaces as building blocks as a metaphor for information management. Another key component of this project is the internal structure which has to be self-sustainable and interdependent. For this we decided to adopt the physical mass-spring paradigm, considering the modularity and the mechanics of the object. Thinking about toy buildings kits such as the popular *Meccano* we can observe that they are basically composed of joints (such as magnetic spheres) and some structural parts (such as small iron tubes) that serve as connections. We can easily replicate such a system and consider that the connecting spheres are masses and the structural tubes are springs. The masses detect the position and receive the force applied from the springs (which act as a link) and in turn they receive the position of the two masses and output the forces between both of them. Our malleable object can be therefore composed with a series of masses and springs which reflects all actions and forces applied a) to the entire volume b) or in a single vertex c) and the relation between them, since each part is linked to the others.

Virtual structural

The internal dynamic structure is not only physical but its also defined by a virtual environment driven by the received sensor data. That structure is used as a model for real-time sound synthesis, the idea of reverberation of a physical structure within a virtual one (and vice versa) is very important. For this first prototype series -that we are going to describe later in detail - we have used the Pure Data library *pmpd* developed by Henry [2] to define and experiment with this structure. *Pmpd* is a library made for interactive real-time physical sound modeling employing the mass-spring paradigm. The composer can build a set of relations between masses and springs and interact with its two- or three-dimensional visual representation. This is a very useful tool to experiment with structures and to immediately explore the possibilities of a sounding structure.

figure 3. Interaction with one module

Initial prototypes

In order to embody a potential structure and experiment with the tangible interaction quality, we developed two mockup prototypes without any electronics or sensors. This design step should keep the initial statement clear and allow its verification through the experimentation with different possible solutions. These objects should form a framework for the experimentation with the overall shape, the malleable surface and the structure and also allow to test the various configuration for different sensors. The first prototype is a tetrahedron made of four wooden spheres and metal springs connect them together. This prototype can be broken down into a single sub-module made of a couple of masses and one spring. This configuration is very useful for attaching different sensors to be tested in a simple and effective way. The second is a larger prototype of the final object composed of a larger number of these structures with wooden balls and metal springs. Covering it with different materials for testing the surface quality and filled with different materials for also testing its tactile response. As we described above this was intended as a representation of malleable and tangible qualities of clay, this notion should be maintained in this prototype.

figure 4. Interaction with a covered module

Sensor experiments

The implementation of the sensors part reflects the current development stage of our project. In order to create a physical structure which sonically reverberates the physical actions by the user, the sensor implementation forms a key part of the development. The structure itself has to be composed from sensors with specific characteristics: they should detect stretching, pressure, distance, orientation and map this multidimensional data directly onto the virtual model for sound synthesis. We tried and evaluated different settings and configurations of commercial sensors, this kind of sensors usually have mechanical, size and manufacturing requirements that limit their use in non-standard applications. Comparing this to the development of wearable and textile materials suitable for interactive and augmented usage scenarios to the rigid and plain surface of the standard sensors, pushed us into the direction of a combination of modified or custom-made sensors.

Light sensor

The first problem that we had to solve is how get a virtual representation of the physical structure. Before thinking about the behavior and the malleable object characteristics we had to determine how to get the most accurate measurement of the distance variation between each masses through the springs. One of the most simple and effective way to detect this kind of information is to measure the distance between two points with an LED and a Light Dependent Resistor (LDR) and then read the variable value of that resistor. We connected this LED/LDR assembly to an Arduino micro-controller to collect the data. We used the first module described above, and attached these two elements on the opposite sides of each mass. This way one can obtain the real-time information about the variation of the distance and therefore a discrete image of the whole structure. The further way the LED is from the resistor smaller the value of the detected light. This sensor configuration is functional but not very suitable for our project. Its easy implementation and relatively low component cost did not correspond to the global usage requirements. Each couple needs a at least eight connections, which meant a lot for such a simple structure. Also the springs had to be covered for external light protection, and squeezing of the structure is neither clearly detected.

Stretch-sensor

This malleable object require a stretchable and moveable structure. We are researching on sensors and materials which can read this kind of variations. The development of new conductive materials and electromechanical components – which are used now in robotics applications- are a good starting point. We tested the Stretch Sensor[1] made by Images-Scientific Instruments1, a polymer cylindrical cord of .060-.070 diameter and 5mm of length. This component change resistance when stretched and the variation is around the 50% more of the resistance. That curve is very rapid but we noticed that the relaxation part is very slow and it shows an high impedance. We add a 1M Ohm resistor in parallel for prevent this behavior, but the variation is far for consider it for a real-time detection. We should add that the small dimension and the high price make this solution not suitable for our project.

Slide potentiometer

Our third experiment consists in the detection of the distance between two masses by using a modified slide potentiometer. As we mentioned above this approach also contains several limitations, but provides sufficient stability and robustness. This kind of variable resistors are for example used in audio mixers and are generally designed to be manipulated by hand. Their design and

[1] http://www.imagesco.com/sensors/stretch-sensor.html

appearance is very rigid, flat and of small size, therefore these elements can be easily fit into each of the individual connecting modules.

Global sensors

In addition to these mechanical sensors, we are also planning to investigate the integration of alternative sensors in order to more accurately observe the structure and behavior of the entire object. Additional pressure sensors can for example be employed for the detection of forces applied to the different surface areas of the object, while three-axis accelerometer and gyroscope can provide the object orientation in space as well as motion gestures by the user.

Embodied sound

At this point we are not going into detail regarding the methods for sound synthesis and the mapping of control data within the auditory domain. But need to discuss the question, where does the sound come from? As we described above an autonomous object should appear to produce and emit the sound by itself, which means that the sound production and speaker has to be placed inside the actual structure. This assumption is relevant for the design of our device, because humans or other living beings as well as any traditional musical instrument produces and modulates the sound inside its very body. Like the human mouth our sounding sculpture not only modulates the sound through tangible articulation but also in the production. The hands manipulating the object are influencing the timbre by filtering its sound coming from inside. Our device is characterized by an organic sound quality created and modulated not only within the actual sound synthesis, but also by the material and the physical structure of the object itself.

Conclusion and future work

This paper present the state of an early prototype development of a malleable tangible interface for musical expression through the metaphor of sculpting sound. We believe that this artifact can be an example for a new hybrid musical object, which incorporates an organic and tactile feeling. This quality has an intimate relation with the sound production: the user shapes the sound by molding the object. The goal of this project is to provide musicians an artifact for musical performance as well as for children and people with limited musical skills. The further research and development efforts will include the following tasks:

- Improvements to the sensors modules for a more accurate mapping on the virtual structure;
- Refinements to sound synthesis model and a an improved mapping strategy;
- Improvements to the organic and tactile object characteristics;
- Relation of tangible and embedded interaction to other paradigms
- Explore the relation between the internal and external object properties;
- Exploration of the embodied sound metaphor through synestaetic object, sound and interaction design;
- Reveal through the sound synthesis and the material what is inside the object How can the

internal structure can be perceived through manipulation?.

Sculpton not only represents an individual object design but a framework for the experimentation in the area of tangible musical interfaces with a new type of physical-digital sound object: beyond music controllers and gestural interfaces we are experimenting with embodied sonic sculptures.

Acknowledgements
This work is currently under development at the Interface Culture Lab of the University of Art and Design in Linz, Austria. I'd like to thank Prof. Laurent Mignonneau and Prof. Martin Kaltenbrunner for the support during the development and documentation of this project within the Tangible User Interfaces class.

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