GESTUS: TEACHING SOUNDSCAPE COMPOSITION AND PERFORMANCE WITH A TANGIBLE INTERFACE

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ABSTRACT

Tangible user interfaces empower artists, boost their creative expression and enhance performing art. However, most of them are designed to work with a set of rules, many of which require advanced skills and target users above a certain age. Here we present a comparative and quantitative study of using TUIs as an alternative teaching tool in experimenting with and creating soundscapes with children. We describe an informal interactive workshop involving schoolchildren. We focus on the development of playful uses of technology to help children empirically understand audio feature extraction basic techniques. We promote tangible interaction as an alternative learning method in the creation of synthetic soundscape based on sounds recorded in a natural outdoor environment as main sources of sound. We investigate how schoolchildren perceive natural sources of sound and explore practices that reuse prerecorded material through a tangible interactive controller. We discuss the potential benefits of using TUIs as an alternative empirical method for tangible learning and interaction design, and its impact on encouraging and motivating creativity in children. We summarize our findings and review children's biehavioural indicators of engagement and enjoyment in order to provide insight to the design of TUIs based on user experience.

AUTHOR KEYWORDS

Tangible User Interfaces, Soundscape Composition, Audio Textures, Audio Feature Extraction, Concatenative Synthesis, Musical Information Retrieval, Acoustic Ecology, Empirical Design, Musical Expression, Children Learning.

1. INTRODUCTION

Devices and systems that make use of gestures are fairly common in modern technology, and most users of that technology are familiar with use of gestures on tangible interfaces for everyday tasks [1]. We can distinguish a range of gestures used in communication, independently of computers and technology. The gestures we use differ greatly between cultures, but they are always intimately linked to communication [2]. Gestures exist alone or in combination with other objects.

Tangible user interfaces work through the direct manipulation of physical objects and thus provide concrete means of interaction. They are more explorative, collaborative and expressive compared to traditional graphical interfaces [30]. While the use of TUIs in society is steadily growing and tangible interaction benefits entertainment (games, fun applications) and learning (educational toys, robots for children), there is research that reports lack of empirical evidence supporting the benefits provided from TUIs. [6] [30] [4]. Common reviews of studies that focus on tangible interaction, mostly discuss the potential benefits that TUIs can bring to adults in terms of usability. Although, not much is known for younger ages [32]. We predominantly aim to investigate how tangible interaction can be beneficially used as an alternative method for teaching children. We developed an interactive tangible interface, called Gestus, which enables kids to experiment with basic-to-advanced music composition principles and explore soundscapes through audio textures. Our aim is to activate kids' imagination by providing them a blank canvas with minimum-to-none set of rules to draw upon. Similar to the early stages of drawing, children are exploring art materials in a playful way. Scribbles transform progressively from random and uncontrolled, to steady and more controlled gestures. Drawings then become far more detailed and complex.

2. BACKGROUND

2.1. Initial Condition: An Informal Learning Environment

Our educational experiment was based on the premise that learning differs between children and adults in that children can learn through playing while having fun at the same time. Therefore, it makes sense to create educational game-like environment for creating sounds. An example of a learning environment that is less rigid than a traditional classroom is the informal museum [30]. Such environments motivate schoolchildren to learn by permitting them to experiment freely and do the things which they like. This experiment also involved exploring the potential of a introducing a fun-based TUI as a learning tool to support children's musical education as well as to encourage social interaction and increase collaborative work.

2.2. The Role of Gestures

Most of us have been exposed to various devices and systems that make use of gestures [1]. We can distinguish a range of gestures used in communication, independently of computers and technology. The gestures we use differ greatly between cultures, but they are always intimately linked to communication [2]. Gestures exist alone or in combination with other objects.

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With respect to objects, there are a broad range of gestures that are almost universally understood or used. These gestures can be classified into three types according to their function [3] :

- *semiotic:* those used to communicate meaningful information.
- *ergotic:* those used to manipulate the physical world and create artifacts.
- *epistemic:* those used to learn from the environment through tactile or haptic exploration.

Additional research reviews the educational uses of tangible devices from a psychological and educational perspective [4]. It claims that tangibles are beneficial for learning since:

1. physical activity is important in learning. Children can demonstrate knowledge through physical activity.
2. physical - hence concrete - objects are important in learning. Children can often solve problems when given concrete materials to work with.
3. physical materials give rise to mental images which can then guide and constrain future problem solving in the absence of the physical materials.
4. learners can abstract symbolic relations from a variety of concrete instances.
5. physical objects that are familiar are more easily understood by children than more symbolic entities. [4]

3. RELATED WORK

3.1. Related Work on Tangible Interfaces

We mention here research which has influenced the design of our TUI: Digital Manipulatives [7] [8] are TUIs that build on educational toys such as construction kits, building blocks, and Montessori materials. CALL is a computer-assisted language learning in a ubiquitous computing environment. The environment, called TANGO (Tag Added learNinG Objects) system, detects the objects around the learner using RFID (Radio Frequency Identification) tags, and provides the learner the right information for language learning [9] Webkit, an application which uses a large-screen graphical user interface and a tangible user interface to teach children important rhetorical skills [10]). I/O Brush, a new drawing tool aimed at young children, ages four and up, to explore colors, textures, and movements found in everyday materials by "picking up" and drawing with them [11]. Sensetable is a system that electromagnetically tracks the positions and orientations of multiple wireless objects on a tabletop display surface. The system offers two types of improvements over existing tracking approaches such as computer vision [12]. The scoreTable is a tangible interactive music score editor which started as a simple application for demoing "traditional" approaches to music creation, using the reacTable [13] technology, and which has evolved into an independent research project on its own [14]. Finally, Shapiro et al. have developed *BlockyTalky*, a Python based environment for teaching the programming of interactive music applications to children [15].

3.2. Audio Feature Extraction

In our work the main aim was to make the exploration of recorded sounds and the performance or composition of soundscapes from them more approachable to artists and children. We use our TUI as instrument to explore the textural elements of natural audio sources that surround us in our acoustic environment using Audio Feature Extraction. Examples of include: OpenSMILE [16], Marsyas [17] and Yaafe, an audio features extraction toolbox in which users can easily declare the features to extract and their parameters in a text file. Features can be extracted in a batch mode, writing CSV or H5 files [18]. Audio Metaphor uses techniques from natural language processing, machine learning, and cognitive modelling to autonomously create audio mixes from text sentences. The application of the AUME is a generative and interactive system for sound art, film sound, and game sound using a sub-query generation algorithm, SLiCE (String List Chopping Experiment) that accepts a word-feature list, parsed from a natural language query by another component of the Audio Metaphor system, and returning recommendations to the soundscape composer [19] We used SCMIR (SuperCollider Music Information Retrieval) [20] as way to perform Concatenative audio synthesis.

4. THE GESTUS TUI SYSTEM

The basic design of Gestus is inspired by the reacTable system. Gestus consists of a semi-transparent surface for placing objects with fiducial shapes for identification (using the Rear Diffuse Illumination, method for tracking) and a camera for inputting the objects, an open source software component for tracking these fiducials (ReacTIVision), a software component for translating the messages received from the tracking system into state changes, and system for real time CSS based on the tracked states. The software has been developed on a Macbook Pro using SuperCollider as a logic and real-time synthesis programming environment.

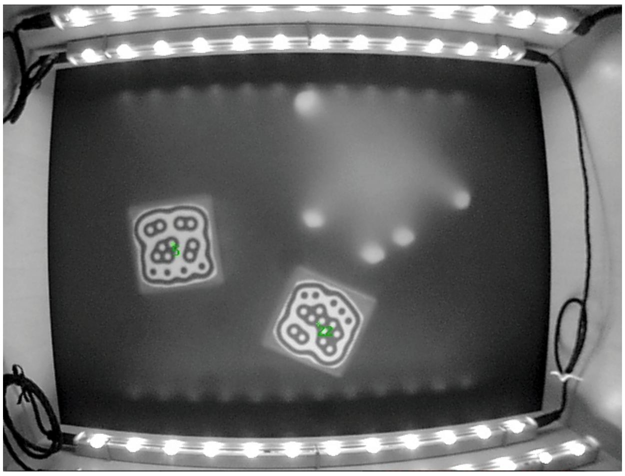

Figure 1: Interior view of the Gestus system, showing the touch surface with fiducial objects and fingers touching.

Gestus uses TUIO for transmission of touch-events. TUIO is a communication protocol based on Open Sound Control [21] designed to meet the requirements of table-top tangible interactive surfaces. [13] [22]

Figure 2: Pictures of the Gestus system

To control sound synthesis on Gestus, the user places cubes or other objects which show fiducial shapes on a flat surface of a semi-transparent acrylic material. An infrared camera can detect these fiducial markers through Computer Vision. Each fiducial can correspond to one sampled sound coupled with a sound processing algorithm. When the user places a fiducial object on the board, the corresponding sound starts playing, and when the user removes the object, the sound stops. It is thus necessary for the system to know when a new object is placed on the board and when one is removed from it. However, for each frame analyses by the Touch Detection Computer Vision software, TUIO transmits a vector listing the IDs of the fiducial elements detected together with their position and orientation on the board. In other words, the system does not give any indication when a new fiducial element is placed on the board, or when one is removed from the board. We designed an algorithm that detects when objects are placed or removed from the board. We compared the three events in the timespan of an objects existence on the table to the events “birth”, “death” and “life”.

- Birth: the appearance of a new fiducial object on the table-top surface.
- Death: the removal of a fiducial object from the table-top surface.
- Life: the continued existence of an object on the table-top surface. Each life item is accompanied by the ID of the fiducial and its position and orientation on the table.

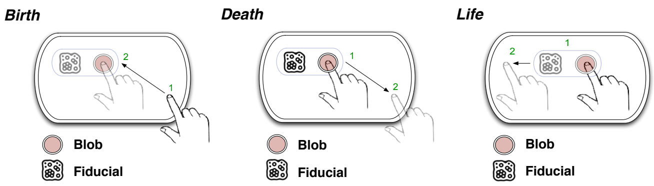

Figure 3 Three states of a fiducial event.

5. CONCATENATIVE SOUND SYNTHESIS

CSS is a method for re-synthesising textures from sound samples, by combining (concatenating) small fragments of a sound sample based on their perceptual features. We used it in this experiment because it is an efficient method for navigating inside sampled audio interactively using perceptual features of its contents as a criterion. So far, CSS synthesis has not been tested on an interactive tangible interface or an interaction model in a free exploratory manner.

CSS focuses on four main synthesis applications: high level instrument synthesis, re-synthesis of audio, texture and ambience synthesis and free synthesis [30]. In CSS, audio samples are selected based on their features. A feature is understood here as the value of a parameter describing a property of a sound object. The relevant features in CSS are properties related to their a number or a component that describes a property of an object. Relevant properties in the field of digital audio are those that relate to perceptual properties of the sound according to psychoacoustic research, i.e. timbre, pitch, harmony, smoothness etc. Examples of measurable features through analysis are spectral centroid, spectral flatness, Mel-frequency cepstral coefficients (MFCCs) etc. CSS is particularly effective in the synthesis o audio textures, that is sets of short-duration-samples whose perceptual features remain stable over relatively long time intervals (e.g., rain, wind) [23].

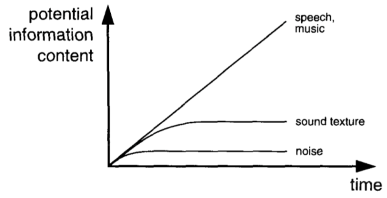

Figure 4: Potential information content of a sound texture vs. time [22].

1. Sound textures are formed of basic sound elements, or atoms;
2. Atoms occur according to a higher-level pattern, which can be periodic, random, or both;
3. the high-level characteristics must remain the same over long time periods (which implies that there can be no complex message);
4. the high-level pattern must be completely exposed with in a few seconds (“attention span”);
5. high-level randomness is also acceptable, as long as there are enough occurrences within the attention span to make a good example of the random properties [22].

We applied feature extraction methods on sounds recorded from sound sources in the natural environment (e.g. sounds of a forest, rustling of leaves, chirping of birds) or created by some interaction between the children and nature (e.g. scratching wood, rubbing a rock, washing hands on a well etc.). Feature were extracted using the SCMIR [19] library on SuperCollider. We then used these sounds in teaching and workshop sessions with schoolchildren, encouraging them to experiment with sounds in order to compose music using the Gestus TUI.

6. THE EXPERIMENT

6.1. The Workshop

Our educational experiment was conducted in the framework of the EASTN children workshop and lasted for 5 days. The participants 32 schoolchildren of both genders (18 male, 14 female), aged within 93% between 6 and 15 years. The children were volunteers and parental permission was given to participate in the workshop. All participants used Gestus daily. Only 5% had used similar interactive interfaces before, however another 52% had used interactive learning environments one or more times.

Our workshop anatomy involved an iterative cycle of four steps: *experience*, *record*, *listen* and *improvise*. Thirty two participants were assigned to one of four groups based on their age (2x 6-10) and (2x 11-15) with gender roughly balanced. Ten short experimental compositions were created for the purposes of the study. We provided guidance through the entire process of the workshop. For the recording we let all groups out in the field for one hour to capture natural sounds relating to gesture and touch. In each group, all children participated in all process stages until the project’s completion and in each duty role (recordist, boom operators, tangible user, audio editor, pre and post production). Each member of the group has completed a training session which involves three main tasks to experiment with sound. Users were taken out on the field to explore sounds made from natural sound sources and relate them to hand gestures with view to their potential of creating new sound textures. Users were asked to write down when a particular gesture was causing a significant interest or represented balance. Each group has recorded at least 3x samples for each individual (approx. 25) using using a Tascam DR100 handheld recorder at 24bit/96kHz. Those were collected to form a sound library. All tasks were accompanied with set of written survey questions and a series of qualitative interview questions, reported by [29]. The workshop was recorded on video.

Figure 5: Photographs taken during the EASTN workshop.

Ten experimental compositions were created by the kids under the title “Touching The Village”. This study is not a fully controlled experiment; yet we can discuss results in terms of groups, ages and genders and make statistical comparisons taking into account data from each group. The data analysed were: videos of work sessions with the children, a questionnaire about the experience of working with Gestus, and the recordings of performances made with Gestus. We looked for common traits in usability, machine learning, fun-driven and motor cognitive learning as well as musical aspects such as spectrum, timbre, duration, textures of each one of the 10 compositions.

6.2. Evaluation Guidelines

The goal of the evaluation is to determine whether the system is able to provide an alternative educational yet entertaining way to learn how to create sound textures and to evaluate methods for improvisation and experimentation with Gestus as a learning tool that could be applicable in music schools, workshops and live performances. In addition we sought to identify errors in the system’s design in order to develop new interaction ideas. Therefore we analysed data based on user experience studied key factors that may contribute to further development of the system.

We assessed the initial experience of the user with the system. We asked teams to answer both open-ended (for each group) and closed-ended (for each individual) questions:

- Were participants able to gain a thorough understanding of the basic interaction of the system? What did they learn?
- Were all participants able to "play" even with a little guidance? Were participants experience any problems with the multitouch surface and the objects?
- Were participants able to work as a team? Does team work helped them to learn about the collaborative music composition?
- Were participants able to comprehend how their choices affect the state of the game in real-time? Did they comprehend that there is not a specific order of use?
- Were all participants regardless of age able to comprehend the different types of audio features through interaction with the interface?
- We all participants able to describe the interactive experience? Did they like the game? Would they like to play again?

A seven-point scale (Likert) was used for this evaluation where 1 represents “strongly disagree" and 7 “strongly agree”. The closed-ended questionnaires were analysed according to descriptive statistics (average, median, standard deviation) in order to determine how effectively the system has responded to the initial objectives of design interaction. We also studied all participants’ responses in order to re-evaluate and create open-questions which will provide a new framework for research. Additionally, we conducted informal interviews with all participants during the course of the weekend. The analysis of the results was based only on questionnaires. Reports of informal interviews were held only in cases that they provided a framework for results. We tried to identify any issues in areas where responses were less positive. Other evaluation questionnaires (artists / amateur use) are not listed in the tables presented on this report.

6.3. Questionnaire Results

Table 1. Questionnaire: Experiential qualities of using Gestus

Questions	Average	Median	Standard Deviation
Q1. Playing this game I gained better understanding of interaction in music creation.	5,4	5,5	1,113
Q2. Playing this game I realised how easy it is to make changes to sound in real-time.	6	6	0,632
Q3. By playing this game I have actively collaborated with other players.	5,4	5	1,019
Q4. I played the game mostly on my own.	4,1	4,5	1,513
Q5. Collaborating with others helped me learn something new about creating music in groups.	5,4	5	0,489
Q6. I like to play this game with other players.	5,5	7	2,334
Q7. I liked the fact that I could use my hands to move objects on the multi-touch surface.	6,1	6	0,7
Q8. I liked the fact that I do not need to wait for my turn, in order to play this game.	6,2	6	0,785
Q9. I enjoyed playing this game because I have learned how to create music without musical skills or the ability to play a musical instrument.	5,3	5	0,642
Q10. I would like to play this game again.	5,8	6	0,748
Q11. I enjoyed playing this game.	6,1	6	0,538

7. OBSERVATIONS AND DISCUSSION

When recording sounds, all teams used various interactive ways (scratching, hitting, rubbing, touching, interacting using objects) in order to create audio textures. This shows the immediacy of the first primitive thoughts when it comes to create sound textures by using hand gestures. These first efforts of interaction we could mainly describe as continuous, simultaneous and hasty. This shows children’s confusion and the resultant hesitation to interact at the initial stages of the experience [30]. Sometimes children needed guidance and encouragement to develop their own sound production techniques. For example in the recording process for the track called “Bell”, kids were hesitant to experiment with textures by exploring the surface of the bell, shouting in the bell's cavity or interacting with any other way. Instead they were creating sounds by naturally using the bell (pulling the rope).

With the completion of the first two cycles (*experience*, *record)*, samples that were interesting in terms of texture and showed variety in terms of frequency were assigned to fiducial objects.We noticed that it doesn't take long for children to recognize the relationship between their movements and the objects placed on the surface. As this development stage progressively unfolds, children begin to control their movements by varying their motions and by repeating certain actions that give them particular pleasure.We observed that occasionally youngest kids had a tendency to accelerate and the fiducial objects vigorously, to an extent that might endanger the experimental setup.

All participants have used the system to interactively experiment with the sound samples. At the end of each group session, we created small teams in order to evaluate the system's interaction design when used concurrently. Most of the participants described their second experience with the system as "very entertaining". Additionally, we observed that children were using the system more methodically. Some maintained that they had developed their own techniques and others believed that they invented unique "combo actions". By the end, the majority of the kids had developed their own methods of interaction with the system and the musical structure of their compositions had improved remarkably. Scribbles were transforming into methodical based-actions. One could notice a shift towards exploring the textural aspects of each sound, along with the desire for soothing moments and the effort to create points of climax in the composition. We observed that as the kids gained more experience they strove to work individually. We classified children's interactions into categories, based on their characteristics.

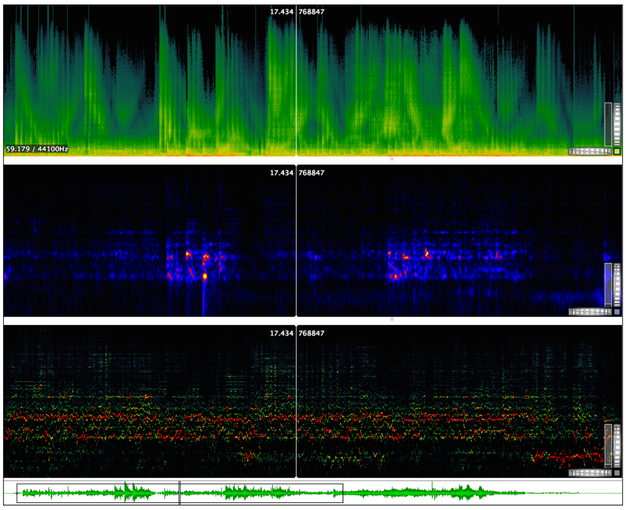

Figure 6: Spectrum, Dynamic Peaks, Harmonicity.

Scribbles may not make any sense to adults but they are very important to a young child. Drawing and scribbling are the first steps of using the skills children will need later for writing [33]. We observed that some of the primitive gestures of the kids were simply musical scribbles, other were more determined and complex, or even some that were real-time oriented. All of them were clearly age-related. Children of younger ages (6-9) were creating random and uncontrolled movements in order to explore the surface and to play with Gestus similar to a toy or a drawing game. We provided some guidance for them to start identifying how their gestures affect the corresponded sound changes. We can classify their movements mostly as uncertain, abstract and explorative. Children of the second age group (9-12) were more interest in exploring the system's limitations by forming various geometric patterns and shapes (circles, squares, ovals) but without being as wildly creative. Their movements were controlled and consisted predominantly of straight lines (vertical, horizontal, zigzag, etc.) They were predefined and directional. Children in the last age group (13-15) were creating more complex moves. They experimented with speed (acceleration and deceleration the objects), rotation (spins or spinning while moving the object simultaneously), or creating asynchronous movements and combinations using both hands and multiple objects. Children explored sound textures interactively based on what they were hearing in real time. Finally, there were movements representing symbols, lettering or word spelling. We can describe this age-group movements as explorative, complex and dynamically experienced.

Children's reactions were mostly positive. By eliminating rules or gameplay limitations we observed an increased tendency for experimentation, collaboration and fun. This included smiles, playful moods and excited reactions, as well as moments of concentration and a plethora of questions. These were mostly interaction oriented questions (in terms of system usability and music composition) and questions that concerned system's construction (what is inside the box, cost, mobility etc.). We observed that females worked with more concentration on creating unique textures while asking for advice from time to time, in comparison with males that worked independently aiming to have fun and enjoy their session time. Finally, we randomly formed collaborative teams consisting of either a mix of both genres or a M-M and F-F members.

8. CONCLUSIONS

We presented an experimental study based on user experience feedback in order to form an empirical basis for usability and learning benefits of tangibility (exclusively in music composition using audio textures). Gestus is tangible interactive tool which is designed to emulate a musical blank canvas. We developed this abstract user interface to be used as an alternative learning method of teaching children how to explore and experiment with non-musical elements such as the audio textures. The system uses characteristics and properties of similar TUIs regarding the design, construction and the operation of the system. It creates its own autonomous data-processing algorithm and develops an alternative method for engaging creatively with sound. It also uses 1/10 the cost and at least 1/3 the size of existing interfaces. The first contribution is the development of an extensible TUI prototype for sound texture design using audio feature extraction as the main framework for work. The second contribution is that it provides an experiential approach for teaching art in primary education [31]. The third contribution is the set of design recommendations as an incentive to develop similar educational training TUI interfaces. Furthermore, we believe that next steps in this study could lead to an extended version of the system addressing kids with disabilities and behavioural difficulties. We suggest that a future study should test artists and experienced users to investigate issues of advanced interaction. In future evaluations, it would be interesting to research the behavioural effects with respect to gender. In addition, we plan to continue our investigation of how Gestus can be combined with other approaches to enhance the output of the system, such as real-time graphical educational representation of the audio, color-based audio classification and puzzler music games. Our hope is that research in this direction will lead to interfaces which can solve behavioral problems that cannot be readily solved using the current predominant approaches to tangible edutainment.

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