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The Teinophon

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ABSTRACT

This paper presents the Teinophon, a hybrid string instrument enabling alternative and unconventional playing techniques. Specifically, the Teinophon provides multiple possibilities in terms of string interaction and sound production, allowing the player to violate norms of string instrument performance. The interface features seven strings laid horizontally and parallel to one another. A string can either be plucked or it can be pulled in the upward direction, each technique resulting in a distinct articulation, and affording considerable expressive potential. The paper explains the interaction design approach, the system architecture of the interface, and parameter mapping choices. Furthermore, the sound synthesis algorithm is described, and an autobiographical evaluation is carried out. Lastly, possibilities for future improvements and features are discussed.

1. INTRODUCTION

The technology boom in recent years has stimulated the development of novel and innovative musical instruments. Due to the vast availability of microcontrollers, the development, prototyping and iteration of electronic instruments has never been easier. However, most commercial electronic instruments rely on buttons and knobs as their primary sources of interaction, wherein the familiarity with traditional instrumental techniques are fading away. In live situations, the ability for the player to expressively and artistically convey their musicality has therefore become difficult in many scenarios.

This project tries to move away from such common narratives, by allowing more natural physical interaction possibilities. Kristina Andersen states in her research into innovation processes, that if an unknown object acts or looks like a known one, it may have similar characteristics or even carry some of the original objects' essence, and elicit notions of "magical thinking" and "making strange" [1]. Andersen ask questions like: "How do we design magic?" The Teinophon resembles the look and feel of well-known instruments, but provides interactions and sounds which are impossible to achieve with traditional instruments. Its design hopes to achieve just a small bit of the whim of magic which she writes about.

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2. RELATED WORK

The instrument was primarily inspired by a performance project *HOMO RESTIS* (lat. "Men on Strings") by Jens Vetter and Sarah Leimcke where they used modular instrument system for live and public performance [2]. They wore full-body costumes which had strings attached to them. Opposite ends of the strings were attached to a modular system which produced sound by pulling the strings out of it. So as they were moving, different sounds were being produced and controlled by the movements.

BodyHarp, an instrument designed by Doga Cavdir, et al. [3] is another instrument that incorporates strings that can be drawn out of the instrument, in addition to the more traditional plucking techniques. The instrument is partially wearable, and its design attempts to mutualize the body and the instrument as a different way of thinking about embodied musical interfaces, in order to capture expressive dance-like body movements, as well as nuanced gestural interactions.

Other related work includes projects such as Pendaphonics, a musical installation using Gametraks devices (as were also utilized in the BodyHarp), but ceiling mounted rather than floor-based in order to function as musical pendulums. This installation created physical dynamics that can attempt to engage participants in communal musicking, be they musicians or novices. It also included a hidden affordance of plucking the pendulum strings, in order to trigger a note. This project and others utilizing similar technologies are described in Freed, et al. 2009 [4].



Figure 1. The Teinophon - demonstration shown at https://youtu.be/_tMA2xVPZfs

3. CONCEPT

3.1 Interaction Design Approach

One of the advantages of building a novel instrument is the ability to design the interaction with the interface. Morreale and McPherson have explained in their research in design of digital musical instruments (DMIs) that the instrument design should include “signature features” that are exclusive to that DMI, and support unique playing styles [5]. The Teinophon aims to accomplish just that, but it also aims to offer familiarity with conventional instruments (thereby providing a certain level of intuitiveness). Strings are core elements of many traditional instruments. Their length and type of material, together with the body determine the timbre of an acoustic instrument. However, strings on such instruments are by necessity stationary, with their vibrations defined by physics (excitation leads to predictable resonances). The Teinophon breaks free from the idea that strings cannot be played in other manners, by incorporating extended movements of the strings in order to produce new types of sounds and a wide range of timbres. The general concept of such disruptive design practices has been explored prior, as discussed by Lepri, et al. [6].

3.2 General Interface Design

The concept of this electronic instrument is defined by specific goals. It is meant to be used by anyone, regardless of musical experience, but also to accompany a certain level of virtuosity. Wessel, et al. [7] coined this concept as having a “low entry fee with no ceiling on virtuosity”. The overall project goals are set as followed:

- **Transparency.** In order for the instrument to be accessible, it is designed while thinking about how to provide a high level of intuitiveness. This consideration means that the player should quickly be able to realize how the instrument is played.
- **Precision.** The input data and processing of the data should be precise and accurate to enable the player as much control as possible.
- **Expressiveness.** The instrument should allow many qualities of human expressivity to be portrayed (serving as a “conduit”) in order for a player’s virtuosity to come through, and keep their interest in using it.

4. DEVELOPMENT PROCESS

4.1 System Architecture

The instrument consist of the following electronic components: 14 potentiometers and 2 small push buttons, which are connected to a Teensy 3.6 microcontroller¹ made by Paul Stoffregen. The Teensy handles the input data and the processing of the data. The Teensy Audio Adaptor Board, which is mounted onto the microcontroller, and

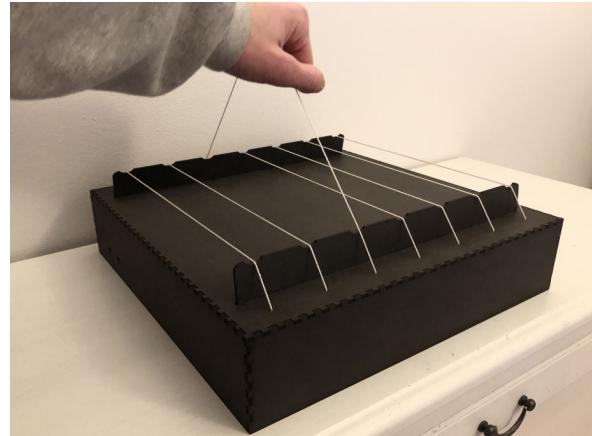


Figure 2. Interacting with the Teinophon.

TeensyAudio², a complete audio library for a microcontroller platform, are used to synthesise sound. 3D-printed housings³ (see Figure 3) are holding the potentiometers in place, and the control shafts of the potentiometers are inserted into an internal part of the housing: the spool. The spool is also used to hold the ends of the strings and a metal spring in the middle. The springs are used to create tension so when the strings are pulled and released, they retract into their original position, thus turning the control shafts of the potentiometers accordingly. The spiral spring is inserted into the housing as shown in Figure 4.

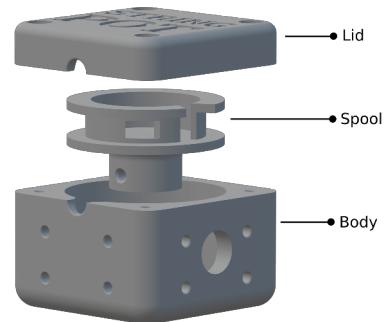


Figure 3. 3D model of the housing.

4.2 Prototype Instrument Design

All of the parts of the instrument are put into their predetermined positions in the simple rectangular box. The box was laser cut after the design was made using Autodesk Fusion360, and Adobe Illustrator. The material used is a high-density fiberboard in black color with 3 mm thickness. Positioning of all the elements is shown in Figure 5. The components are held in place using velcro tape.

² https://www.pjrc.com/teensy/td_libs_Audio.html

³ <https://www.thingiverse.com/thing:4329275>

¹ <https://www.pjrc.com/store/teensy36.html>

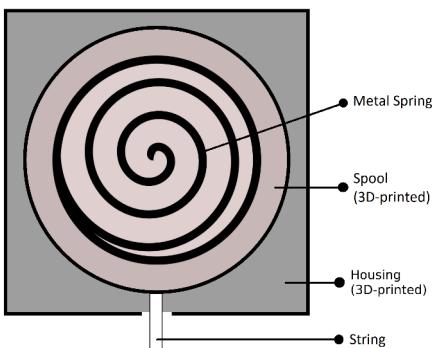


Figure 4. Representation of the inner part of the 3D-printed housing where the spool with the spring is visible.

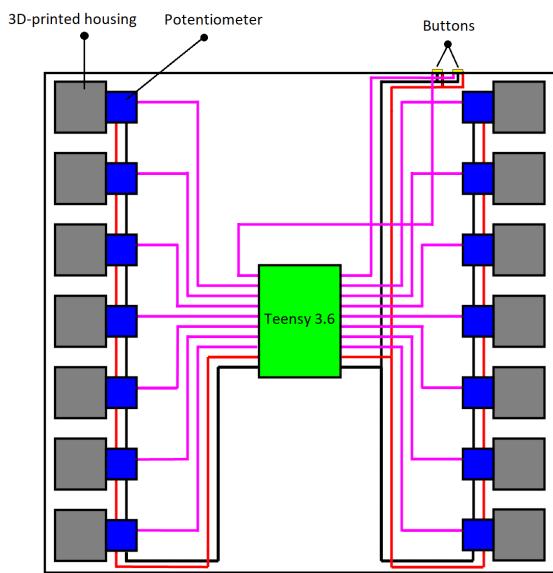


Figure 5. Simplified representation of the assembled Teinophon, with connections to the spools/potentiometers (each string connects to two of them).

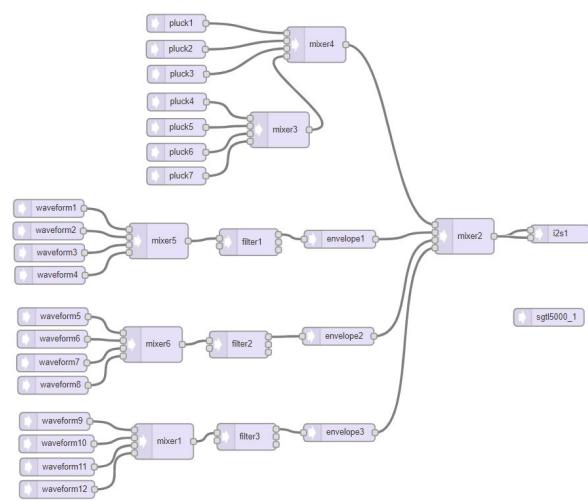


Figure 6. Teinophon's audio synthesis algorithm, as designed in <https://www.pjrc.com/teensy/gui/>.

4.3 Audio Algorithm

Using the Audio System Design Tool (see Figure 6), the initial phase of the algorithm was easy to implement. The first type of sound, triggered by plucking, is implemented using the Karplus-Strong synthesis method. The second type of sound is produced by combining 4 sawtooth waveforms, the first with the fundamental frequency, while the rest are integer multiples of this fundamental thereby providing a richer sound. There is also a low-pass filter and an amplitude envelope applied. All of the strings can be plucked at the same time, but the sustained sound can be produced only by 3 strings simultaneously in this prototype (due to limited memory of the microcontroller). However, in practice, this has proven not to be an issue, since it is rather impractical to pull more than 3 strings simultaneously.

4.4 Parameter Mapping

As each string is moving the control shafts of two potentiometers opposite to one another, the inputs from those two potentiometers are used simultaneously to control the sound. Each string is tuned to a specific frequency, based on a chosen key of a modern Western scale. On the side of the instrument there are two buttons used for changing the key. One button switches between major and minor scales, while the other button changes the key. The range of key changes is two octaves. By pulling the string slightly and releasing it quickly (plucking), a first, short sound is produced at a frequency that corresponds to that string. The amplitude of the sound is dependant on the position of the string when it was released, in order to imitate actual plucking. When the string is raised more than approximately 5 cm from its original position, a sustained sound is produced which has the frequency of the corresponding string. Pulling the string further controls the cutoff frequency of a low-pass filter for that string. When a string is raised, higher frequencies are passed through. Lowering the string will then eliminate higher frequencies proportionally to the height at which the string is held.

5. EVALUATION

Evaluating the experience of playing the Teinophon was approached according to autobiographical design methods (ABD). ABD design research draws on genuine reflection on experience by those creating or building a system [8]. The method ensures an open-ended approach at the early stages of the designing and prototyping a new system, and captures personal perspectives on new interaction methods, through the lens of bespoke instrument designs with which the authors play, explore, and continue iteratively developing.

Reflections on playability and performance of the instrument were based after hardware assembly and over a one month period, during which the audio algorithm was also developed, tested, and refined.

During the evaluation period, there was no noticeable latency when interacting with the instrument. Although the feel of each string is not identical to one another due to a

slight difference in string tensions, the playability of the instrument is satisfactory. Interacting with multiple strings simultaneously also meets expectations; multiple strings can be played simultaneously with both techniques. However, both techniques cannot be performed on one string simultaneously. For example, the string cannot be pulled out and then plucked. Only after the string returns to its resting position, can it be plucked. The material of the box encapsulating the instrument is a lightweight high-density fiberboard. Because of that the box can move slightly on the surface when interacting with the instrument, which can be distracting.

That said, playing the instrument feels intuitive and ergonomically satisfying. Even though the responsiveness of plucking the strings is not on the level of some acoustic string instruments (the strings do not actually vibrate), after learning and acquiring a certain playing technique, strings can be plucked and give the expected sound. The strings need to be displaced to a certain level from their resting position and then quickly released to give the desired sound. This could be improved by further refinement of the pluck detection algorithm. The alternative playing technique, resulting in a sustained sound, always works as expected. After a certain level of string displacement, the resulting sound is output and the low-pass filter control is very responsive. The buttons on the side of the instrument are used to change the key and switch between the major and minor Western scales. Locking the strings to a Western scale offers familiarity, but it is also a constraint. Having a larger selection of scales, and the option to tune the strings to any frequency, would allow more tonal freedom.

6. CONCLUSION & DISCUSSION

This prototype does meet its predefined goals after the iterative development process described. The similarity with traditional string instruments makes the plucking interaction intuitive, and the novel pulling interaction is interesting and easy to perform. Therefore, playing it does not require any complicated skills. The plucking interaction, however, could be improved for an even more natural playing style. This could be improved through better data processing and algorithm refinement. The current state of the instrument allows the player to express their musicality by playing sounds and melodies with different timbres and amplitudes, thus enabling it to be used as a creative tool for sparking new musical ideas, but the audio algorithm could be improved to reflect more subtle details when playing. For example, controlling the decay time when plucking the string, depending on how the string was plucked. Furthermore, a better choice of materials for the body would make the instrument more sturdy and robust.

A useful feature that could be added to the Teinophon would be allowing the player to precisely tune every string. The player could, with a press of a dedicated button, move a string from one side to the other (allowing one end to retract more than the other), and thereby set the frequency of the string. Another expressive feature would be pitch-bending, where the player would move the strings, in the same way as tuning them, to control the continuous pitch of

a string while playing. Furthermore, an abundance of different sounds could be used, since the strings can be pulled upwards up to around 40 cm from their original positions. Different levels could morph into new sounds, as the player pulls the string higher, and the sounds would change from one to the other. Finally, more sensors could be added to the system (such as an ultrasonic sensor on the side of the instrument), which would allow the player to use the motion of their hands to control various audio effects or other sound manipulations.

The Teinophon is an innovative electronic string instrument supporting players' musical expressivity. Although the first prototype presented here still has a plenty of room for improvement, it has great potential for continued development, and can already be used in a variety of musical scenarios. It has a wide target audience, since musical experience is not necessarily required to play it, and our initial autobiographical evaluation found both areas for improvement as well as areas in which it excels. The prototype Teinophon allows musicians interested in alternative forms of interaction to convey their creative ideas through the string-based instrument, by means of interesting new techniques for performance. The participation to the conference was supported by the European Art Science and Technology Network (EASTN-DC).

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