The Viblotar - a big box that makes noise (and vibrates too!)

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Abstract— **This paper describes the Viblotar, a digital musical instrument designed to allow the evaluation of a number of hypotheses concerning digital instrument design. These include ideas regarding the suitability of sensors for specific tasks in a digital instrument and the usefulness of vibro-tactile feedback in digital instrument performance. The design of the instrument is described, along with its implementation, mapping and synthesis sytem and directions for possible future work.**

Keywords— **digital instrument design, vibro-tactile feedback, mapping, sensors**

I. Introduction

THE use of sensor technology is a fundamental part of the creation of interfaces for computer music. However little investigation has taken place into the suitability of particular sensors for specific tasks in these interfaces. While a number of taxonomies and evaluations of sensors have taken place [2] [10], these have not been concentrated on the use of such sensors in musical applications.

Of the few works to concentrate on the use of sensors in musical applications, [15] has attempted to show a mapping between sensors and classes of musical task. This work classified sensors by the form of input that they sensed (linear position, rotary position, force etc.) and classified musical tasks by the range and form of input they required (static, absolute dynamic and relative dynamic). Some experimental work has attempted to verify the theoretical framework proposed in this work [16]. Following on from this, further experiments have attempted to more thoroughly examine this framework and attempt to experimentally determine the suitability of sensors for tasks in musical interfaces [6].

The Viblotar was conceived as a result of these final experiments. Having found strong indications of the suitability of certain sensors for note selection and note modulation tasks in an digital musical instrument, it was decided to develop an instrument which was played almost entirely using these tasks and to implement it using the sensors which the experimental data indicated were best suited to these tasks. In this way it was hoped to verify the results which had been obtained from these experiments.

Another aspect of digital musical instrument design which was also being investigated was that of the usefulness of vibro-tactile feedback in performing with a digital musical instrument. Work on traditional musical instruments has shown that while visual feedback in an instrument is important for learning the instrument [15], more advanced performers make more use of tactile and kinesthetic feedback [5]. This feedback in traditional instruments is caused by the vibration of the instrument body which is a direct result of the method of sound generation within the instrument [9].

Most digital musical instruments do not have this intrinsic vibro-tactile feedback. The sound is usually generated electro-mechanically by a computer and loudspeakers, which most often not a part of the instrument itself but are placed away from the instrument. This can result in a disassociation between the instrument and the sound and can reduce the closeness of the performer-instrument bond [15]. Thus, it was decided to incorporate the sound generation of the Viblotar in to the instrument body itself. This would provide a vibro-tactile feedback caused by the resonance of the body from the output of the speakers. This feedback would be directly related to the sound being produced and so would offer a more direct feedback to the performer [13].

II. Design

Based on the overall aims of the project, a design was created which had the following requirements:

- The instrument should be playable using only note selection, note modulation and amplitude modulation gestures.
- The gestures should be sensed using the sensors which had shown to be most suitable for these particular tasks, a linear position sensor for note selection and a force sensing resistor for the modulation gestures.
- The instrument should provide direct vibro-tactile feedback to the performer and this feedback should be directly related to the sound produced by the instrument.
- It should be possible to play traditional musical pieces using the instrument, which should offer a good range of continuous pitch control.
- The overall design of the instrument should aim towards an instrument in which all aspects of the system are integrated (i.e. no external systems are needed to perform with the instrument.

With these overall goals in mind it was decided to develop an instrument based on traditional monochord-type instruments. A number of cultures have developed monochord-style musical instruments, for use in education, research or as performance instruments[3]. One such instrument is the Dan Bau, a Vietnamese monochord, which is used to play melodies using the harmonics of the string. The instrument is played using the right hand both to damp nodes if the string at the position to accentuate the harmonics and to pluck the string to excite these harmonics. The left hand is used to modulate the note produced by increasing or decreasing the tension of the string, which is connected to a length of bamboo at this end.

It was proposed therefore to develop an instrument which was based on the Dan Bau, but offers methods of playing not

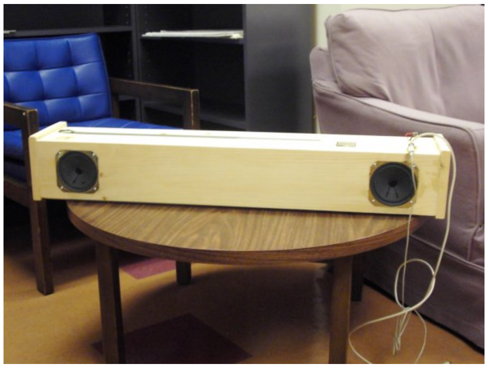

Fig. 1. The Viblotar enclosure

Fig. 2. Layout of the sensors on the Viblotar (from the performers point of view)

possible on the acoustic instrument[1]. This instrument could be classified as an instrument-inspired controller [1][17], as it would not create the sounds of the acoustic instrument, but its methods of interaction are directly inspired by the Dan Bau and other monochord-style instruments.

III. Construction

A. Physical Construction

The body of the instrument is constructed from 1" thick pine boards. The overall shape of the instrument is a long rectangular box and is designed to allow performance of the instrument when placed on a desk or a keyboard stand. The body also acts as an enclosure for the speakers, allowing a better frequency response that that of the speakers in free air. The overall dimensions of the body were arrived at by balancing the size of the sensors, the speakers and the necessary playing surface with the dimensions which had been arrived at to maximize the frequency response of the speakers. These dimensions were determined by modeling the speakers in an enclosure using MathCad models with the Thiele-Small parameters of the speakers[2], which were determined by small-signal analysis[14][11][12]. This resulted in the enclosure shown in Figure 1. The sensors are placed on the top of the instrument, with the speakers are on the front, facing towards the audience, should there be one.

To allow for interaction with the instrument a long linear position sensor and a long force sensitive resistor (FSR) were placed on top of each other towards the right side of the instrument. Two smaller square FSR's were placed to the left of these sensors, one above the other. Figure 2 shows the layout of the sensors on the top of the instrument.

All electronics are mounted internally, on top of the board which is the bottom of the body. This board can be removed for easy access to the electronics.

B. Electronic Construction

The electronics for the Viblotar consist of three major sections. Each of these sections is concerned with a specific aspect of the instrument interaction.

1) Sensors and Signal-Conditioning Circuits: This section of the electronics is concerned with taking the interaction from the user and converting it to a voltage in the range of 0 to 5V. The long FSR and linear position sensors only require a 5V supply in order to operate in this way, whereas the smaller square FSR's require a signal conditioning circuit to allow the to produce a voltage rather than the resistance which is inherent in the sensor. A simple voltage-divider was created for these FSR's using two resistors [8].

2) Analog-to-Digital Conversion: The analog-to-digital conversion system used for the Viblotar was an AVR-HID USB device [7]. This device samples all of the inputs at a rate of 100Hz and provides 10-bit precision digital values to the computer over a USB connection. It also provided the +5V signal required for the sensor and signal conditioning circuits.

3) Sound Production: For the first prototype of the Viblotar, the synthesis is performed on a computer. However, the actual sound production is performed in the instrument using the two 3" diameter speakers mounted on the front of the instrument body. Two small audio amplifier circuits were created which are capable of providing 1W of power into these 8Ω speakers from a 5V supply. The power for these amplifiers was taken from 6 1.5V batteries and run through a regulator to provide a stable 5V power supply. This system allows for the production of a maximum of 93dB of sound output at a distance of 1m from the instrument.

IV. Sound Synthesis

The synthesis engine for this system consists of a physical model running in the Max/MSP environment. The model comes from the PeRColate package by Dan Trueman and R. Luke DuBois[3] which is a port to Max/MSP of instruments from the Synthesis ToolKit (STK) by Perry Cook and Gary Scavone[4]. The physical model currently being used is a hybrid model called the blotar (thus the name Viblotar for a vibrating blotar). This model is a hybrid of an electric guitar model and a flute model. This allows for a large range of sounds to be produced by the system, while the use of physical modeling

[1] see http://www.mcld.co.uk/oddmu/danbau/ and http://www.thanhcammusic.com/ for more information, pictures and videos of the Dan Bau

[2] See http://www.quarter-wave.com/ for details of the models used and their derivation

[3] Available from http://music.columbia.edu/PeRColate/

[4] See ccrma.stanford.edu/software/stk/

gives a more traditional instrument-like sound to the sound created by the Viblotar.

V. Gesture to Sound Mapping

As one of the main aims of this project was to evaluate the results of the previous experiments on mapping of sensors to musical tasks, the majority of the gesture to sound mapping was implicit in the system design. As such it was already determined that position along the linear position sensor would map to the frequency of the output sound. Pressure on the long FSR would control the amplitude of the sound. Finally, pressure on the smaller square FSR's would map to pitch bend up and down from the output sound frequency.

The use of physical modeling synthesis allows these mappings to be made in an intuitive way. For instance, instead of mapping the output from the long FSR to a variable in an equation for synthesis, the physical model allows us to map it to the blowing pressure. The physical model takes this blowing pressure and applies it to the necessary equations to generate the variables for the synthesis. This approach makes it easier to interface the controller with the synthesis and allows for a much better understanding of the way which the instrument will react to user actions, through explanations such as "pressing harder on the controller is like blowing harder on the flute" [4].

The current mapping of the controls are as follows:

- Position on the linear position sensor controls frequency of note played. Continuous linear mapping increasing from left to right. The total frequency range is from 100Hz to 1000Hz (just over 1 octave).
- Pressure on the long FSR control both the breath pressure and the overall output sound volume, with a linear mapping from the output of the sensor to each variable.
- Pressure on the smaller FSR's is mapped to a +/- 10% change in the frequency of the played note. Again this is a linear mapping from the sensor output to the frequency change.

VI. Discussion

A. Physical and Electronic Construction

Construction of the Viblotar was not particularly difficult. The work necessary to construct the body itself (speaker analysis and calculations, sensor measurements, box design and construction) took the majority of the development time. However as the form of the instrument was a major component of the design aims it was necessary to spend this time on the body construction.

The electronics were reasonably simple, making use of a small number of building-block style circuits, all of which had been previously designed. Components used were all commonly available and so this did not significantly add to the development time. The only major difficulty occurred during the creation of a home-made linear position sensor, which was designed to give a physically longer sensor for frequency selection and which was accidentally destroyed.

B. Mapping and Synthesis

As already stated the synthesis used for the Viblotar is a Max/MSP implementation of a physical model. This synthesis system was available for download and only required minor modifications to work with the Viblotar. The advantage of this is that the synthesis was already designed and known to work and so it was not necessary to devote much time to this portion of the instrument. The disadvantage is that the sound is not quite what was initially desired for the Viblotar. This area will require more work in order to achieve the desired sound of the instrument.

The simple mappings used to control the synthesis were predefined by one of the goals of the instrument design. These mappings were implemented successfully and appear to result in an instrument which is quickly playable. Some more work will be required to change some of the linear mappings to non-linear ones, to improve the "feel" of the interaction with these parameters. Also, some further practice with the instrument will be required in order to perfect the ranges of the various parameters that are being interacted with.

C. Performance

Informal practice and performance with the Viblotar has revealed that the instrument is quite playable. The vibro-tactile feedback and internal sound production create the feel of an instrument much more so than a controller. Rather than it appearing that the performer is using the Viblotar to play the computer, the performer appears to be playing the Viblotar.

The chosen sensors and mappings work well, allowing performers to quickly learn to play simple pieces. Due to the controls provided the instrument is also complex enough to allow performers to create musically interesting pieces and allows for exploration of the capabilities of the instrument.

The use of a physical model as the synthesis mechanism has resulted in a sound which is similar to the kinds of sounds produced by existing acoustic and electric instruments. This gives a sound which is in some ways familiar to the performer and listeners but is obviously not possible using just an existing acoustic or electric instrument. Again, this allows for much exploration of the sonic qualities of the instrument by the player.

VII. Future Work

While the Viblotar has been successful in meeting the initial design goals, there is still much work which remains to be done to improve the instrument. Firstly, as already mentioned, the ranges of the parameters being effected by the sensors need to be evaluated and refined. Also, the synthesis itself needs some refinement to create the sound which was initially envisioned for the instrument (however, it should be noted that a change in synthesis may require a corresponding change in the name of the instrument, which is a daunting prospect).

The physical interface of the instrument itself provides for all of the requirements initially set for the instrument and is mostly complete. A further development here will be to try again at constructing a longer linear position sensor to allow the playing space to be fully utilized and to allow for easier control of the frequency range of the instrument.

Perhaps the largest are for future work will lie in the electronics of the instrument. While embedding the sound production in the instruments body has produced an instrument with a tighter performer-instrument bond, the Viblotar still requires a computer for the synthesis. It is still not a fully integrated instrument. To remedy this, once the synthesis system has been finalized, work will begin to implement the synthesis on a microcontroller platform. This will allow the sound to not only be produced in the instrument but also generated there. The result of this will be a fully integrated instrument, which can be played without any additional hardware or software required.

VIII. Conclusion

This paper described the design and development of the Viblotar, a digital musical instrument designed to integrate a number of areas of research into digital instrument design. The choice of sensors for specific tasks in an instrument was discussed, along with the influence of some experiments in this area on the design of the Viblotar. A method of implementing vibro-tactile feedback within a digital musical instrument was also presented. Construction of the instrument was discussed, as well as the mapping and synthesis system used to produce the sound of the instrument. A number of aspects of the instrument were discussed in relation to the design goals for the instrument. Finally, this paper covered areas for improvement to the Viblotar and presented the next stages in development of the instrument.

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