The Squiggle: A Digital Musical Instrument

Brian Sheehan
University of Limerick,
Ireland.
Brian.Sheehan@ul.ie

Figure 1. The author playing the Squiggle.

ABSTRACT

This paper discusses some of the issues pertaining to the design of digital musical instruments that are to effectively fill the role of traditional instruments (i.e. those based on physical sound production mechanisms). The design and implementation of a musical instrument that addresses some of these issues, using scanned synthesis coupled to a “smart” physical system, is described.

Keywords

Digital musical instruments, real-time performance, scanned synthesis, pd, tactile interfaces, sensors, Shapetape, mapping.

1. INTRODUCTION

Computer music has yet to fully tap into the tradition of the musical instrumentalist, for several reasons. Firstly, sensor technology still has a long way to go before it can provide the musician with a control interface that effectively captures all physical interactions with it (as traditional musical instruments do). Also, it is only in recent years that computers have become powerful enough to allow real time control over sound synthesis. And now that real time control is possible, the problems of creating an expressive and engaging instrument are only just coming to light, in explorations of the mapping problem [3][4]. Work on the mapping problem has provided many useful guidelines that help to construct an effective mapping between the output of a control interface and the input of a synthesis algorithm, but mainly in the area of digital recreations of existing acoustic instruments. There are still no clear guidelines on how to approach the mapping of new digital instruments that have no precedent.

Scanned synthesis generates a pitched sound with a time evolving spectrum by scanning some slow moving dynamic system [6]. In recent implementations of scanned synthesis instruments [1][2], it is a virtual model of a physical system that is scanned. In this paper it is contended that by using some suitable sensor as the dynamic system to be scanned, the mapping problem can be avoided. As a result of this, the instrument created will share many of the characteristics common to all traditional musical instruments: consistency over its range and modes of playing, initial ease of use, potential for the development of more sophisticated techniques, and interesting sonic results [5].

2. SENSOR TECHNOLOGY AND DIGITAL MUSICAL INSTRUMENTS

An important characteristic of most traditional musical instruments is that they can be interacted with in a virtually limitless number of modes. Because the control interface and the sound production mechanism are tightly coupled (and in many cases, are one), any physical action on the instrument will have some effect on the sound produced. A guitar can be banged and scraped in any manner, and energy will be passed on to the strings to produce some sort of sound. This multi-modality gives traditional instruments and engaging responsiveness.

In contrast to this, all controller interfaces for digital musical instruments loose a huge amount of the musician’s interaction with it. This is a limitation of current sensor technology, where sensors are generally designed for one mode of interaction. We can measure how fast something moves, the pressure exerted on it, its position and orientation in space, and the state of its environment (temperature, light, etc), among other things. However a specially designed sensor is usually needed to measure each of these things. And so, control interfaces rarely integrate multiple modes of interaction into a single control – it can be very hard to do so. In light of this, it is important, insofar as possible, to use sensors that somehow mask this loss of information.

3. THE MAPPING PROBLEM

With regard to digital musical instruments, mapping refers to the way in which the gestures of a musician (as captured by a control interface) are related to the parameters of the synthesis method being used. This facet of designing digital instruments has only recently been recognized as a highly important, and although much headway has been made in the area, it appears that devising a mapping for a signal model instrument is still down to a large amount of trial and error.

Current guidelines for mapping [4] suggest using a multi-layered model. In this approach, sensor data streams are grouped into some number of “performance parameters”. These performance parameters encapsulate some higher-level aspect of a musician’s performance, such as “energy”, by combining data from low-level measurements of the musician's gesture. On the sound production side, low-level parameters of the synthesis method are grouped to provide control over sound/perceptual parameters such as brightness.

Musical instruments can be categorized by the degree of separation between the musician's gesture and the sound production mechanism; in other words, the number of levels of mapping necessary to allow satisfactory control.

As mentioned in section two, traditional instruments allow the musician to interact directly with the sound production mechanism. This intimate relationship is responsible in a large way for the expressivity of the instrument.

Digital instruments based on physical models could be said to have two degrees of separation: a layer of mapping between the output of the controller and the abstract performance parameters, and another from these abstract parameters to the parameters of synthesis. Instruments based on signal models have three degrees of separation: as before, controller inputs must be mapped to abstract performance parameters. These in turn are mapped to abstract sound production parameters, which are then mapped to the actual parameters of the synthesis algorithm. The more layers of mapping required, the more work that is necessary on the part of the designer to find a mapping that makes the instrument expressive and engaging as a whole.

In comparison to this, an instrument based on scanned synthesis, that scans a dynamic physical object, would fit in the same category as traditional instruments. In both cases there is no separation between the gesture of the musician and the sound production mechanism. Consequently, given the right sensor technology, it should be possible to build a scanned synthesis instrument with expressivity comparable to that of a traditional musical instrument. This was the motivation behind the construction of the new instrument described in this paper.

4. THE SHAPETAPE

Once it had been decided to build a scanned synthesis instrument that scanned a physical system, implementation depended on the availability of some controller whose physical shape could be sensed in real-time by a computer, and whose shape could be manipulated easily by human hands.

The Shapetape[1] is such a device. The model that was at the disposal of the author (the S1280CS) consists of flexible, plastic-coated strip of metal, with dimensions of 1.3 x 13 x 1800 mm. At one end the tape is attached to a digital interface that can be connected to a computer; at the other end there is a sensorized region 480mm long. The sensors consist of pairs of fiber optic loops that together can measure the bend and twist of the tape over a small region. Data can be collected from the tape at a frequency of 189Hz, and a model of the sensorized region's shape can be constructed from this data in real-time. For all intents and purposes the model and the physical tape can be considered as one.

[1] For more information about the Shapetape, see www.measurand.com

The sensorized region of the tape can be bent and twisted freely to form a continuum of various shapes, and data collection and construction of the virtual model of the tape can be performed quickly enough to allow high-speed gestures to be captured. The Shapetape is very sensitive – anything that changes the shape of it in the slightest manner is picked up by the sensors, allowing interactions with it that are multimodal to some degree.

5. DESIGN OF THE SQUIGGLE

Having found a suitable control interface in the Shapetape, the rest of the instrument (named "The Squiggle") was designed around it. There were three main issues to be dealt with: firstly, how best to use a three-dimensional system with scanned synthesis; secondly, how pitch control would be dealt with; and thirdly, how the Shapetape would be mounted to facilitate its use as a musical controller.

5.1 Scanned Synthesis using a three-dimensional dynamic system

The Shapetape can be manipulated freely to create fully three-dimensional shapes. Two of these dimensions could be scanned periodically to produce pitched sound pressure waves. This left one of the measured dimensions of the Shapetape unused. It was decided that instead of using movement in this third dimension to perform some arbitrary manipulation of the scanning of the other two dimensions, rotation of the virtual model of the Shapetape would be allowed. In this way, all degrees of freedom of the tape would have influence over the sound produced by the instrument (while the rotation was being performed), but in a way that was readily understandable by the musician. The conceptual model used was of:

- Sound being produced by periodically scanning the silhouette of the tape, as viewed from a particular vantage point, and writing it to the DAC of the computer.
- The ability to rotate this vantage point around the tape in a circular arc.

Obviously, an input device would have to be found that could control this rotation. Also, to facilitate the user's understanding how this rotation worked, a visual display could be included that would show the instantaneous shape of the tape as viewed from the current vantage point.

The rotational controller had one main constraint: it should be operated using the feet, since the hands would be busy manipulating the Shapetape. The author felt that an existing controller should be adapted for the purpose, and when an old Singer sewing machine table was found in an antiques shop, it was used.

A Singer sewing machine table uses a large flat pedal to rotate a large wheel. The operator sits at the table with both feet under it, resting on the pedal (which is mounted just above floor height between the legs of the table). In its original use, the pedal drove the wheel, which powered a mechanical sewing machine on the tabletop. The author felt that it would indeed be hard to find a controller better suited to the task of rotational control by the feet while in a comfortable sitting position.

5.2 Scanned Synthesis with a Scanning Path of Varying Length

Since the Shapetape is effectively non-elastic, different shapes made by it would inevitably create silhouettes that vary in length in both dimensions. As such, it is not possible to scan the silhouette of the tape along some dimension that never varies in length (as is the case with the virtual string models used in other scanned synthesis instruments). Hence, for a given scanning frequency, as the tape was manipulated, the length of the scanning path would change, and so the pitched produced would vary accordingly. Using a scanning path of variable length to control pitch has not been used in other scanned synthesis instruments to date.

5.3 Mounting the Shapetape

When scanning the silhouette of the tape, if it were in a completely flat pose, no sound would be generated. This pose was of vital importance, since it would be the only way of silencing the instrument. This meant that the tape should be mounted in such a way that it could be flattened very easily.

A couple of strategies for mounting the Shapetape were considered. One way it could be mounted was to fix the start of the sensorized region in a clamp, letting the tape hang downwards under the force of gravity. This configuration had the advantage that the tape would not be constrained in any direction by a supporting structure, allowing it to be moved very freely. In theory, if the tape were released, gravity should return it to the flat pose.

The tape could also be mounted on a flat surface. Here the start of the sensorized region would be clamped to the surface, and the other end would be left free. This had the disadvantage that movement of the tape would be somewhat constrained by the surface it was clamped to, but the surface could also be used to help create shapes not possible with only two hands. Again, the flat pose could be articulated by releasing the tape from the hands and letting gravity lay it along the flat surface.

After experimenting with both of these configurations in the early stages, it was decided to use the second. It was found that the tape had a certain amount of memory, and that gravity alone would not be sufficient to return it to a completely flat pose. Because of this, using the first configuration the tape could not be flattened easily. However, mounting it on a flat surface allowed the musician to smooth the tape along the surface very easily.

It was considered that the tape could be used without clamping it at all. However, it was felt that unless the position of the start of the sensorized region was itself tracked and used as a parameter to synthesis, this freedom would in fact be counterproductive. This is based on the author's reasoning that if a controller is to be intuitive, all its degrees of freedom should have an impact on sound generation. Because of time constraints, tracking the tape's movement was not an option, and so this approach was not investigated further.

6. IMPLEMENTATION OF THE SQUIGGLE

Following from the design outlined above, the Singer sewing machine table was adapted. Software was written to synthesis sound from the output of the rotation controller and the Shapetape. An overview of the system is given in Figure 2, below.

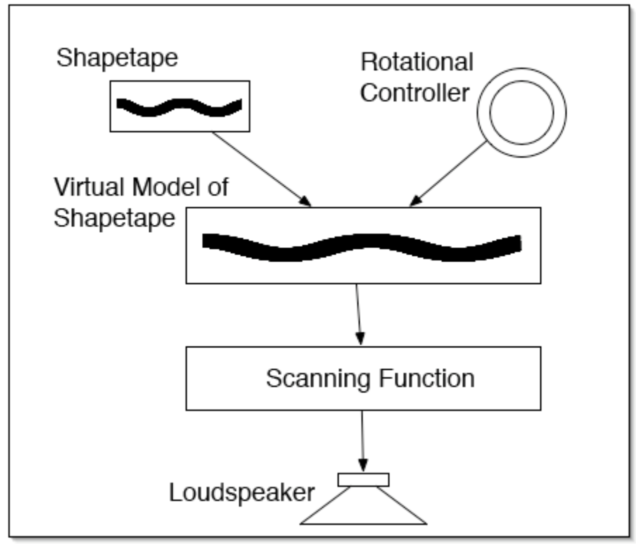

Figure 2. Overview of the Squiggle

6.1 The Rotation Controller

It was hoped that the phase of the sewing machine wheel could be sensed in real-time. In this way, the vantage point from which the silhouette of the tape was scanned could both be rotated to a particular position and held there, or could be rotated continuously around the tape. Unfortunately because of time constraints it was only possible to sense the speed at which the wheel was turning, and not the phase.

Figure 3. The sewing machine table, showing the pedal and wheel mechanism. A dynamo can be seen mounted near the top of the wheel.

Measurement of the rotational speed of the wheel was necessarily quick and dirty. A rubber wheel from a toy car was attached to the shaft of a small 5 volt dynamo. This was mounted so that the rubber wheel made firm contact with the large iron wheel of the Singer table. The output of the dynamo was wired to a small light bulb, which was housed in a lightproof casing with a light-dependant resistor. The resistor was wired in place of a potentiometer in a circuit for a MIDI expression pedal, and plugged into a MIDI interface that was connected over USB to the laptop. This allowed the speed of the wheel to be scaled to between the MIDI values 1 to 127. It worked!

6.2 Implementation of the Software

The synthesis algorithm (implemented as an external for Pd[2]) involved periodically polling the Shapetape software for the current state of the tape, converting this state to a wavetable, and outputting the result as sound. In more detail:

Every 10 milliseconds, Shapetape coordinates were plotted directly in a three dimensional wavetable, and interpolation between the coordinates was performed.

This 3D representation of the Shapetape was rotated according to the current rotational speed of the sewing machine table wheel.

The wavetable was scanned periodically along one dimension (i.e. the timeline), with the corresponding value of another dimension being output through the computer's DAC.

The Pd external accepted as an argument the name of a Pd graphical array. If an array of this name existed in the patch containing the external, the silhouette of the tape was written to it. This provided visual feedback that would help the musician understand the effect of rotating the sewing machine wheel.

7. RESULTS AND CONCLUSIONS

Most exciting about the instrument was the interdependency between pitch, timbre and dynamics. The pitch of a sound created is dependant on the length of the silhouette of the tape (longer ones creating lower pitches, and shorter ones higher pitches), and the amplitude is dependant on its height. Doubling the tape over creates shorter silhouettes, whereas in contrast, long silhouettes are formed when the tape is not doubled over. In this way, longer silhouettes have a certain, less complicated, characteristic shape than shorter silhouettes. But because the spectral content of the sound is dependant on the shape of the silhouette, this means that the timbre of a note will vary characteristically over the pitch range of the instrument, and similarly for the dynamics of the instrument. This is an important characteristic of traditional acoustic instruments, and one that is very hard to achieve with signal based digital instruments, unless an effective mapping can be devised.

The instrument was exhibited at Digital Arts Week Now, 2003, at the University of Limerick, Ireland. This five-day exhibition gave the author a good opportunity to get feedback from members of the public about the instrument.

Immediately obvious was the initial ease of use of the instrument. People young and old immediately learned how to control pitch and loudness of the Squiggle.

The novelty factor of using an old Singer sewing machine table as part of a "high-tech" instrument added greatly to people's interest in it. People were impressed at not having to touch a computer to play such obviously new, digital sounds.

A number of older people remarked that they felt no way intimidated by the Squiggle, as they often would when otherwise dealing with computers. One person remarked that they were glad that somebody had revived an obsolete yet beautiful artifact like the Singer table, which they could identify with and understand.

The ad-hoc way in which the wheel of the sewing machine table was used to rotate the model of the Shapetape worked reasonably well. When the wheel was rotated slowly, a tremolo effect would be heard in the sound of the instrument. As the wheel was rotated faster, this amplitude modulation lead to sidebands appearing in the sound, creating some strange timbres.

8. ACKNOWLEDGMENTS

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