A Comparison of Sensor Strategies for Capturing Percussive Gestures

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ABSTRACT

Drum controllers designed by researchers and commercial companies use a variety of techniques for capturing percussive gestures. It is challenging to obtain both quick response times and low-level data (such as position) that contain expressive information. This research is a comprehensive study of current methods to evaluate the available strategies and technologies. This study aims to demonstrate the benefits and detriments of the current state of percussion controllers as well as yield tools for those who would wish to conduct this type of study in the future.

Keywords

Percussion Controllers, Timbre-recognition based instruments, Electronic Percussion, Sensors for Interface Design

1. INTRODUCTION

Electronic percussion is one of the most well established electronic music interfaces after the piano keyboard and mixer-type devices; yet, these interfaces are often crude devices that merely capture the velocity of the striking implement at the moment of impact. Obviously, there are many more factors present in a percussion strike.

What information besides strike velocity is important and how can it be used to accurately translate the gestures of an expert performer? Geometrically speaking, there is the angle of incidence, velocity of the strike, the polar position of the strike on the surface and the number of points of contact. [1] In order to capture these gestures and translate them into data usable by a computer we must examine the issue of latency versus information gain and the effect upon real-time performance.

A cost/benefit analysis of controllers can be very complex. This paper will give guidelines to be considered when dealing with percussion interfaces as well as providing a thorough survey of the different models currently available and their design decisions and consequences.

[1]Some playing techniques, such as the rimshot, require the player to hit the drum in multiple places simultaneously.

2. OVERVIEW OF CURRENT MODELS

There are many different methods of capturing the gestural information of percussive strikes using a variety of sensors. In this section a survey of the most common techniques will be described from simple methods using piezo to more modern sensor technology.

2.1 Piezo

Piezo sensors take advantage of the piezoelectric effect in which mechanical energy is converted to electrical. Electrical charge results from the deformation of polarized crystals when pressure is applied [7].

These sensors are often found in older and cheaper commercial percussion trigger pads. In order to be effective they must be isolated from the vibrations of nearby impacts on different pads. This isolation is never perfect and is called crosstalk.

An example of an interface which uses these sensor to great advantage is the Jam-O-Drum [8]. This interface uses an array of commercial piezo-based drum pads mounted into a surface to provide a collaborative instrument/installation for use with novice players.

The largest electronic percussion instrument, the Rhythm Tree [16], uses piezos to detect impacts. The instrument is comprised of 300 sensors that can detect a direct or indirect hit. The sensors are embedded in a soft rubber pad that can be lit up with an LED to provide visual feedback for the performer.

2.2 Force Sensing Resistors

Force sensing resistors (FSR) use the electrical property of resistance to measure the pressure exerted upon the sensor. FSRs are used in experimental and commercial drum controllers. The main advantage of an FSR for a drum controller is that the sensors only pick up strikes which directly strike the surface. This results in no crosstalk between the sensors, which is a major problem with piezo based devices. There are two types of FSRs: ones that measure the amount of pressure and ones that measure the amount of pressure along an axis, thereby yielding position.

The Drumkat[2] is an example of a popular and powerful

[2]http://www.alternatemode.com

commercial device that utilizes these sensors. The Handsonic (HPD-15)[3] is another commercial device that uses FSRs to emulate a hand drum interface. The Buchla Thunder[4] is an alternate controller that has more than a dozen pads that sense both pressure and position.

The javamug has FSRs placed ergonomically onto a coffee mug that control the randomness of techno-latin drum loops [1]. This device demonstrates a simple mapping that leverages percussive techniques to control macro-level mappings in an interesting and simple manner.

The Electronic Tabla (ETabla) [4] is an interface designed to model the traditional playing technique of the North Indian classical Tabla. It uses FSRs in strategically placed areas of a custom built head to gather gestural imprints of Tabla performance.

The Electronic Dholak (EDholak) [4] is a multi-player Indian drum controller which uses both piezo and FSRs for gesture capturing events inspired by the Jam-O-Drum. The piezos are used to trigger time critical events while FSRs are used to control parameters which are less time critical, but give more expressive notions than with just the piezos alone.

2.3 Fiberoptic Sensing Pads

In this sensor technique a network of fiberoptic sensors detect pressure as well as position. An original device using this technique is the Tactex[5] Multi-Touch-Controller (MTC) which contains a grid of 72 sensors that can distinguish multiple sources of pressure. The STC-1000 - a newer version of the MTC pad - has been designed by the Mercurial Innovations Group.[6] This device is a Singe Touch Controller that outputs MIDI. The Ski is an example of a Tactex pad being used as an interface for musical expression [3].

2.4 Capacitance

The radio drum is one of the oldest electronic music controllers [9]. Built by Bob Boie and improved by Max Mathews, it has undergone a great deal of improvement in accuracy of tracking, while the user interface has remained nearly constant. There is an antenna at each of the four corners of the drum. The drum is played with two sticks that operate at different frequencies. The radio tracking technique depends on the electrical capacitance between the radio transmission antenna in the end of each mallet and the array of receiving antennas in the drum. The drum generates 6 separate analog signals that represent the x, y, z position of each stick versus time.

2.5 Microphone

A special mention must be made for the Korg Wavedrum. Most owners of this controller claim that it is as flexible as an acoustic instrument [17]. The Wavedrum has three contact microphones underneath the drumhead. The signals from the drumhead are used to combine with the synthesis engine of the drum to make sound. This results in the sound changing as the excitation is moved around the drumhead. These different signals are either used to excite the synthesis engine, are passed through the DSP chain, or are passed directly to the output after completing one of the previous tasks.

Timbre-recognition based instruments use timbre a control parameter. Work has been done by the authors towards this implementation in a percussion controller [5]. The system utilizes digital signal processing and machine learning techniques to classify the timbre of the instrument. The labels correspond to different playing techniques and striking implements that have been identified to the system from human labelled instances. Since different playing techniques produce different timbres it is a matter of collecting training instances of the desired technique and retraining the classifier.

2.6 Accelerometer

The PhiSEM controllers are shaker-like interfaces that utilize accelerometers to trigger physical models of shakers [1]. These interfaces demonstrate a simple use of percussive gestures to control physical models of shakers.

A recent use of accelerometers in a percussive interface has been developed by Dianna Young.[6] This interface used 2 two-axis accelerometers augmented with two single-axis accelerometers. The sensors were placed inside of a pair of bachi sticks by hollowing out the end of the sticks to relay three axes of acceleration and the angular velocity of the sticks. A Bluetooth® emitter was also placed inside of the sticks so that the performer did not have any wires impeding their gestures.

2.7 Electromagnetic Tracking

Electromagnetic sensors can relay their position in six dimensions; this makes them ideal for tracking stick motions. The Vodhran [2] uses these sensors embedded into the stick to track position and to use this information to drive physical models of a drum.

2.8 Infrared

The Buchla Lightning uses infrared light tracking in order to track the position of the wireless sticks in two dimensions. Each stick uses a different frequency of light so that they may be tracked independently. The lightning also include a button on each stick that may be used to trigger events or send metadata.

2.9 Camera Tracking

While there are very few controllers that have employed video tracking for capturing percussive gestures there has been some interesting research on these motions using video capture. Sofia Dahl has done significant amount of work analyzing the motions of drummers and percussionists using video capture in addition to motion capture via a Selspot system.[7] [10]

Motion capturing systems such as VICON[8], allow for more precise collection of human movement. Experiments with these type systems for musical gesture analysis is shown in [12].

3. DESIGN EVALUATION

By observing something you must change its state. This is a consideration when designing any computer or sensor

[3] http://www.rolandus.com
[4] http://www.buchla.com
[5] http://www.tactex.com
[6] http://www.thinkmig.com/
[7] http://www.innovision-systems.com/
[8] http://www.vicon.com

based instrument. For percussion instruments there are three main ways of augmenting the performance to capture the gesture: placing sensors on the drum, placing sensors on or in the stick, detecting the motion of the body.

Throughout this section we will reflect upon the interfaces and sensors mentioned above and offer methods and considerations for evaluating a complete capture system. The needs of any project have to be assessed before the information provided here is to be of any real value. The end goal of any system is to provide maximum control with minimal inhibitions without compromising the potential for advanced techniques. Percussion instruments are excellent examples of simple interfaces that retain the potential for virtuosity.

The bandwidth of a percussionist is a major consideration. The world record for fastest single stroke roll is currently 1199 strokes per minute[9] which translates into approximately 20 Hertz. This only represents a single stroke roll; double stroke rolls have been recorded with up-wards of 1400 strokes per minute. The percussive interface must be able to capture these events with enough resolution to extract the desired information, such as: position, velocity and angle. The sampling rate must be high enough to resolve the complexities of the motion of stick between the strokes.

3.1 Drum Surface

An augmented drum offers many possibilities for freedom but also many design problems. When embedding sensors into or on the drum they must be protected from the impact force of the striking implement. Many commercial products achieve this by using rubber pads with the sensor embedded inside or using a foam bed lying underneath the drumhead. This does yield the possibility to use many different implements, thus allowing the performer to use their preferred traditional stick.

Wiring is a consideration in this case. In commercial devices the analog signal from the sensor is transmitted to a drum brain for processing. Another approach is to utilize the space inside of the drum shell to hold the wiring and circuitry and providing the processed data as output (the eTABLA is an example of this technique).

By placing sensors on the drum you do alter the vibrational properties of the instrument. When fabricating a synthetic drum, not intended to make sound itself, this is acceptable; but when extending a traditional drum with sensors this can be a problem.

The piezo offers a simple way of capturing percussive gestures. They were the first sensors used for this application and have been widely used in many of the available commercial interfaces. Using one piezo it is possible to capture the timing of strike and a plausible indication of velocity. The disadvantage of these sensors is that you cannot capture position with a single sensor. It is possible to find position using a network of four piezos, as has been shown [11].

FSRs give more precise pressure data than piezos and some types also give a position parameter as well. Since you must touch an FSR in order to trigger it, it is necessary to have either a large sensor with a custom shape or a small surface that accommodates the shape of the sensor. Again, since it is triggered by pressure they greatly reduce crosstalk.

[9] http://www.extremesportdrumming.com/

The main makers of the fiberoptic sensing pads are Tactex and the Mercurial Group. These interfaces come only as a prepackaged device. In order to incorporate them into new instruments they must be disassembled, as in the The Ski. These devices provide position in two dimensions as well as pressure data. The MTC pad connects via serial to a computer running Max/MSP. There is a custom object that comes with the interface to connect directly to Max/MSP thus allowing easy mapping from physical gesture to messages in the program. The main advantage of the MTC is that it is capable of discerning different touch points, allowing for multiple simultaneous striking events. Besides being a prepackaged product, the main disadvantage for percussion is the inherent latency of the sensors.

Capacitance offers continuous data in three dimensions. Having the continuous z parameter offers a great deal of creative possibilities. There is a nonlinear response when using this technique that makes it difficult to accurately track absolute position. A major disadvantage is that both the drum *and* the sticks have to be augmented in order to capture their position relative to each other.

The Korg Wavedrum provides an interesting combination of controller and effects processor. The acoustic sound received by the embedded microphones is used to excite physical models. The result is that the performer is not limited by the data that the interface can capture. If the gesture makes sound, which it should in order to produce music, then it will be captured by the microphones and transformed into an output signal.

A new approach to capturing gestural data is the timbre-recognition based instrument. The main advantage is that the overhead for setting up this system is minimal; it only requires a microphone. Many current musical situations are recorded and most musicians have become accustomed to having their instruments captured by microphones. The precision of this system is constantly being improved. The main disadvantage is that it is yet be seriously tested in real musical situations. While it performs well in a closed studio environment and reasonably well with the addition of noise, the proper compensation for the interference of a musical environment seriously complicates the situation.

3.2 Stick Augmentation

Embedding sensor systems within a stick allows performers to play any drum, traditional, modern, augmented, or even thin air. However, the modified stick will never feel the same as a traditional one, with added weight from the sensor packaging. Transmitting data using wires obviously proves to be cumbersome. Wireless transmission may be an impressive laboratory stunt, but can result in loss of data and non-reliable systems not usable for performance on stage.

Accelerometers on sticks can aid in capturing kinematic performance gestures, though data will be noisy and cannot be used to derive accurate position of strikes. Adding a gyroscope into the mix, as accomplished in AoBochi, provides a reference in which to derive position, making for a more informative and expressive system.

The use of magnetometers as seen in the Vodhran captures orientation with respect to the north pole. These sensors are usually surface mount sensors and require custom PCB boards to built for experimentation, making them less easy to use then sensors like FSRs and Piezos.

Infrared light tracking allows for an elegant solution to wireless sticks. As the performer gets further away from the receptor the field of capture gets larger, the largest possible field being 12 feet high by 20 feet wide. One disadvantage of the Lightning is that when multiple instruments are put in the same space a great deal of interference occurs and it is very difficult to control the system. The Lightning comes as a prepackaged product that is easily adapted to other tasks but is limited by its MIDI output.

3.3 Detecting Body Movement

Analyzing human body movements during performance of drumming offers another avenue of detecting a percussive gesture. A traditional technique is to analyze video camera footage which is completely unobtrusive requiring no sensors attached to sticks or drums. However the frame rate of the video camera along with time needed for post processing does not allow for fast percussive interaction.

Using motion capture systems such as VICON, more precise gestures can be captured at high sample rates. A marker is placed on each of the joints of the hand, and in key positions along the length of the arm. These points are captured by six cameras at a high sample rate providing accurate temporal and spatial data that is superior to most sensor interfaces. However the system is quite expensive.

The major problem with both these methods is that camera systems are difficult to use on stage. Variable lighting, camera orientation, calibration, are all issues which can end up being a nightmare during sound check, and even worse, during a live performance.

Building devices that embed sensor systems directly to the skin or within clothing, as mentioned in Paradiso's work [13], are promising. For accurate percussive gestures however, they might prove useful only in conjunction with other methods.

4. CONCLUSIONS

Clearly, there are many different considerations when developing a percussion interface. This paper has given an overview of different sensor strategies currently employed, as well as other strategies that are becoming possible through the work of many researchers.

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