EZITHER: EXTENDED TECHNIQUES FOR CUSTOMISED DIGITAL BOWED STRING INSTRUMENT

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ABSTRACT

The EZither is a custom designed musical instrument that affords extended musical control through the use of electronic sensors and a microcontroller. This extended control allows the possibility of new forms of interaction with the instrument and new approaches to sound. This paper outlines the custom hardware and software design of the instrument. It also discusses how the relationship between musical instruments and technology can provide new possibilities and approaches to composition.

1. INTRODUCTION

Music has a rich history of creating new practices by integrating new technology. One way in which technology has been integrated into music practice is by taking traditional designs and modernising them with new technology. This is often advantageous as users can bring years of experience to a device, and technology can have the role of complementing and extending an already existing device. This has been particularly true in designing new interfaces for musical expression.

The Hyperbow [1] is an instance of how technology is enhancing the possibilities of expression with the addition of sensor technology. The Hyperbow provides in-depth data about the subtleties of how the performer is using the bow, which is then used to affect the sonic outcome through digital signal processing. The Hyperbow is coupled with the Hyperviolin [2], which is designed in a way that, through multi-channel audio analysis software and embedded wireless bow hardware technology, allows the performer to have greater control over the sonic output.

Other instruments have combined traditional acoustic instruments with electronic sensors to extend the functionality and capabilities of the instrument. The ESitar [3] is a modified 19-stringed, pumpkin shelled, traditional North Indian instrument. Through the information received from multiple sensors placed on the instrument, the user is able to capture data about fret number, pluck time, thumb pressure, as well as pluck direction and three axes of the performer's head tilt. This allows the performer to have more control over the sound output of the performance through effects and looping mechanisms as well as deduce important data from the performance for analytical and documentation purposes.

Dan Overholt has also worked with expanding the range of possibilities for string instruments with his Overtone Violin [4]. He utilises data from the movement of the bow and the bow hand, as well as the sound information produced by the player. This information is then used to sculpt the sound and the sound is then sent back to the sounding body of the fiddle through an internally mounted tactile sound transducer, which is controlled via DSP running on an attached iPod Touch. This creates a two-way communication system and the body of the fiddle is resonated, giving the performer haptic feedback.

The EZither's design is influenced by these modern hyperinstruments discussed above. It has been named the EZither as it can be loosely attributed to the zither family of instruments. However, its influences range from the guitar to the ancient Chinese Guzheng and the Japanese Koto. Traditionally, a zither is a string instrument, usually found in Eastern or Asian countries [5]. They have no neck and the strings are connected directly to the sound box. The design of the zither allows it to be played either on the lap or on a flat surface. There are fretted and fretless varieties and the number of strings varies widely throughout the family. Usually Zithers are plucked however, some, like the Hammered Dulcimer, are struck and some are bowed. Most Zithers have many strings that are fixed in pitch to allow the performer to be able to play melodies in various keys.[1] The EZither is a ten-string zither that is designed to be played on a flat surface. It is designed to be bowed, however it can be struck and plucked as well. It features a dual-bridge system, which allows for a wide range of tunings and the possibility of unique techniques.

This paper contains six sections: Section 2 describes the build of the physical body of the EZither. Section 3

[1] http://en.wikipedia.org/wiki/Zither

describes the playing techniques that are possible on the instrument. Section 4 gives an overview of the electronics that are used and Section 6 describes how the instrument has been implemented. The paper concludes with a discussion on how the interaction between the performer and instrument is enhanced due to the electronic components in Section 7.

2. DESIGN OF PHYSICAL BODY

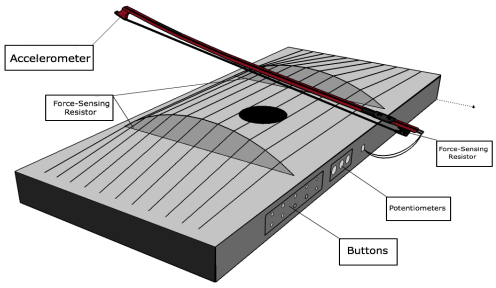

Fig. 1. This figure shows an overview of the design of the EZither.

2.1. Body

The EZither's body is made from a simple box design. Plywood was used for affordability and was glued and nailed together to create the box. A hole was drilled into the top of the box to act as a sound hole to promote greater acoustic volume. The choice of using a box shape as the body of the instrument was integral to the intended use of the instrument. The instrument was designed originally to create drone textures and the box shape is an acoustic structure which reinforces frequencies and promotes the sustain of the instrument. Aluminum sheet metal was screwed into the wooden body to act as reinforcement to the base. Due to the tension that the strings put on the body of the instrument, as well as the structure being weakened by drilling holes through its frame to mount sensors, the metal base was necessary to ensure the body was structurally sound. Aluminum sheet metal was also used to mount buttons, lights and potentiometers to the body and the material for the bridges.

2.2. Bridges

The bridges were an important aspect in the design of the instrument, as we wanted to be able to isolate a single string when bowing. This was achieved by creating a bridge with a circular segment, based on traditional string instruments. The two bridges also divide each string into three segments, each with their own pitch. This allows for up to 30 pitches to be tuned. The tuning of each segment is determined by the tension and the length of the section, meaning that proportional relationships can be used to create a system of pitches, which are in tune with each other. The bridge is made out of aluminum sheet metal, which produces a strong metallic timbre and is a very malleable material. The bridges are not fixed and instead are secured by the downward force of the strings and small tabs, which help to anchor the bridge.

2.3. Strings

The strings used are metal wound strings, designed for acoustic guitars. They were chosen because of the metallic quality of their sound and for pragmatic reasons like cost and accessibility. They are secured into the body of the instrument by guitar bridge pins, which stop the string into the base of the body.

3. PLAYING TECHINIQUES

The EZither has been designed so that the user can easily bow or pluck the strings of the instrument. It allows for a wide array of playing techniques that are mirrored in other instruments as well as some unique techniques, made possible by the design of the instrument.

3.1. Bowing

The strings can be bowed and the full range of traditional techniques used with other string instruments are applicable to this instrument. Sul ponticello bowing is especially pronounced on the instrument as the metal bridges severely alter the sound, as the bow gets closer to them. The metallic timbre is most pronounced when the strings are bowed in the sul ponticello position or when they are bowed with much pressure. The resulting sound is similar to the grating sound of a string instrument being bowed directly on the bridge or a scratch tone being produced.

3.2. Pizzicato

The strings can be plucked and, due to the choice of strings, the resulting sound is more similar to a guitar than a classical string instrument. Each string is easily isolated as the distance between strings is much greater then other string instruments.

3.3. Vibrato and Pitch Bending

The dual bridge system allows for the free hand of the user to manipulate the pitch of the string. Since the bridges split the string into three sections, the user can change the tension of a string in one section and bow or pluck in another section. This is very similar to the Chinese Guzgheng and Japanese Koto, which can be manipulated in the same way. This also allows the user to be able to play more pitches than the ten pitches the strings are tuned to, expanding the pitch functionality and capability of the instrument.

3.4. Harmonics

By lightly touching the string with a fingertip, harmonics are easily played on the EZither. It is very responsive to harmonics and numerous harmonic nodes can be obtained.

4. ELECTRONICS

The sensors used on the EZither are an accelerometer, three force-sensing resistors, three potentiometers and five buttons each with an LED. They all communicate with a computer via an Arduino Mega 2560.[2]

4.1. Arduino Mega 2560

The Arduino Mega 2560 is the microcontroller that forms the core of the electronics in the EZither. It allows for the sensor data to be communicated to the host computer. The Arduino Mega was chosen because it features several parallel on-board analog to digital converters allowing for the extraction of data from multiple analog and digital sensors, as well as, controlling visual feedback outputs.

4.2. Accelerometer

The accelerometer used is the ADXL 335 Triple Axis accelerometer with a breakout board. It allows for three axes of movement and sends continuous analog data. It can measure the static acceleration resulting from motion, shock or vibration. The accelerometer is positioned on the tip of the bow.

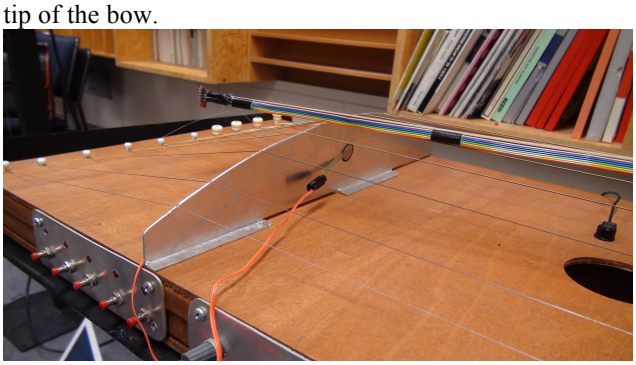

Fig. 2. This figure shows the position of the accelerometer at the tip of the bow.

4.3. Force Sensing Resistor

FSR's will vary their resistance depending on how much pressure is being applied to the sensing area. The harder the force, the lower the resistance. These FSR's can sense applied force anywhere in the range of 100g-10kg. Three FSR's are used on the instrument. Two 0.5 inch FSR's sit on the left bridge of the instrument, which makes them easily accessible to the left hand of the performer and one smaller 0.16 inch FSR is fixed onto the bow near the frog. This is placed so the performer can access it easily with their right hand thumb.

4.4. Buttons and LEDs

The buttons used are simple momentary panel-mounting buttons. They function as a toggle button and a LED represents the state of each button. The buttons and LEDs are mounted onto the instrument with a panel made from aluminum sheet metal.

4.5. Potentiometers

Three 10k ohms, linear rotary potentiometers are used on the EZither. They are simple components that allow a great deal of control and have been used to control the master volume of the output and the wet/dry level's of effect chains.

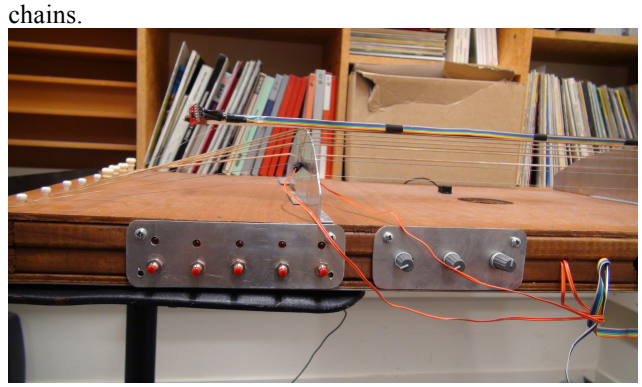

Fig. 3. Shows the position of the buttons, LEDs and potentiometers.

4.6. Hiduino Firmware

The Arduino was modified using Dimitri Diakopoulos' 'hiduino' custom built firmware, which converts the Arduino into a class-compliant, driverless MIDI/HID device [6]. Normally, the Arduino microcontroller communicates by implementing a virtual COM port via USB for basic serial I/O. This provides a problem because most music programs do not recognise serial data natively, and thus the data needs to be converted by an intermediary program so that the data can be implemented. The hiduino firmware bypasses this extraneous step, and allows the Arduino to communicate directly to musical applications via MIDI. This makes the data chain more streamlined, universal and stable.

5. IMPLEMENTATION

5.1. Data Implementation

Multiple parameters of the bow movement can be extracted from the three-axis data of the accelerometer. The raw data gives the static position of the bow. By storing a history of the data, the velocity and acceleration

[2] http://www.arduino.cc/

can be deduced as well. This gives nine, continuous streams of analog data that can be mapped to sound parameters just from the accelerometer.

Often, during live performance, the accelerometer data may want to be triggered on and off. The force-sensing resistor that is positioned on the bow allows the performer to have control over when the accelerometer data is being received and updated by the user. While the FSR is held down, the accelerometer data will be continuously read and updated. Otherwise, the accelerometer data is ignored and the values are locked to the last received message. This is helpful as it allows the performer to change a parameter of the sound with the accelerometer and when desired, hold that parameter at a constant point while being free to move the bow.

A layer system has been implemented with the buttons to maximize their functionality. Each layer has one instance of the five buttons which all send out an on and off message on a unique channel. By pushing the two outer buttons simultaneously, the layer is changed and the buttons now send on and off messages on a new unique id. This can be repeated endlessly, and to return to the original layer, the first and third buttons can be pushed simultaneously.

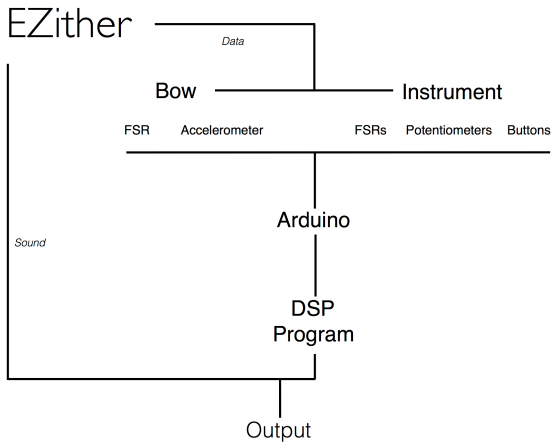

Fig. 5. Shows the signal flow of data.

5.2. Musical Implementation

The control data sent from the EZither has been implemented in multiple ways to extend the EZither. The electronics can serve as an on board sampler which can trigger sounds. In this case, the function of the control data is to accompany the acoustic sound of the instrument.

These sounds have been triggered using two methods so far. The buttons can be used to simply launch a sound, leaving the FSR's, potentiometers and accelerometer free to affect the samples. The acceleration data from the bow can also be used to trigger sounds. Certain gestures can be captured, allowing for a gestural creation of the sound. By using the bow to create samples, the connection between the physical gestures of the performer and the sound created is easily apparent for the audience.

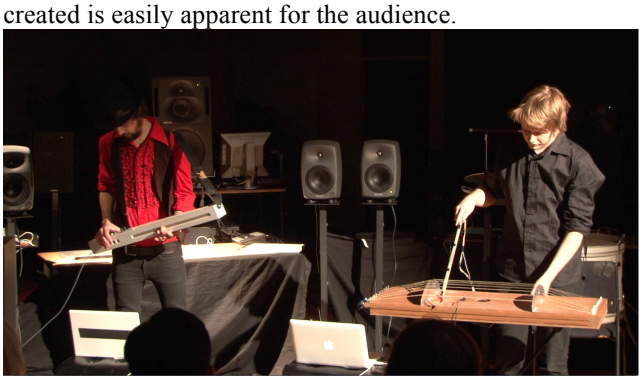

Fig. 4. Insomnia being performed.

The function of the electronics can also be to extend the acoustic sound of the instrument by controlling digital signal processing. This method has been used in two compositions that have been written for the EZither and other new musical interfaces. In these pieces, a contact microphone is placed on the face of the instrument and the incoming audio is then processed in Ableton Live[3]. Using a contact microphone has proven to be the most suitable as it isolates the sound coming from the EZither, which lowers the potential for feedback, and it also picks up the resonance of the instrument. Other programs could have been used but Ableton was chosen as it easily allows for MIDI mapping and custom-built Reacktor[4] patches can be used in Ableton with the Reaktor FX plugin.

In both compositions, the incoming audio was received on one channel and then sent out via busses to auxiliary channels. On each channel, a different effects chain was implemented and the buttons controlled which channels were armed. Various plug-in effects were used including the built-in Ableton effects, as well as, third party plug-ins and custom built plug-ins made in Reaktor. Within these effects chains, parameters of the effects were controlled by the control data received from the accelerometer, FSR's and potentiometers.

Other ways that the EZither has been implemented is by using the buttons to control a looping module. This allowed for sounds to be recorded and layered on top of each other. This is quite an effective implementation for the EZither as it can create mass chords and dense textures. This implementation allowed the EZither to function as a supporting instrument within an ensemble.

[3] http://www.ableton.com/
[4] http://www.native-instruments.com/#/en/products/producer/reaktor-5-player/

The data available from the performers interaction with the bow has been the most expressive and interesting out of the sensors. By using the bow to control the processing of the acoustic sound, the performer can control the sound by using physical gestures. This allowed for a more expressive performance, and for the audience to understand the link between the performers interaction with the instrument, and the resulting sound.

6. CONCLUSION

In all forms of music using acoustic instruments, gesture plays an important role in the production of sound and the interaction of the performer with the audience. In the case of an acoustic instrument, the performers interaction with the instrument and the resulting sound is an easily discernable causal chain. When a performer pushes down a piano key, the audience hears the result of this physical gesture. This is not always the case in live electronic music. Performers may use a range of interfaces and instruments that are new and whose methods of sound production are unknown to the audience. This creates a disjunction in the audience's understanding of the performers interaction with an interface or instrument and the resulting sounds.

By using electronic sensors to capture gestural activity, the causal connection of the performers physical gestures and the resulting sound output can be mirrored and even enhanced. The resulting sound output can take various forms but the causal connection can still be apparent to the audience. Instruments like the EZither that utilise electronic sensors to capture the performers gestural movement can mirror the causal chain of acoustic sound production. The accelerometer is used in this way on EZither as gestural movement is translated into a sonic outcome. As the bow is rotated, the sound of a reverb effect can swell and then be quickly muted by a flick of the bow. When using the acceleration data of the bow, a forceful flick of the bow can trigger a new sound or amplify the acoustic sound of a gesture. In this case, the bow can function in its traditional role of producing sound by vibrating a string, as well as, controlling the sound manipulation over the resulting sound.

With more development, these types of interactions can expand the gestural control of a performer, and because the sound is not limited to the acoustic restraints of the instrument, the interaction can be more expressive then previously possible.

7. ACKNOWLEDGEMENTS

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