Electric Slide Organistrum

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ABSTRACT

The Electric Slide Organistrum (Figure 1) is an acoustic stringed instrument played through a video capture system. The vibration of the instrument string is generated electromagnetically and the pitch variation is achieved by movements carried out by the player in front of a video camera. This instrument results from integrating an ancient technique for the production of sounds as it is the vibration of a string on a soundbox and actual human-computer interaction technology such as motion detection.

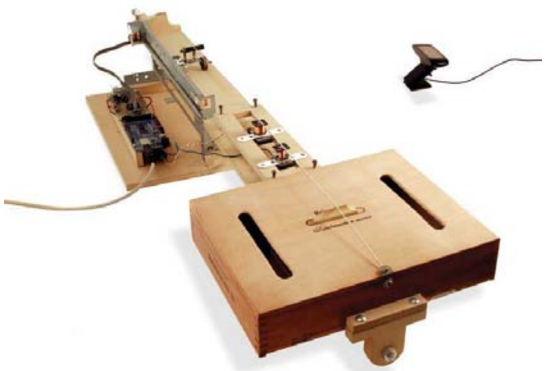

Figure 1: Electric Slide Organistrum.

Keywords

Gestural Interface, eBow, Pickup, Bowed string, Electromagnetic actuation

1. INTRODUCTION

This paper features an instrument which combines the rich sounds of acoustic instruments with the easy usage and entertainment provided by the current motion detection interfaces. The performance of this instrument requires no physical contact between the player and the instrument since the string vibrates by means of an electromagnetic field and the pitch varies depending on the position of the performer over a video camera.

This research is not aimed at creating an instrument capable of competing with the versatility, expressiveness and other attributes of traditional acoustic instruments. The goal is to propose an attractive, easy and intuitive way of making music with an acoustic stringed instrument.

2. BACKGROUND

There are mechanical stringed instruments such as the Organistrum (Figure 2), considered predecessor of the Zanfona and the Hurdy-Gurdy, which produce sound when the player spins a rosined wheel (usually made of pear wood) that rubs the strings continuously. The rosined wheel plays a similar role to that of the bow used among the instruments in the orchestral string family.

One of the interesting aspects of the rosined wheel is that it enables a constant sound to be produced for as long as the player desires since, unlike what happens with bows, here the element used to rub the strings has no end. Even though it is true that there are bowing techniques that allow an expert performer to minimise the noise gap produced by changes of direction of the bow, the rosined wheel performs better for this purpose.

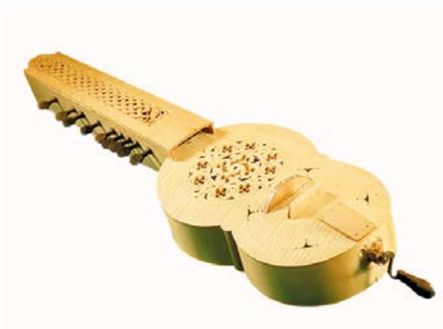

Figure 2: Organistrum.

2.1 Violano Virtuoso

When compared to the traditional bow, the rosined wheel shows many mechanical advantages regarding the automation of the string friction of an instrument. While the movement of a traditional bow requires at least incorporating a mechanism that changes the movement direction when reaching the ends (tip and frog), the wheel can be attached to a motor that spins only in one direction to produce sound. The Violano Virtuoso (Figure 3) patented in United States in 1905 by Henry Sandell [9], is an instrument used to auto-

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matically play the violin utilising rosined wheels to bow the strings, and small mechanical "fingers" activated by electromagnets to stop the strings. The melodies of this instrument were engraved in punched paper rolls made by the same manufacturer of the instrument (Mills Novelty Company).

The Violano Virtuoso solved all mechanical and constructive challenges presented by the creation of an automatic string instrument, reason why it was inevitable to consider it the ideal candidate to incorporate a gesture interface. Unfortunately, nowadays these instruments are very rare which makes it very hard to access and even harder to intervene one.

Figure 3: Mills Violano Virtuoso Standard Model

Considering this, it was decided to orientate this research towards the search of an alternative method to provoke the vibration of the strings and vary the sound pitch automatically, preserving the sound effect of bowed instruments.

2.2 Previous Work

The string excitation by means of electromagnetic fields has been used to generate sounds for at least 40 years. The most influencing antecedents of this work are mentioned below[1].

The EBow[5] (Electronic Bow or Energy Bow) is an electronic device that is used for playing the electric guitar. This device can cause the vibration of the strings without the need for the player to touch them. The vibration is induced electromagnetically and results in an infinite sustain.

By the end of the 70's, Nicolas Collins began to experiment with electric guitars connected to an amplifier's output and managed to electromagnetically induce the strings to slightly vibrate in response to audio signals. Collins named this connection scheme "Backwards Electric Guitar" and subsequently built other devices based on the same work guidelines. In his article[4] Collins describes one of these devices called "Level Guitar" for which he assembled the driver coils over rails enabling the performer to move them through the strings to shift the overtone balance.

In their work named Electromagnetically-Prepared Piano Berdahl, Bloland and Smith[3] study in depth the excitation of certain strings of an acoustic piano using electromagnets driven by software generated signals.

Subsequently McPherson and Kim [8] introduced an electromagnetic actuation system that embraces the whole range of pianos at a reasonable cost and they also included a feedback-based control strategy that aims at merging the traditional technique for the creation of sound (hammer actuated) and the electronic control, resulting in a natural extension of the piano.

Shear and Wright [10] suggested an augmentation of the Rhodes Piano based on electromagnetic actuation. Among the parameters that this system enables to control are slow attacks and infinite sustain.

One of the robots built by Sergi Jordà for the performance "Afasia" [6] called *The Violin Robot* includes an Ebow to cause the vibration of a string and a glissando finger controlled by a stepper motor which can slide up and down along the string. This instrument is played using an exoskeleton equipped with multiple sensors.

2.3 Comparison with Previous Work

The Electric Slide Organistrum uses the same feedback loop principle as Ebow to initiate and maintain the string vibration. The main difference from the piano based works mentioned before is that no external signals are used here to provoke the vibration. In this instrument the signal of the driver coil is the amplified output of a magnetic pickup. Unlike The Violin Robot, this instrument does not use electrical amplification for the sound but uses a wooden soundbox instead. In terms of interaction this instrument uses motion detection based on the processing of images taken with a video camera. Finally, another aspect that characterizes this instrument is that it was built with hardware from unused devices such as printers, scanners and relays.

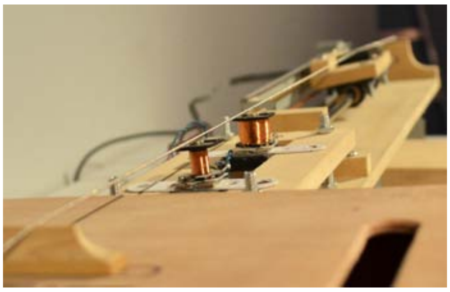
3. ELECTROMAGNETIC ACTUATOR

As mentioned earlier the vibration of the instrument's string is achieved through an electromagnetic actuation system. This system is based on a positive feedback audio amplifier circuit (Figure 4(b)). All the elements in the circuit are standard except from the driver and pickup coils (Figure 4(a)). The movement of the string in presence of a magnetic field induces electrical current the input coil which is amplified by the audio amplifier and fed to the driver coil. This produces a varying magnetic field on the driving coil that drives the string at its resonant frequency, and sustains the vibration. Because of the positive feedback, this system is able to induce the vibration from rest.

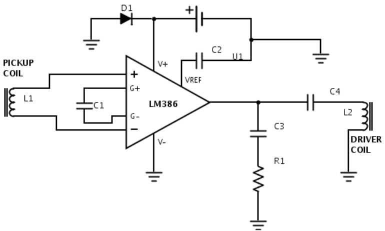
While looking for adequate coils, experiments were made with various windings taken from unused electronic devices such as head-phones, telephone receivers, microphones and transformers taken from compact fluorescent lamps, however, none of these coils performed effectively. Finally, a test was done with coils of 12 V relays usually used in cars.

In order to adapt the impedance of these coils to the amplifier, the amount of wire turns was reduced until reaching an impedance of 50 Ohms in the pickup coil and 8 Ohms in the driver coil. When the desired impedance was reached, a permanent magnet taken from the stator of a DC motor was incorporated to the base of each of the coils to provide the magnetic field required for the electromagnetic induction. When bringing both coils closer to the strings of an acoustic guitar, the system was capable of inducing the vibration. This test also showed that the gap between the coils has a big impact on the production of sound. A gap of less than 5 cm quickly produces a high-piched sound comparable to that of the audio feedback when a microphone points to a loudspeaker. As the gap increases between the driver and the pickup coils, the sound becomes low-pitched and the "bowed string" effect begins to be noticed. Moreover, as the gap between the coils increases, the system takes longer to cause the vibration of the string. The distance determined to preserve the bow sound without compromising the string excitation period was 8 cm.

[1]Only one subgroup of string instruments which use electromagnetic fields to provoke the string vibration will be mentioned. This paper does not aim at a detailed review of robotic string instruments created over the years; however this is available in Ajay Kapur's paper[7]



(a)



(b)

Figure 4: 4(a) Driver and pickup coils mounted on the instrument. 4(b) Electromagnetic system's schematic

4. DESIGN OF THE INSTRUMENT

4.1 Pitch variation mechanism

Sliding a metal pipe along a vibrating string (slide guitar or bottleneck guitar technique) enables to vary the pitch without stopping the vibration. Taking into consideration that the electromagnetic actuation system needs approximately one second to induce audible vibrations, it is desirable to change the pitch without stopping the string. As an additional advantage, it is easier to implement a mechanism to slide a metallic cylinder along a string, varying the contact point, than a system capable of stopping a string against a fingerboard in different spots (e.g. the one used in the Violano Virtuoso).

The print head positioning mechanism of an inkjet printer was adapted so that, instead of moving an ink cartridge across a sheet of paper it moves a metal slide back and forth along a guitar string. In order to accomplish this, the metal slide was assembled on a wooden piece and this attached to the stepper motor using the carriage belt. In this way the movement of the stepper motor of the print head positioning system determines the position of the contact point of the metal slide and the string, hence varying the sound pitch. A driver circuit based on an H-Bridge L293D was built to control the stepper motor and an Arduino [1] board was used to command the movement from a computer through an USB port.

4.2 Body of the instrument

The design of the body of the instrument was determined by two significant factors:

- Interaction with the instrument
- Shape of the inkjet printer chassis

Due to the selected interaction model, designing the body of the instrument to be hand held was not an option. Rather, its physical design/morphology should allow the player to move his/her hands in front of the video camera. For this reason, it was decided to design a table top structure

The inkjet printer chassis (designed to be placed on a desk) was used as the core element of the instrument to take advantage of its morphological and mechanical characteristics. Figure 5 shows a top view of the instrument. In order to make the user experience as intuitive as possible, the chassis was placed in such a way that the movement of the metal slide headed in the same direction than the player's hand in front of the video camera. The aim was that the player perceived that the metal slide was following the movement of his/her hand[2].

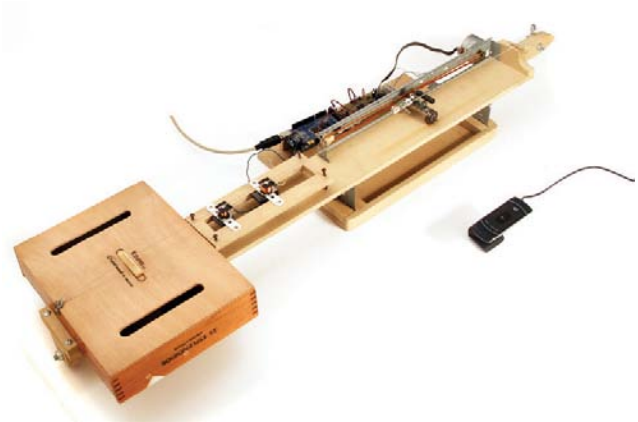


Figure 5: Top view of the instrument

4.3 Soundbox

A wooden cigar box was used to couple the vibration of the strings to the surrounding air. The bridge transfers the motion of the string to the top plate of the box, causing it to vibrate at the same frequency. To achieve a reasonable sound amplitude the side of the box built of thinner wood was chosen as the top plate. Two sound holes were cut longitudinally so the top plate can vibrate more easily and to allow the exit of air displaced as a result of this movement. Figure 6 shows the sound box, the sound holes and the bridge.

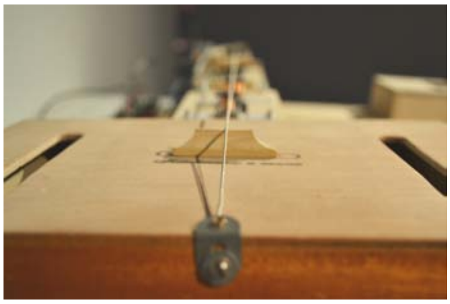


Figure 6: Sound box, sound holes and bridge

5. INTERACTION

5.1 Expected user behavior

The user interface of the system was designed pursuing discoverability. This means that through this interface a person should be able to interact with the instrument without receiving instructions. It is therefore important that the user can establish a natural connection between the gesture that is made and the system response.

Certain assumptions about how people would react when faced with the instrument were made:

[2]A demonstration video can be found at: http://vimeo.com/23871661

Visual exploration: Since this is an unfamiliar object it was anticipated that the first phase of the interaction would consist on a visual evaluation.

Hand gestures: Supposing the exploration phase provides sufficient visual information and arouses interest, the assumption is that the user would proceed to interact with the instrument using his/her hands.

Figure 7 shows the expected behavior at the moment the user faces the instrument.

5.2 Camera position

Placing the video camera and the instrument at the same level and capturing the player from a very low angle reduces the number of objects present in the scene and enables to have no undesired moving objects in it. This fact certainly simplifies the image processing and, furthermore, allows the system to shut down when no moving objects are captured, meaning no user is intending to interact with the instrument.

Because of the way in which the parts of this instrument were laid out, the user was expected to move forward his/her head to explore it visually from above. When that happens, the head enters in the visual domain of the camera. Consequently, the instrument starts producing sound and the metal slide moves. This response from the system intends to make the user understand in few seconds that when an object enters the visual field of the camera, sound is produced, the metal slide follows the object's position and sound changes its pitch. Then the user can choose to continue interacting by moving his/her head or proceed to try another gesture (e.g. using his/her arms).

(a) (b) (c)

Figure 7: Expected user behavior: 7(a) The user is standing in front of the instrument. 7(b) Comes closer to observe in detail and as a consequence enters the camera field of view. The instrument starts producing sound and the metal slide moves. 7(c) The user starts to interact using his/her arms.

5.3 Blob tracking

Images from the video camera (Logitech HD Webcam C910) are processed by a blob tracking application developed in C++ using OpenFrameworks [2] that allows obtaining the moving object's position within the scene. Every time an object is detected on the scene the application determines the x coordinate of the center of the object's outer rectangle. That value is mapped in the range of values where the stepper motor can move preventing the metal slide from reaching the end of the chassis, and is subsequently transmitted to the Arduino board through an USB port.

To ensure that the instrument produces sound only when someone is using it, the application that processes the images sends a special character before each update of the detected objects x coordinate. This character defines the state of a relay that connects or disconnects the power of the electromagnetic action circuit depending on whether it detects an object on scene or not. To avoid false positive detections, only blobs whose area exceeds a predefined threshold are tracked.

6. CONCLUSIONS

This paper proposes a method to establish a nexus between the production of sounds through acoustic means and interfaces based on motion detection technology. An electromagnetic actuation system capable of initiating the vibration of the instrument string producing a bowed-string effect was built. The instrument was tested by users during two exhibitions[3] [4] where it was observed that the interaction is intuitive and the experience results attractive. Based on feedback from users and specialized reviewers, future actions include the addition of more strings so as to cover a wider range of tones and reach a greater intensity of sound. Regarding the user interface, future work includes extending the image processing software to be able to recognize gestures. Those gestures will enable the user to trigger predetermined sound effects like vibrato and tremolo. The electromagnetic actuation system can also be significantly improved since an important range of sound effects can be produced processing the electrical signal that is fed to the driver coil.

7. ACKNOWLEDGMENTS

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