URECA RESEARCH PAPER

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Digital Theremin : Old Ideas Meet New Technology

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Abstract - Music is an artform. Its cultural significance such as religious rituals and social activities speaks to great lengths of its importance. Musical instruments are the means through which music is produced and hence have extraordinary value. These instruments have changed and developed through the course of time. They help control pitch and volume, which in turn leads to creation of sound. Sounds that follow a rhythm and contain a melody helps create music.

In 1928 Leon Theremin patented the infamous Theremin – an electronic musical instrument in which a musician's hand movement is extrapolated to create music. One hand controls volume and another controls pitch. Another of his inventions was the Terpsitone, which uses the movements of a dancer to create music. In this paper we research the usage of modern technologies to implement these age-old musical instruments. The Kinect sensor by Microsoft technologies allows users to track skeletons of a moving human body. We use this feature to implement a digital Theremin. Our objective is to provide an easily accessible and monetarily feasible form of the Thremin. We investigate its possibility as a modern-day musical instrument and its ease of usage by first time learners.

Keywords – Theremin, easily available modern technologies, skeletons

1 INTRODUCTION

It has been almost 90 years since a group of ten musicians took to stage at Carnegie Hall, USA, each carrying an instrument that was new and quite popular with the community. Among the ten musicians sat the inventor himself, Mr. Lev Sergeyevich Termen or more popularly known as Mr. Leon Theremin [1]. He was a Russian and Soviet inventor with an avid enthusiasm in both music and physics. His love and passion for both these subjects led to the invention of one of the first electronic musical instruments to be mass produced: the Thereminvox or more commonly known as the Theremin. The instrument used changes in capacitance of electronic circuits in order to control both sound and pitch of the oscillator [2]. These changes were achieved by the movement of hands in the proximity of two metal antennas thus, allowing the user to play the instrument without any physical contact.

The Theremin, as an instrument has lost popularity over the decades. There are multiple reasons for this, firstly being the lack of physical contact. Although it seems quite intriguing, the lack of contact in an instrument makes it difficult for mediocre musicians to correctly place their hands and coordinate their motions. A very good or average sense of music or particularly pitch is required in order to master the instrument [3]. Furthermore, the instrument's very precise response to change in capacitance makes it very much aware of surroundings as well as presence of other objects around it. Thus, a need for it to be tuned at every new location as well as for every new performer [3]. The Theremin also poses the challenge of having limited number of octaves or range of frequencies which can be played on it. Finally, considering the demerits, the Theremin or its contemporary counterpart is sold today at 300 US$ by Moog Music.

Our research aims to address these problems related to the original Theremin and thereby find a new cost-effective and easily available platform to promote the Theremin. This is achieved by using modern technologies in order to implement similar functionalities as that of the Theremin. Our previous research focused on using LEAP motion technology in order to achieve this. It used advanced finger tracking technology to measure distance between a user's fingers and a flat surface. This allowed the user to control pitch as well as volume with minimal movement and provide adequate properties as that of the Theremin.

Although this provided a breakthrough, we felt the need to provide a more interactive and visual sense of playing the Theremin. This leads to our research in the use of Microsoft's Kinect technologies which we will be elaborating on in this research paper. It uses full body tracking capabilities to implement the Theremin. This allows us to overcome many challenges with the original Theremin, such as effect of surroundings, frequency range and overall cost. It also falls in line with our objective to have a more holistic experience while playing the Theremin.

2 BACKGROUND THEORY

The Theremin is one of the more renowned and well-known inventions of Sir Leon Theremin. It's structure generally comprises of a wooden rectangular box which houses its electrical components. Attached to the box are two metal antennas, one generally in an up-right position while and another antenna having a curved form.

The curved antenna both start and end attached to the box. Both these antennas serve different functions. The up-right antenna is responsible for the controlling pitch. The Theremin player moves his hand respective to the antenna. Greater the distance between the player's hand and the antenna, higher the pitch produced by the instrument. Similarly, Shorter the distance between the player's hand and the antenna, lower the pitch produced by the instrument. The curved antenna is responsible for volume control. The greater the distance between the player's hand and the antenna, the higher the volume whereas smaller distances generate lower volume.

The sound produced by the Theremin works on an electronic principle known as capacitive reactance. Capacitive reactance is generally known as a capacitors opposition to alternating current.

$$Xc = \frac{-1}{\omega C} = \frac{-1}{2\pi f C}$$

The above equation shows the relation between reactive capacitance and a capacitor. In a Theremin, our hands act like the ground plate of the capacitor. While changing the position of our hand, what we are in fact doing is changing the properties of the capacitor, which in turn leads to a change in capacitive reactance and finally resulting in a change of frequency which is then interpreted as pitch or volume. The distance required to control pitch or volume is non-linear in nature, as the capacitance change is much greater closer to the antennas [6].

The Terpsitone is a lesser known counterpart of the Theremin, works in a similar way as the Theremin. The Terpsitone consists of a mainly a metal plate or platform that serves a similar function as that of the antennas of a Theremin. The Terpsitone player, uses his body to adjust the distance from the metal plate, leading to changes in inductive capacitance. These changes are then interpreted as changes in pitch, allowing the musician/dancer to control the pitch using their body movements in an almost dance like motion. It is by all accounts nearly impossible to control and hence is not as popular as the Theremin.

The Theremin and Terpsitone have complex internal circuitry. Which it makes it difficult to mimic its functionality using modern-day technological advancements. The modern equivalent "Moog Etherwave Standard Theremin" sells at approximately 1000 US$ on E-Shopping websites. The Etherwave performs similarly to that of the original Theremin and produces a non-linear, monophonic sound.

The Theremin itself poses various challenges for musicians. Since the antennas are very sensitive to hand movements, it requires the player to remain almost completely still while playing the instrument. Any slight changes in hand positions, will leads to a false note being played. Since the sound produced by the Theremin is continuous, minute errors tend to be quite noticeable.

Our goal is to develop a more attractive alternative of the Theremin. we investigate modern day technologies which can be used to possibly replicate the Theremin and its functionalities in a more cost-effective and easily available manner.

3 PREVIOUS RESEARCH

Our previous research dealt with investigation into LEAP motion controller as a possible alternative to the Etherwave. The LEAP motion controller uses optical hand tracking to provide near-perfect hand and fingertip positions.

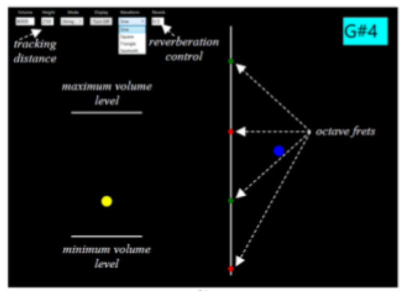


Figure 1 User-Interface for LEAP-Theremin

We measured fingertip positions with respect to a platform from on which the device was kept. The heights were then averaged and used to correspond to pitch and volume. The right-hand fingertips helped control pitch while the left-hand fingertips helped to control volume with an accuracy of approximately 2.5 mm [5]. An accompanying Windows Form Application was developed.

The use LEAP motion controller is available for approximated 80 US$ on E-Commerce websites. It is moderately available and affordable. Its use allowed for the development of a software application that produces a very similar sound to that of the Theremin.

3.1 ACHIEVEMENTS

The application provided a visual representation of our hand positions with respect to the platform. This allowed the player to more precisely control his movements. Thus, allowing them to acquire skill in the instrument at a much faster pace.

It allowed the musician a greater degree of freedom to move his body without affecting the music to a great extent. Additionally, the platform on which the device was placed, allowed the user to rest his elbows while he performed.

3.2 DRAWBACKS

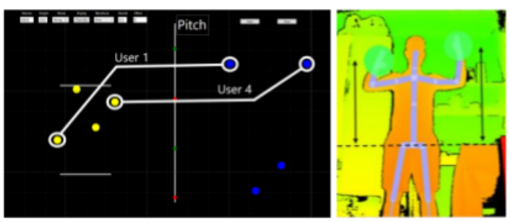
- The user was limited to the platform and was not allowed to move to a great extent
- The device required a heightened platform
- It was only feasible to be used by a single user

These drawbacks are in line with inventor's vision for the Theremin to be a musical instrument which can be shared and use by everyone.

4 FURTHER DEVELOPMENT

To tackle the drawbacks mentioned in section 2.1.2 we investigated the use of Kinect Sensor technologies.

The Kinect sensor uses full body optical tracking to track the skeleton of multiple users. It is currently being used in the gaming industry as game controller for Xbox. It uses IR Emitter, Colour Sensor, IR Depth Sensor and Tilt motor to perceive objects, their locations and relative depths [5]. It is easily available and costs around 250 US$



(a) (b)

Figure 2 (a) Multi-user interface. (b) Skeleton representation using Kinect sensor

We used the features provided by the device to redevelop our existing software. We use hand positions as tracked by the Kinect sensor to control pitch and volume. The lower spinal point was used to as a dynamic origin. We use horizontal distance between the hands and the dynamic origin as a measure of control. The right-hand controlled pitch while the left-hand controlled volume.

In addition to this, we used its capability to track multiple skeletal figures to incorporate a multiple user functionality. Thus, allowing more than one user to play the instrument concurrently. The software uses a player class to keep track of the movements of ever individual user and play their corresponding output pitch and volume.

4.1 ACHIEVEMENTS

The use of a dynamic origin allowed the user to control music even regardless of the position of his body. This would allow users not only to use the system while moving but could possibly allow user with disabilities to share in the experience of playing music on the Theremin.

The functionality to track multiple users allows for a greater depth of learning. It allows first time learners to follow professionals with great accuracy. This would allow them to learn and master the instrument at a faster pace.

4.2 DRAWBACKS

The Kinect sensor may sometimes fail to detect certain skeletal points. This may lead to loss of data and occurrence of wrong values of pitch and volume. This loss of data leads to crackling sounds while the users performs.

While using the application with multiple users, a bottle neck may occur. This may cause a lag between hand movement and actual playing of the sound with right pitch.

5 CONCLUSION

This research investigates the possible alternatives for the 100-year-old electronic device, Theremin. It investigates possible alternatives that can easily replicate the sound and experience provided by a Theremin. The possible alternatives include LEAP motion controller and the Kinect Xbox sensor that use optical tracking capabilities to track fingertip and hand positions respectively. It then uses these positions to produce a corresponding sound of given pitch and volume. These easily affordable technologies would allow any aspiring Theremin enthusiast to quickly acquire and master the Theremin.

5.1 FUTURE WORKS

The use of Kinect sensor can be further extended to implement a Terpsitone. Using various exoskeletal points, it may be possible to implement a Kinect alternative to the Terpsitone. This would allow users to use their entire body in a rhythmic fashion to produce music.

It may be possible to introduce a MIDI file player into the Windows Form Application which would allow users to follow the hand movements of virtually any song.

Addition of overlapping sounds may remove the monophonic tone produced by the Theremin which could make the instrument more attractive to first time users.

5.2 APPLICATIONS

The Theremin could possible used as a modern-day instrument. It could possible be used in concerts for its eerie and unique sound.

It can be used in engagement among elderly and disabled people as it is only required hand movement in free space.

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