Virtual Theremin with Pitch Guides

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***Abstract*—Theremin is a proximity sensor based musical instrument that requires rigorous training to master. Beginners may struggle in playing the correct tune because of the lack of physical contact to the instrument. Virtual reality serves as an excellent source to provide guidelines for beginner training. The proposed project outlines a simple platform to provide guidance on the played pitch.**

I. Introduction

Theremin is an electronic instrument with antenna and LC circuit for distance sensing. The instrument produces an eerie sound without direct contact with the performer. The lack of physical contact makes it particularly difficult to accurately tune to the intended pitches. One hand controls the pitch, while the other controls the loudness (Fig. 1).

While one can play the theremin by moving the entire palm closer or farther away from the antenna rod, professional thereminist uses their knuckles and fingers to vary the sensing distance (Fig. 2). By keeping the palm static, the performer anchors a reference point to easily find neighboring pitches on the scale. Therefore, it is crucial to train novice learners to utilize finger movements to vary pitches.

II. Motivation

Professional and homemade theremins alike lack the physical pitch guidelines for training. The guidelines must suspend in the air to provide a radial calculation of the pitches. The issue with physically suspending a paper guideline is that the guide will be one-dimensional and fails to capture radial distances. By using virtual reality, we can adjust the pitch guides according to the performer's view angle. We can also easily add and remove such pitch guides according to the performer's aptitude (Fig. 3).

III. Related Work

Early works of multiple object tracking for six degrees of freedom consisted of inertial sensors, such as accelerometers, gyroscopes, and electronic compasses [4]. The use of these inertial were primarily used in wearable sensors to detect translational and rotational movements [5]. Via Bluetooth, the wearable electronics then communicates with the reference modules to send and receive position and orientation updates. In recent years the use of stereo camera and infrared light projector has enabled tracking of user movement without requiring wearable devices [6]. In particular, the Leap Motion Controller used in this project includes a pair of stereo cameras and three infrared LEDs to track both hands with details on the finger and knuckle positions.

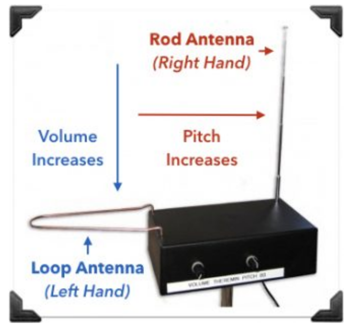

Fig. 1: Theremin working principles [1]

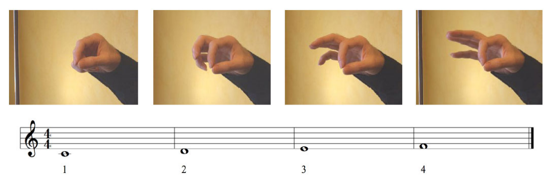

Fig. 2: Theremin working principles [2]

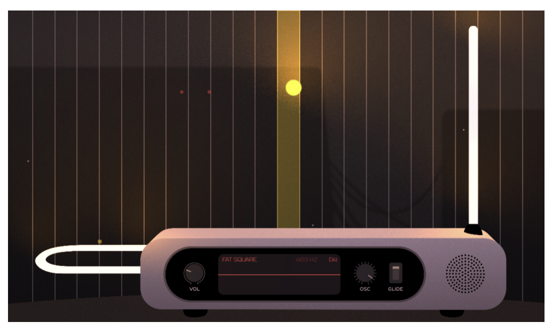

Fig. 3: Virtual theremin with pitch guides [3]

IV. Implementation

The project is built using the View-Master VR head mounted display for 3D stereo rendering and the Leap Motion Controller to detect hand motions. The virtual environment which contains the theremin and the pitch guide is created using Unity.

A. Theremin Instrument and Finger Tracking

To save time on recreating the 3D theremin object, I downloaded the object without audio embed from the web [7]. The audio aspect of the theremin is then created by calculating distance to rod. The distance between the right pole and the closest finger is of inversely proportional to the pitch; the closer to rod the higher the pitch, and vice versa. By adjusting the playback speed of a single audio file, I was able to shift the pitch accordingly using equation [8]. By speeding up the playback speed by 1.05946, the pitch is shifted up by one semitone. Similarly, slowing down the playback speed contributes to a lower pitch.

$$f_{semitone} = 1.05946^{-distance} \tag{1}$$

The volume adjustment on the left hand requires lower volume when closer to the loop and louder when further away. This is modeled as a linear function that is proportional to the distance between the left palm and the loop.

B. Pitch Guide

A pitch guide for beginners is created by keeping track of the minimal distance between the right hand and the pole. The mapping of distance to semitone conversion is recreated with a gradient indicator. Figure 4 shows that the orange label on top of the indicator is updated according to the finger closest to the rod. In other words, the label updates according to the extension and flexion of the knuckles even if the palm position remains unchanged. Because the semitones are relatively close to each other, I only labeled the C octaves. Figure 5 shows the relative right and left hand position on the two ends of the leap motion controller.

C. Stereo Rendering

To create three-dimensional image, the stereo windows are rendered using depth map calculation and Barrel digital correction. Figure 6 shows the rendered left and right images with a rounded edge that illustrates the applied Barrel distortions so that after the Pincushion distortion by the lens the user will still see straight lines.

A gyroscope and an accelerometer is used in the headset such that rotations around the base of the neck will translate to a shift in the scenery. Panorama view is also supported in the project using 3D saliency cube map images to allow for an immersive VR experience [9].

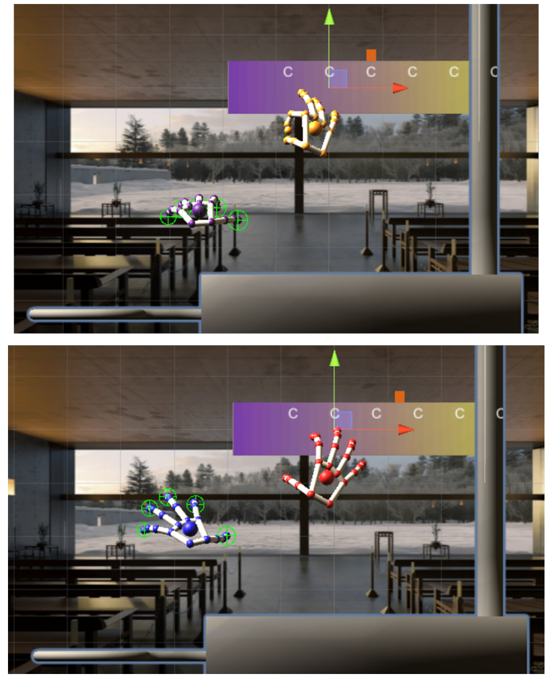

Fig. 4: Finger tracking pitch guide

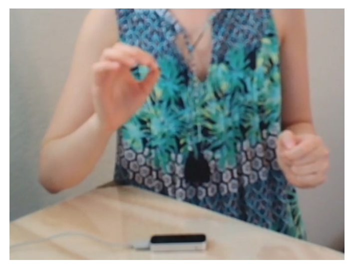

Fig. 5: Using Leap Motion controller to track finger position

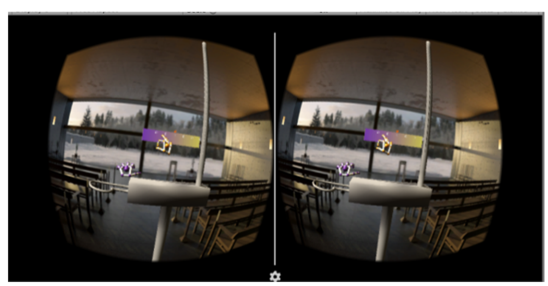

Fig. 6: Stereo view creates depth

V. Conclusion

Overall, the virtual theremin produced similar sound effects and user experience. The lack of physical contact with the theremin in real-life makes it ideal to replicate in the virtual reality environment with a similar playing experience. However, a steep learning curve persists for beginners even with the help of the pitch guide. The main issue is that the distance between semitones is quite narrow and makes it difficult to label all pitches rather than just the octaves. Extensive practice is needed to control pitches using the finger positions. The jitter of finger tracking using leap motion also introduces unintended vibrato, which causes the pitch to shift locally in an unexpected way.

Rather than gradient coloring, distinct colors for the eight notes in an octave may aid the learner more effectively. As for unintended vibratos due to leap motion image sensing, the use of a second camera at a 90 degree angle may provide an alternative view for hand position corrections.

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