Software Instruments via IR Sensing

ECE 445 Design Document

Colin Flavin, Helen Swearingen, Nick Russo

Group 33

TA: Eric Liang

1. Introduction

1.1. Objective

1.1.1. Music and movement are big contributors of emotional expression. Traditionally, music is dictated by trained musicians, whose interaction with instruments requires dexterity and coordination, as well as the interaction with a physical instrument. This forces composition and choreography to be separated. The goal of this project is to bridge this gap between composition and choreography via a wireless instrument using IR sensors to track a person's motion.

1.2. Background

1.2.1. Wireless instruments were first introduced through the theremin. The theremin was able to control pitch based on the distance a players' hand was from the pitch antenna. This created a variable capacitance, which would translate to different frequencies in an oscillator. That was then fed into a heterodyne system with a fixed frequency oscillator, which was then heard as the instrument's pitch [1]. However, this had problems, because it was extremely difficult to control the instrument's pitch.

In a completely separate set of circumstances, composer John Cage collaborated with Merce Cunningham to create an instrument based on dance, through the use of 12 antennas to sense the proximity of a dancer, which would then play different notes [2]. This was the first attempt at the coordination of composition and choreography.

This design project aims to combine the ideas of wireless instruments, with the bilinear nature of choreography and composition as seen through Cage's work. In addition, this project differs fundamentally from the IMUsic project. Rather than using wearables to track motion, IR sensors will track hand gestures. Also, rather than mixing the music on a computer with software, our plan is to mix the sound with a custom made mixer.

1.3. Physical Design

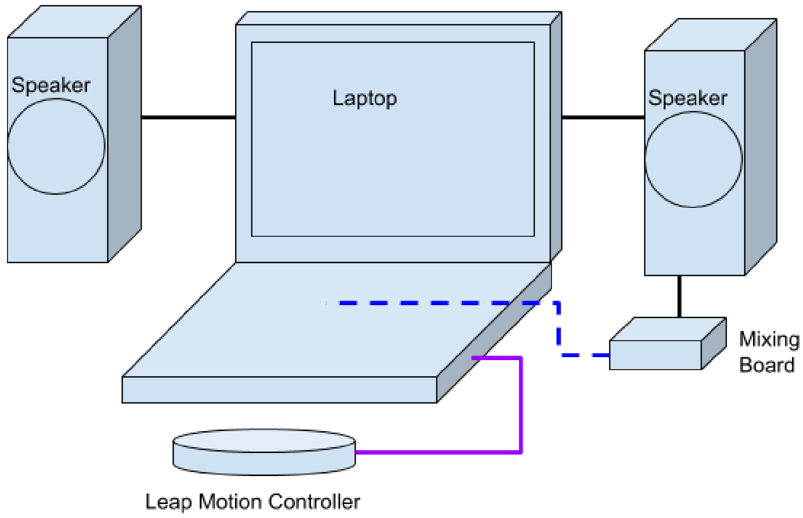

Figure 1: Physical Diagram

A Leap motion controller would sit in front of and connect to a laptop, which would wirelessly connect to the sound mixer on the right, which would process and produce audio signals to be sent to the speakers.

1.4. High Level Requirements

1.4.1. Must be able to register hand gestures and correctly map them to expected motions with preset effects.

1.4.2. Must be able to process gestures, mix sounds accordingly, and play them back with a delay of 100ms or less between performed gesture and the played sound.

1.4.3. The output frequency range should be able to play at least two octaves of notes with a dynamic range of 40-70dB.

2. Design

We have three major areas to this project: interfaces with the outside world, gesture processing, and sound mixing. First, off the shelf IR sensors (a Leap Motion Controller) senses the player's hand motions. This information is sent to the computer, where this data is processed and translated to a set of musical tones. From there, this information is sent to a custom built sound mixer for better sound fidelity, before being sent to speaker sets.

2.1. Block Diagram

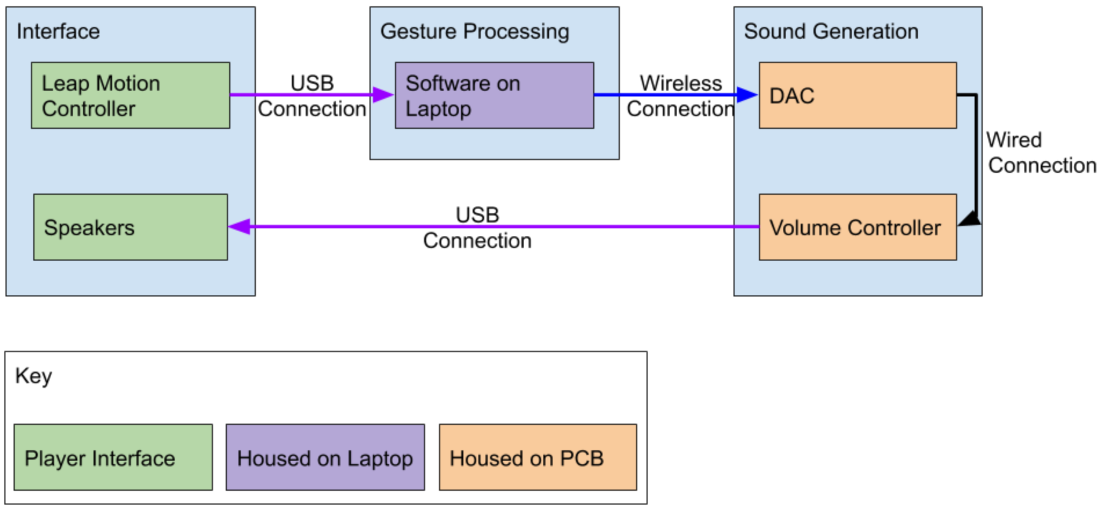

Figure 2: Block Diagram

2.2. Functional Overview

2.2.1. Interfaces

The player must be able to interact with the project: to give it input, and hear the results.

2.2.1.1. Leap Motion Controller

The Leap Motion Controller detects the player's hand motions. It communicates with the laptop via USB.

Requirement: The Leap MC should be able to distinctly identify multiple different hand positions without incorrectly mapping one gesture to an incorrect one

2.2.1.2. Speakers

The speakers play the sounds with given tones, volume and frequencies from the player, as sent from the sound mixer. This will be an off the shelf speaker(s), so no further work should be required other than plugging it into the sound mixer and power.

Requirement: The speakers should have dynamic range of 40-70dB over a two octave range, from 200Hz to 10kHz.

2.2.2. Gesture Processing

Once hand gestures are sensed by the Leap motion controller, this information will be sent to a laptop. The laptop then needs to process this to convert a hand gesture to a pitch with frequency, timbre, and volume. From there, it will communicate with a sound generation module via bluetooth for further processing and conversion to an audio signal.

2.2.2.1. Laptop

Collecting gesture data and mapping detected motions to ones the project will use will happen on a laptop, due to the Leap Motion Controller's system requirements.

Requirement: The gesture processing software should be able to identify a hand motion and determine which preset motion it corresponds to.

2.2.3. Sound Generation

When the laptop decides the pitch and volume of the sound, this is all done in the digital space. This module receives this data, and then converts it to an analog audio signal, which is then placed through potentiometers for a master volume control.

2.2.3.1. Bluetooth Module

Not all laptops have more than one USB port. To compensate this, we plan on making a wireless connection to our sound generation system via an ESP32 microcontroller.

Requirement: There must be communication between the laptop and the sound generation module with Bluetooth speeds of up to 5Mbps.

2.2.3.2. DAC

The DAC takes in the digital data sent by the wifi chip and translates it into analog sound data.

Requirement: The latency of the DAC must be 50ms or less.

2.2.3.3. Volume Controller

The sound must have set maximum volume to the sound. The plan would be to use potentiometers to use as a volume control, which would interact with the analog audio signals, and with dials could manipulate the max amplitudes of the sound.

Requirement: The amplitude of the sound wave must be modulated by the volume control to a tolerance of 5%.

2.3. Risk Analysis

The area which poses the most risk in our project is in mixing the sound. A lot of pieces of our project have off the shelf components, and have relatively low risk to make functional. On the other hand, we need to generate audio outputs to the speakers in a way which is easy to understand, and is safe to the user. This portion of our project needs to correctly synthesize what the player means to play, and do so in an efficient manner, without any hiccups or aliasing in the sound.

3. Ethics and Safety

3.1. IEEE code of ethics states that our project should "improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies" [3]. Our project satisfies this as it promotes the bilinearity of the formation of music and dance.

When dealing with audio, one main safety concern is dealing with the listener's hearing. If unbounded, high volumes of noise can cause prolonged hearing loss. Sounds over 120dB can cause the listener immediate pain, while 85dB of sound over prolonged periods of time can sustain permanent hearing damage [4]. Our mixer will have a max volume of 70dB allowed to account for this.

References

[1] "How the Classic RCA Theremin Works", *Tuvalu.santafe.edu*, 2014. [Online]. Available: http://tuvalu.santafe.edu/projects/musicplusmath/index.php?id=30. [Accessed: 02- Apr- 2020].

[2] "Variations V - Merce Cunningham Trust", *Mercecunningham.org*, 2019. [Online]. Available: https://www.mercecunningham.org/the-work/choreography/variations-v/. [Accessed: 02- Apr- 2020].

[3] "IEEE Code of Ethics", *Ieee.org*, 2016. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 03- Apr- 2020].

[4] "How Loud is Too Loud?". [Online]. Available: https://www.osha.gov/SLTC/noisehearingconservation/loud.html. [Accessed: 03- Apr- 2020].