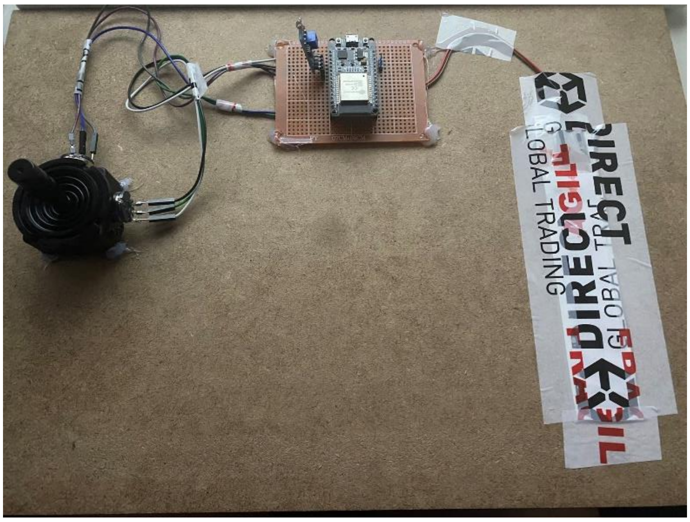
A Digital musical instrument with Physical Modeling and Granular Synthesizer

Introduction

For this project, I developed a digital instrument that generates ambient and drone music. The instrument is mainly based on physical modeling synthesis and Granular synthesizer, combined with several sensors that sample and display physical quantities in real time to modulate the sound. In the end, I achieved a successful drone music output. In this report, I will present my work in two parts. The first part focuses on the hardware components, including the circuits, sensors, and signal sampling. The second part will cover the software aspects, including the physical modeling in MAX/MSP, the melody generation, the Granular synthesis, and the mapping relationship between the sensor signals and the envelope and LFO.

Hardware

The hardware components consist of a microcontroller, a light intensity sensor, a 2D joystick, and a custom-made touch sensor. The overall structure is shown in the following figure. The 2D joystick is on the left side, the ESP32 and photoresistor are in the middle, and the touch sensor is on the far right side.



Microcontroller

I chose an ESP32 development board as my microcontroller, which comes with a built-in WiFi module and can establish a wireless connection with MAX/MSP using the OSC protocol, making it extremely convenient. Additionally, the board has abundant interfaces such as ADC and Touch modules, which can respectively acquire the voltage value of the photoresistor and the touch signal. What's more it can be programmed on Arduino IDE, which has rich library so that it is convenient to use that.

Photosensitive resistor

The photosensitive resistor module is an electronic component that is widely used for light detection in various applications. It is also known as a light-dependent resistor (LDR) or a photocell. The module consists of a photosensitive resistor that changes its resistance based on the intensity of light falling on it.

2D joystick

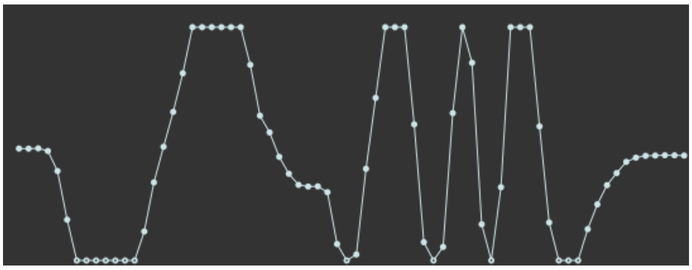
The 2D joystick module is an electronic component that is used to control the movement of an object in two dimensions. It consists of a joystick that can be moved in two directions, and two potentiometers that measure the position of the joystick in each direction. It is a simple and effective component for two-dimensional movement control in a wide range of applications. Its intuitive interface makes it easy for users to control the movement of objects, and it can be easily integrated into musical interaction systems.

Touch sensor

This design was inspired by the hardware design of Plinky[1]. The touch sensor consists of two parts: a bottom copper plate and a surface insulating layer. For the bottom copper plate, I used a rectangular shape made up of two triangles with insulation between them. This design has two purposes: 1. Under constant pressure, it ensures that the sum of the areas where the two triangles contact at different positions is constant, so the pressure can be calculated based on this principle. 2. Since the contact area with the two triangles varies at different positions, the position of the finger touch can be calculated by taking the difference between two values. The specific structure is shown in the following figure.

Sample by MAX/MSP

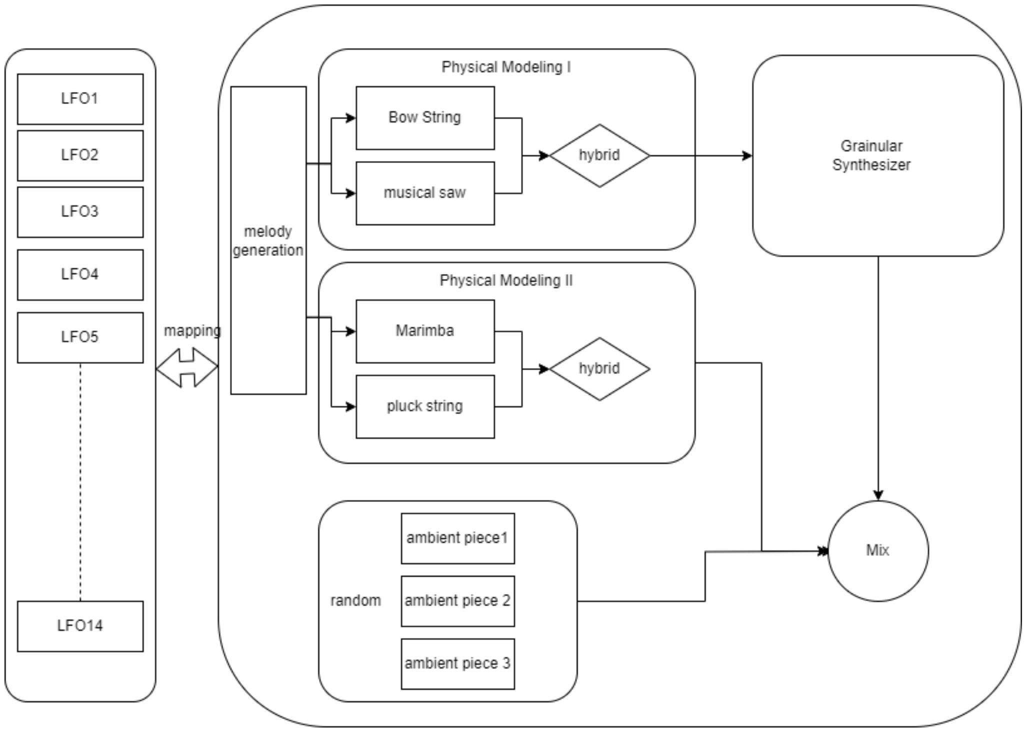
I created a bpatcher(record_sensor) to collect the sensor signals transmitted from the ESP32. The bpatcher will sample the received sensor values and perform interpolation to generate a smooth curve, as shown in the following figure.



Software

Outline

The software part of my project is mainly divided into four parts: Physical Modeling, Melody Generation, Granular Synthesizer, and Mapping, as shown in the following diagram. The process of generating drone music is as follows: The melody generated by Melody Generation is used for sound synthesis in Physical Modeling. The sound produced by Physical Modeling I is then transformed into drone music by the Granular Synthesizer, with the sound produced by Physical Modeling II used as embellishment. Additionally, pre-recorded ambient samples can be selectively played alongside the generated music. The LFO is used to cyclically adjust some parameters in these components.



Physical Modeling

The sound generated by the bowing-like physical modeling is very natural and has a lot of irregular overtones, making it ideal for creating drone music. The bow-string is a very commonly used model, while the sawtooth is a personal favorite instrument of mine. By modifying the parameters, I replaced the material of both the string and sawtooth models with gold, resulting in a sound that is difficult to hear in real life due to its high cost. What's more, I then used Melody Generation to dynamically change the pitch and the mix ratio of the two sounds, adding more variability to the overall sound.

For the marimba and plucked string models, I used a similar approach, with the hybrid of the two sounds adding a staccato and percussive quality to the music.

In this part, I used Modalys [2] a physical model-based sound synthesis environment in MAX/MSP from IRCAM to implement it. The sound of the bow-string model is clear and strong, while the music saw produces a hazy sound. By mixing the two sounds together, the resulting sound inherits the characteristics of both.

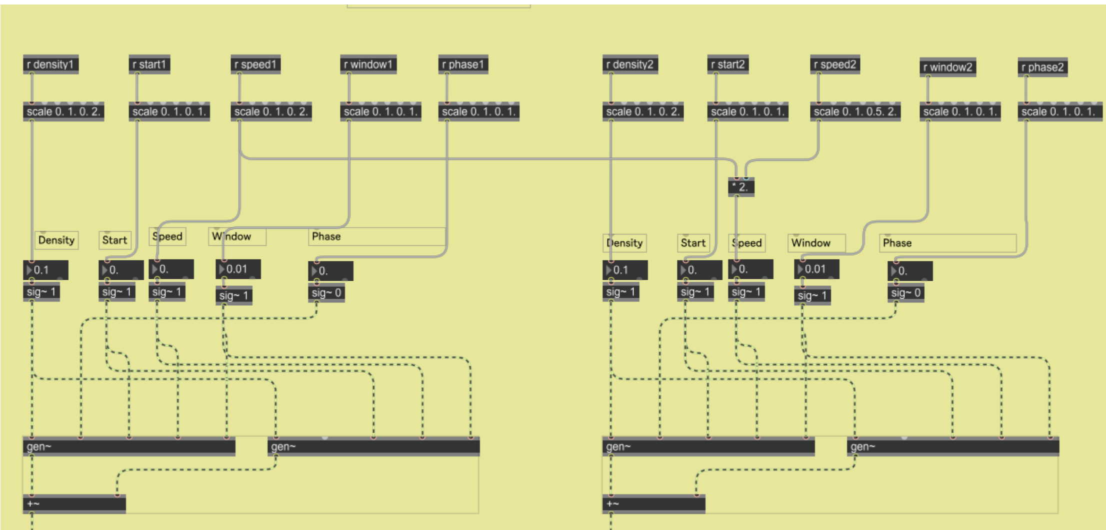
Melody Generation

The Melody Generation part is very simple. I created an unconventional sequence of notes with an equal distance between them, each note being a perfect fifth apart from its neighbor. Then I randomly selected a pitch from the created sequence to serve as the pitch for the Physical Modeling instrument. This makes the sound harmonious while still maintaining variability.

Granular Synthesizer

Granular Synthesizer is a sound synthesis technique that works by dividing a sound wave into small pieces, or grains, and then manipulating these grains in various ways, such as changing their pitch, duration, and amplitude. These grains are then reassembled into a new sound wave that has a different character from the original sound.

In my project, I used Granular Synthesizer to transform the sound generated by the Physical Modeling I component into a drone music sound. It has five parameters density, start point, speed, window size and phase. I created two Granular Synthesizers, both of which processed sounds synthesized by Physical Modeling. The two synthesizers were not very similar to each other because their parameters were modulated by different LFOs. However, there was a connection between their speed parameters, with the speed of Granular Synthesizer 2 being the result of multiplying the speed of Granular Synthesizer 1 by an LFO, as shown in figure below. This made the two parts sound similar but not identical, adding more variability to the overall sound.

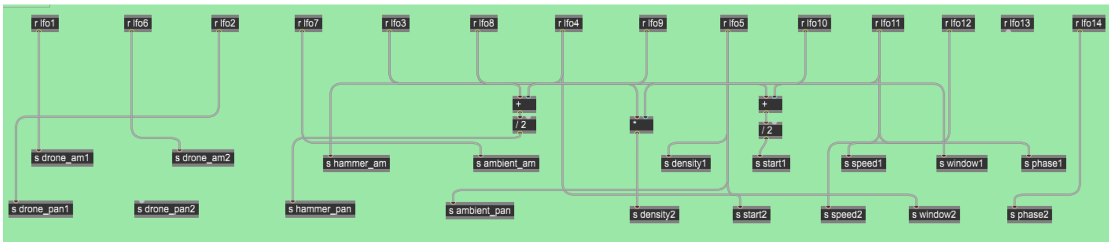


Ambient Sample

To increase the richness of the sound, I obtained sounds of thunderstorms[3], wind[4], and volcanoes[5] from Freesound, which made the sound more atmospheric.

Mapping

Mapping is the core of my project. Through the hardware components, we are able to use a variety of sensors to capture the envelope or LFO we want, rather than just using basic waveforms such as sine or triangle waves for modulation. We can use the non-linear information of forces, light, positions, and other various sensations from our daily life to modulate the music and obtain the sound we desire. This allows us to create music that is more diverse and personalized. In MAX/MSP, I designed a section where users can first collect a variety of envelopes and LFOs. Then, each track of the drone music has various modulation interfaces, such as AM modulation and PAN. I placed these interfaces next to the stored envelopes and LFOs so that users can easily map them by connecting them in any way they want. They can also generate a waveform to modulate the sound they want to modulate by combining sine LFOs or one or more arithmetic operations. This undoubtedly adds another level of variability to the overall music, as shown in the following diagram:



Conclusion

In addition to the light intensity sensor, touch sensor, and 2D joystick that I used, there are actually many other sensors waiting to be explored. These sensors correspond to various sensations in our daily life, such as touch or smell. Through this course, I have found my goal and direction, and I will try various new forms of interaction in music creation in the future.