The imaginary drummer

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ABSTRACT
The imaginary drummer is a drum machine that allows you to drum in the air, using devices with accelerometers you can strap on your hands. This gives accurate predictions for the drum move you do, with 93% accuracy with 5 fold cross validation of test data. When a threshold value is reached, the prediction will be played as a sound. Issues were had with the effects on the data of the second sensor with one handed gestures. In the future a model might be better trained with one hand and then combined later, with extra function to connect to a Digital Audio Workspace.

INTRODUCTION

Music is often made in the mind, in the imagination. Drummers often tap them with their hands, arranging compositions. But what if these could be immediately played wherever they are? With the imaginary drummer, they can play their instrument anywhere. Existing solutions for drumming in the air already exist [1], but they require motion tracking and drum sticks, and thus lack the portability of this device.

IMAGINARY DRUMMER

Tangibility

The imaginary drummers utilise 2 3D printed capsules to house accelerometers to detect hand movements. All corners of them are rounded to not create any uncomfortable spots and give it a modern, simplistic look. It straps on the hands of the user with velcro, making it fast and convenient to use when having a creative moment. When strapped on, the user can simply start drumming with the motions they set up with the training data, and it will play the sounds associated with each gesture, as well as create a graphical show with randomised triangles.

Interactivity

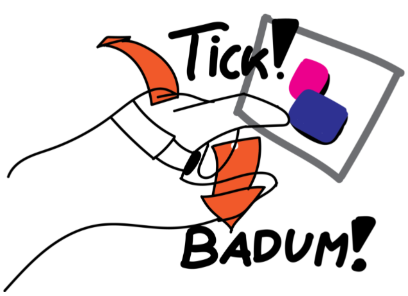


Figure 1. A sketch of the interaction

When a user does one of their gestures, the sound which is related to that gesture will play, as well as visual feedback from a drawn randomised square. This gives very immediate feedback to the user that they are doing the wrong or right gesture for what they want to achieve.

Intelligence

A learning problem was defined in the form of $g(X) = Y$.

To be able to make drumming motions with the hands and get a prediction for which motion it is, two MPU6050 accelerometer gyroscope combinations were used, one for each hand.

This gives $X = \mu(xaccL), \sigma(xaccL), \mu(yaccL), \sigma(yaccL), \mu(zaccL), \sigma(zaccL), \mu(xaccR), \sigma(xaccR), \mu(yaccR), \sigma(yaccR), \mu(zaccR), \sigma(zaccR)$.

4 different motions were implemented, for the 4 drum types mainly used in modern production of music: A kickdrum, snare, ride and closed hi hat.

This gave $y \in Y = \{kickdrum, snare, ride, hi\ hat\}$ and thus $y' = g(X)$.

Hand gestures are different per person, and even if only one person does the gesture, it won't be the same every time, making these gestures non-programmable.

REALISATION

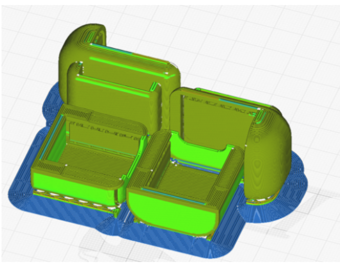
Soundplayer

Firstly, a script was created to create on screen graphics, as well as to play sound. For this, two libraries were used. Firstly, the processing sound library to load in and play sounds. Secondly, the countdown timer library was used. This was utilised to give each sound a delay of half the sound's duration, without stopping the rest of the program. This was necessary as a safeguard to not play double sounds when a gesture was done. The graphics were made by randomising the height, width, position and corners, with the height and width being constrained and bigger for louder sounds. The colours were randomised within a smaller constraint, with each sound having a distinct colour.

Figure 2. Graphics made by playing sounds

Hardware

The shell of the accelerometers in the hands were made by designing a custom 3D model and printing them out on my 3D printer. Then velcro was added in the printed slot to attach them to the hands. The accelerometers were screwed onto the design, with the top of the model press fitting on the other part. One accelerometer had the AD0 pin to ground, and the other to the VCC pin, giving them different I2C addresses of 0x68 and 0x69.



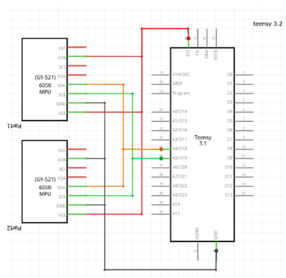


Figure 2. The 3D model ready for printing. Figure 3. Schematic of the electronics

The MPU6050 sensors were read out on these addresses and all converted to a range of 0 to 500 to make them easier to process, before sending them to processing.

Data acquisition

From the MPU sensors the acceleration in 3 different axes were gathered. With the time series data points, the mean and standard deviation of both sensors were calculated, giving 12 total attributes.

The right threshold value took some time to determine, since it should activate even when making softer drumming motions, when in public for example, while not detecting the harder motions in two sets, while the peak of that motion is already over. After some iterations, a value of 80 worked best. This caused noise to be minimised, which is very important for a drum machine. A random sound which shouldn't have been activated playing during a performance can really throw a drummer off. With this a window size of 40 gave the best results, capturing the most important part of the data.

The training dataset had 400 entries, 100 per gesture. This size allowed the program to train the model correctly, minimising the impact the unused hands position had. A testing set of 80, 20 per gesture, was utilised to test the accuracy of the model.

Learning algorithm

A linear support vector classifier was utilised to train the model. A C of 2. was utilised, giving the highest accuracy, being 98.25.

To further reduce noise in the final sketch, two things were done. Firstly, a threshold was also utilised in this sketch, only making a prediction when the threshold value of movement was reached. This firstly saved on computing power, while also making sure no slower non gestures were seen as drumming motions.

Secondly, the prediction was compared to the old prediction. If these were the same, nothing would happen. This made sure a sound would not be played double. If they weren't the same, the sound would play and the old prediction would update to the current prediction.

When trying to utilise double handed gestures, a lot of issues with noise came up, due to movement from one hand transferring through the body to the other hand and creating uncertainty in if a double or single handed gesture was being done. This caused too much noise to be acceptable in a drum kit, and was thus left out.

Another option to smooth out noise, a window, was not utilised. This was done since a window would always cause delay, which would make the drum kit feel a lot less responsive, diminishing the experience and feedback, and thus the usability of the device.

Evaluation

5 fold cross validation was used to test the model, receiving an accuracy of 92,5 percent. With the extra data filtering for the final program, this accuracy was acceptable for the final project. It made the final product feel responsive and accurate to the user.

```
 a  b  c  d  e  f   <-- classified as
 0  0  0  0  0  0 |  a = A
 0 19  1  0  0  0 |  b = B
 0  1 18  0  2  0 |  c = C
 0  0  0 17  2  0 |  d = D
 0  0  0  0 20  0 |  e = E
 0  0  0  0  0  0 |  f = F
```

Figure 4. Confusion matrix

DISCUSSION

Firstly, I had a hard time with noise when implementing two handed gestures. A way to solve this issue might be to train each hand separately, and also only have them output a prediction when above a certain threshold. When both of them are then having a prediction at the same time, a combination of them can be had. This needs to be tested, but might be a solution to this 2 sensor problem.

In the future, having the software connect to a Digital audio workspace, by utilising a MIDI library like MIDIbus, would make it easier to create beats and save them immediately. Furthermore, this would give a lot more options, since midi controls can be bound to almost everything in these programs and thus control everything.

To further add on this, a gradient of inputs with the velocity of the drum could be implemented, differentiating between hard and soft hits.

Lastly, a sensor for the feet can be added to give a more authentic drumming experience, utilising all limbs.

REFERENCES

[1] Aerodrums. (2022, 2 augustus). Aerodrums | Air Drums & Virtual Electronic Drum kit. https://aerodrums.com/

LINK TO DEMONSTRATION VIDEO

https://youtube.com/watch/Aa7EMoOt81E?=si=hWoDwudWeYLY9k5t