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SilentMetronome: Haptics for Musical Training

SilentMetronome

Abstract

This paper introduces the SilentMetronome, a haptic metronome device that utilizes the body's ability to understand and replay music to bring musical instruments and production to people with hearing disabilities, and beginners in music production. The efficacy of this device is based mainly on two theories: [1] Sensory-Motor Contingency Theory, and [2] Dalcroze's Entrainment Theory. The SilentMetronome is an open-source project, aimed at music professionals and beginners on one hand, and makers and developers on the other. It is made to be versatile enough to be strapped anywhere on the human body that the user finds suitable, and programmed to have an input of any BPM required for any track using a USB connection to the computer.

Keywords

Silent Metronome, Dalcroze, haptic motors, body coordination, music coordination, tempo, bpm, rhythm

Introduction

There are countless metronome devices, whether physical or digital, that aim to help beginners and musicians to synchronize their tempo with other members or with a track. These devices have been used for over 100 years and although many disagree on its purpose and use, many others, like Beethoven, believed in its effectiveness and "became the first composer to give his pieces metronome markings" (Gersten, 2017). Today, with the rise of digital metronomes on smartphones or smartwatches and computers, the metronome has become much more accessible by everyone. However, in order to utilize the haptic abilities of the metronome, the user needs to invest in expensive electronic devices like a smartwatch or a wearable metronome, which should not be the case. So, I decided to create a DIY version of a wearable metronome that the user can easily download and recreate in a few hours.

This paper introduces the SilentMetronome, a haptic feedback metronome that utilizes the body's ability to identify, memorize and mimic musical patterns in order to learn musical instruments. The device uses an Adafruit Flora, four haptic motors, one LED, and an optional laser-cut or 3D printed encasement. The current iteration requires the users to connect their device onto a computer in order to edit the BPM (beats per minute) and upload it to the controller. Although the idea of haptic technology being used to replace audio signals as a time mark is not new and has been employed by several researchers and music educators in the past. For example, in their Haptic Drum Kit study, Simon Holland et al explored the full potential of using haptic motors as a way to train multi-limb music coordination that is usually a challenging skill to acquire in music production. As a result of the study, and through user-testing and feedback, Simon Holland et al discovered that users indeed preferred the user haptic feedback motors over headphones or speakers as a way to train their body and muscles to the rhythm and be able to quickly copy the rhythm into their own instruments or body. In addition to that, the music teacher Emil Dalcroze was known for his unusual method of teaching musical instruments using what he termed 'eurythmics', which imprinted the rhythm onto the user's body rather than ears (audio), and that in turn allowed the user to memorize and replay the intended rhythm quicker and more efficiently, especially rhythms that require multi-limb coordination.

In addition to that, "Unlike many human activities, such as vision and language, which primarily use localised parts of the brain, music seems to involve

almost all of the brain" (Simon Holland et al, 2013), which means that for people with hearing disabilities, using a haptic motor can have a significant impact on the way they listen, analyze and replay music, and that is one of the main goals for developing this device.

Although the SilentMetronome is not a finished product and will not be available for sale, the device is readily available online, in an open-source format, ready for download, replications, testing and developing. It is a device to be communally developed and shared.

Terms Definitions

Metronome is a mechanical or electrical instrument that makes repeated clicking sounds at an adjustable pace, used for marking rhythm, especially in practicing music.
(Dictionary.com)

BPM (beats per minute) is the official measurement unit of the tempo or speed of the music.

Monophonic is a musical style employing a single melodic line without accompaniment.
(Dictionary.com)

Polyphonic is a musical style having two or more voices or parts, each with an independent melody, but all harmonizing.
(Dictionary.com)

SilentMetronome - The device

The SilentMetronome is a haptic feedback device that transmits musical tempo or beat into a vibration pattern calculated in bpm. It utilizes the body's natural ability to identify patterns and mimic them.

What's new about this?

An open source haptic feedback metronome:
The SilentMetronome is not the first of its kind. A quick online search will result in a couple of examples available on the market. However, what makes the SilentMetronome different is its inexpensive and simple fabrication on one hand and versatility in its applications on the other. Using the prepared DYI file, the user can simply download, fabricate, code and use the SilentMetronome within a couple of hours.

Also, the SilentMetronome is a first iteration prototype with much room for improvement and development, which is one of the main goals of this project, as a cooperative project which will be posted on Thingiverse and Instructables in order to allow other people to fabricate, test, and improve upon the design.

My initial idea for this device was to repurpose a wearable speaker, which is usually worn around the neck as a necklace, and replace speakers with haptic motors in order to utilize the collar bone on the user's neck for haptic vibrations. However, to truly create a DIY project, a new encasement has to be developed and an open-source file has to be created and uploaded. So, I created a unique encasement that allows development, miniaturization, or simple reproduction.

Relevant Theories

Although the theories used in this study are meant for multi-limb music coordination, they nevertheless provide ample evidence of the SilentMetronome effectiveness in regard to recognizing, identifying, retaining, analyzing and reproducing rhythms, which is ultimately the goal of the SilentMetronome.

Sensory-Motor Contingency Theory

"Sensory-motor contingency, assuming its applicability here, suggests that if learners are to develop their skills in recognizing, identifying, memorizing, analyzing, reproducing and composing rhythms, then their motor actions must be able to actively manipulate those rhythms at an adequately fine level of detail" (Simon Holland et al, 2010).

According to this theory, to fully be able to analyze and react to sensory input, in the case music sound input, the user must be able to reenact the exact patterns being sensed onto their body physically. Hence, the use of haptic feedback motors as a way to skip the hearing step and jump straight into the body sensing level, which results in quicker response times than in the case of audio.

Dalcroze Entrainment Theory

"Simply hearing examples did not appear to be sufficient. Dalcroze proposed that students had to become competent in enacting representative rhythms with their own bodies. Once this had been achieved, problems in dealing with technical and abstract aspects of rhythm seemed relatively easily solved. In some cases, the requirement for bodily enacting a rhythm can be relatively undemanding" (Simon Holland et al, 2010).

According to Dalcroze, his students learned polyphonic rhythms by walking at a regular pace while moving their arms at twice or three times the rate. This method allowed the body to identify and memorize the rhythms, and later be able to replay them. This method is a good example of how haptic feedback motors utilize the body's ability to sense, memorize, and replay certain patterns that the user's memory might not be able to do as accurately.

Key Audience

The SilentMetronome open-source project and its aim is to bring music production to:

A. People with hearing disabilities that might want to explore or express their music creativity.
B. Beginners that find it difficult to identify and memorize rhythm especially during a beginners' musical session
C. Makers and developers who have the skills and desire to contribute and develop this tool to reach a wider audience.

Since the SilentMetronome is a basic, already existing device, I wanted to add something different to it that would make it more of a developing concept rather than a developed concept. I believe this would place on a different scale than creating a crisp, finished product that aims to be on the shelves and waiting to be picked up and paid for.

Rather than claiming to be a finished product, the SilentMetronome encourages users from all over the world to reproduce it, test it, identify key developments, undergo the developments, and reshare with the world. This is what makes the SilentMetronome a more versatile, accessible, and relevant device that has a much wider reach than a finished product sold for a couple of hundreds of dollars.

Future Direction

After careful considerations of how I want to develop this object, I decided to utilize the online and maker community in order to replicate and enhance on this design, including myself. I am a believer in the power and effectiveness of collaboration and open-source ideas for the purpose of development and dissemination.

So, after developing this prototype, a few aspects were identified for future development:

1. After using it in several jam sessions, I noticed that the vibration motors are too weak to be effective during a musical session especially if loud percussions, which create big vibrations, are used.
2. More trials and testing are needed in order to improve the velcro strap used for this iteration.
3. An interactive interface is required for the user to be able to select and adjust the required tempo

Making the SilentMetronome

The Components

1x Adafruit Flora
4x 16,000 RPM vibration motors
1x 3V battery
1x LED
1x Wooden Encasement
OR
1x 3D-printed PLA Encasement
2x Velcro Strap

The Code [Link to code]

```
Metronome
int tempo = 75;
int tap = 150;
int delayValue = ((60000/tempo) - tap);

void setup()
{
  Serial.begin(9600);
  pinMode(6, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(12, OUTPUT);
  pinMode(3, OUTPUT);
}


void loop()
{
digitalWrite(12, HIGH);
digitalWrite(10, HIGH);
digitalWrite(9, HIGH);
digitalWrite(6, HIGH);
digitalWrite(3, HIGH);
delay(tap);
digitalWrite(12, LOW);
digitalWrite(10, LOW);
digitalWrite(9, LOW);
digitalWrite(6, LOW);
digitalWrite(3, LOW);
delay(delayValue);
}
```

Due to my limited, developing, skills in coding, I decided to use a simple, yet functional code in order to translate the BPM values that the user will enter into a formula that code will use to convert to a delay value that ensures the vibration pattern is identical to the BPM intended tempo. The key formula for this conversion is “int delayValue = (60000/tempo) - tap”

The Encasement

Using Fusion360, I created a custom-made box that I believed compliements the shape of the body and is versatile enough to be placed anywhere the user finds suitable.

Wooden Encasement [Link to file]

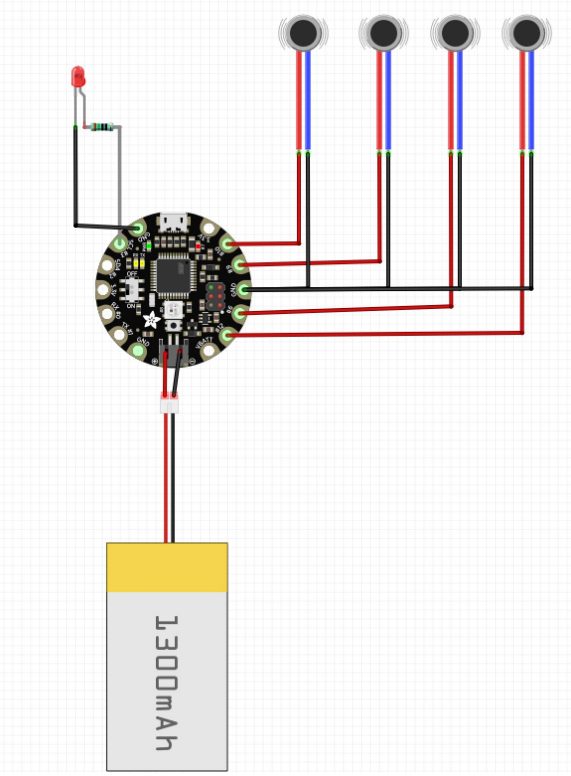
After several tests and attempts, I have decided to use the wooden encasement as my first choice for making this prototype. Using Fusion360 Slicer add-on, I was able to convert the 3D model into thin (⅛ inch) slices that I later ran into a laser cutting machine on a thin sheet of plywood. After cutting the pieces, using wood glue, I constructed the encasement layer by layer until the full structure was created. Then using a palm sander, I created the smooth edges and curves that were planned in the 3D model. The result was a sound containing box than absorbed the sound of the vibration motors and felt more organic on the skin.

PLA 3D printed Encasement [Link to 3D model]

Using PLA plastic as a material for making the SilentMetronome was an important exploration even though was not the right choice for the material. For example, PLA poses a challenges in

order to create a smooth edge and get rid of the printer lines which are ugly and do not feel good on the skin at all. However, after several hours of hand-sanding, the result was a nice smooth surface and sturdy encasement. However, when the vibration motors were installed, the sound they made while touching the plastic was too loud and too distracting for any musician to accept. So, in order for PLA to be a suitable material choice, a alteration needs to be done to the way the motors are attached to the plastic with a material that is able to absorb some of the sound similar to the wood.

The Circuit

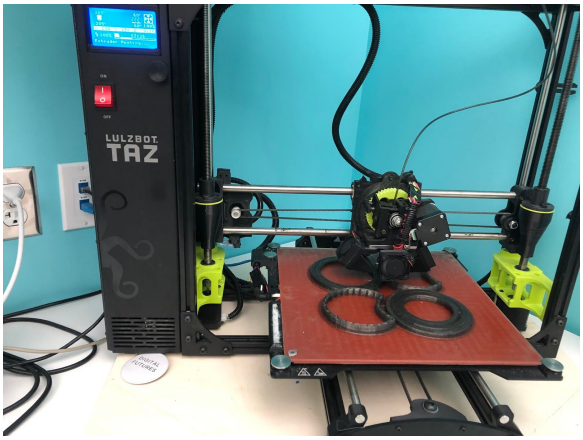


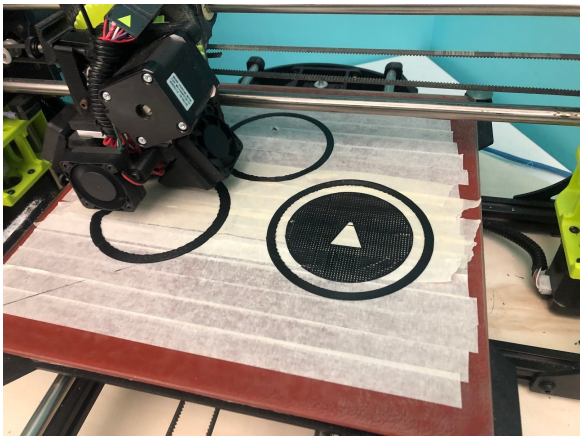
Using the Flora presented a few challenges, first, the Flora only uses 3V, which meant I have manage the circuit in a way that suits a 3V power supply. Second, the Flora only has 4 clear pins for output and one extra pin named SCL, which can be repurposed to use as an output pin.

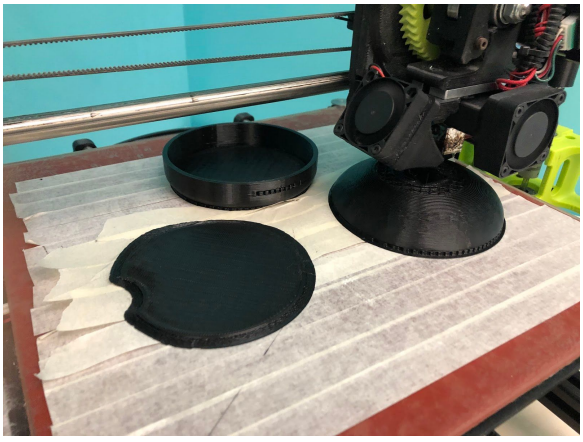
Conclusion

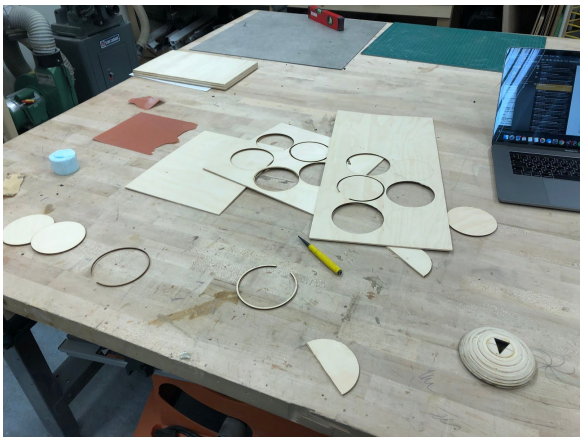
Finally, after enough research and attempts, the SilentMetronome is a prototype that allows users to make their own metronome, experiment with it, and enhance the way they see fit. It is an open-source project and utilizes the skills and needs of people around the world in order to develop it and make it more relevant to more people anywhere in the world. According to Dalcroze, the best way to learn and memorize rhythm is by experience the beat straight on the body, this is territory that more research and more experiments are required in order to fully appreciate and grow our musical skills.

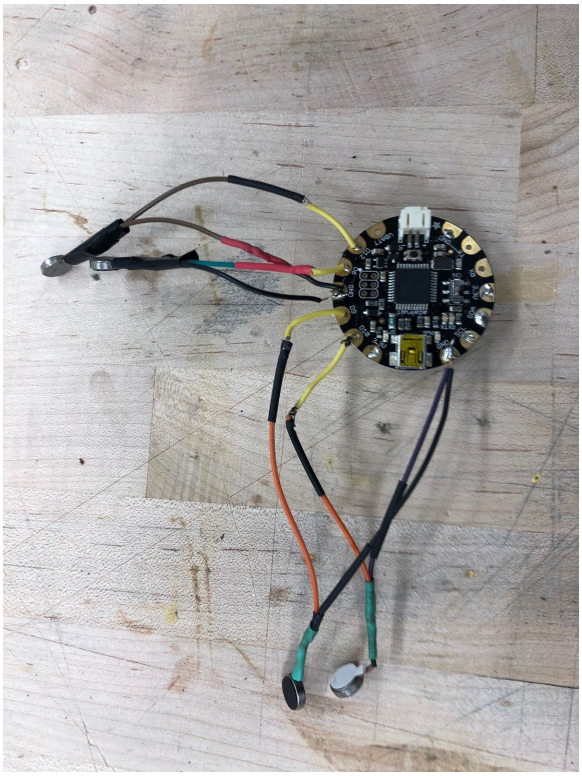
Fabrication Images











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