Synesthetic Xylophone

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May 10, 2019
ME 102B | Spring 2019

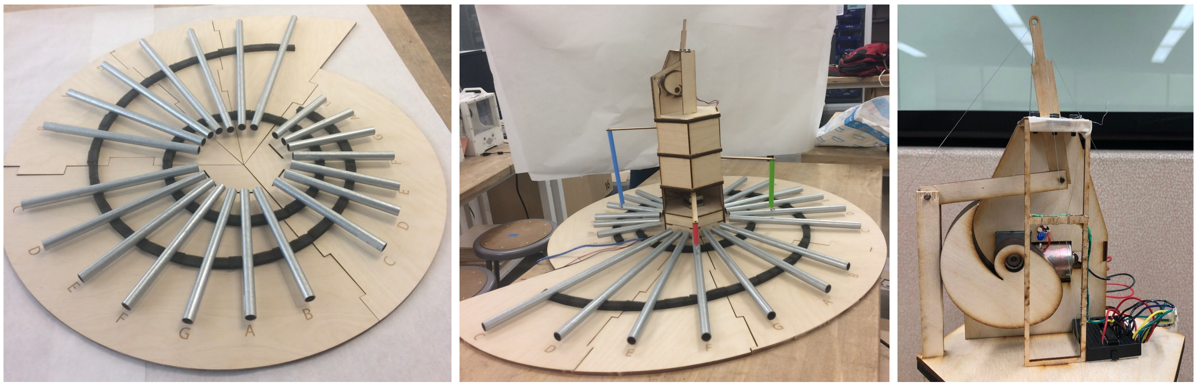
I. INTRODUCTION

Synesthesia is a rare psychological phenomena in which the stimulation of one sensory or cognitive pathway automatically stimulates another. One form of synesthesia, chromesthesia, is the association of sounds with colors[1] which can cause individuals to "see" music and sounds as a cloud or even screen of colors. Although most of these individuals disagree on which color a sound is associated to, by drawing parallels between sound waves and light waves, one potential association relates the pitch of a note to the intensity of the color.

The Synesthetic Xylophone seeks to give individuals without synesthesia insight into the condition. The xylophone plays three-note chords over three octaves, one note per octave, each of which represents one of the red, green, and blue channels of an RGB encoding of color. The lowest, middle, and highest octaves are associated with the red, green, and blue channels respectively. The note within each octave is selected by that color channel's intensity; in other words, its numerical value (0-255) in the RGB encoding. In order to play the Synesthetic Xylophone, there are 3 major components: image processing, arm positioning, and striking and tempo control. The arms are positioned by stepper motors and the striking and tempo control are controlled by a CAM and follower. With the image processing techniques being used to translate color to notes on the xylophone as well as the ability to vary the tempo of the songs, the number of songs that can be played on the synesthetic xylophone is limitless.

II. MATERIALS AND LAYOUT

There are 21 pipes made from ½" conduit tubing. The length of the pipe is related to the pitch of the sound created when the pipe resonates; the shorter the pipe, the higher the frequency/pitch of the sound. The frequency (Hertz) of the pipe is related to its length by the following equation: $frequency = \frac{v}{\lambda}$ where v is the speed of sound in air (330-340 m/s) and λ is the wavelength (roughly 4 times the length of the pipe in meters)[2]. An electronic tuner was used to verify that the pipes were cut to a length that corresponded to the desired frequency. The pipes are laid out in the configuration shown in Figure 1a on sections of case foam. If the pipes were to lay on the baseboard without the case foam, there would be too much contact between the pipes and the baseboard, preventing the pipes from resonating. It was found that the ideal placement of the foam sections along the pipes is between ⅓ and ⅔ the length of the pipe. Additionally, through experimentation, it was determined that varying the location in which the pipe is struck creates no audible difference in tone or volume.



a) b) c)

Figure 1: Synesthetic Xylophone

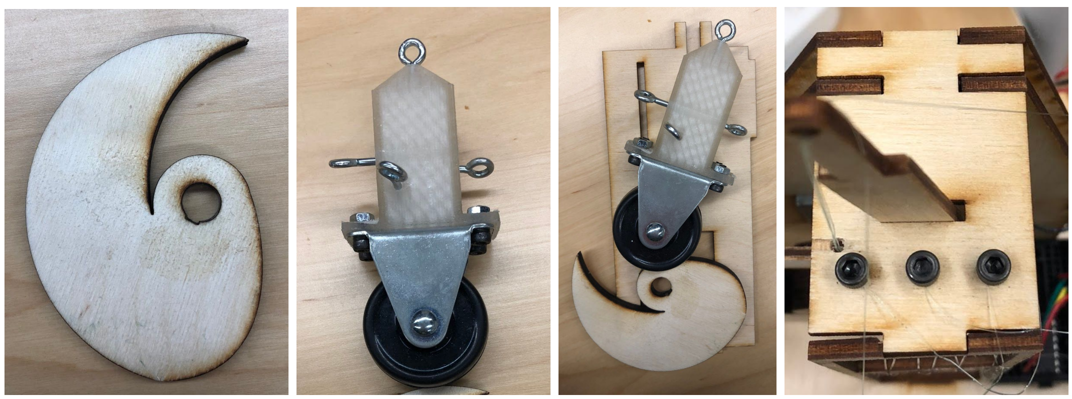
The baseboard and tower are constructed from laser cut plywood. As shown in Figure 1b, the tower consists of 5 levels, from bottom up: Arduino housing, Stepper motor housing for the red regime, Stepper motor housing for the green regime, Stepper motor housing for the blue regime, and the CAM & Follower housing. A hexagonal shape for the tower's floors is used because it allows for an opening of exactly 120° for each stepper motor. The black-box design for each level of the tower creates a minimalist aesthetics as well. At the opening of each level, the arms attached to the stepper motors extend outwards and guide the strings from the top of the tower through the colored straws. The straws are used to limit the amount of swinging created when the arms move between notes, ultimately increasing the accuracy in the position of the hex nuts when they are dropped. When the strings are raised to their highest position, the hex nuts sit snugly in the opening of the straws so that there is no swinging.

An open-top design for the CAM housing is chosen due to the rotational behaviors of the stepper motor arms; the walls of a closed-top design would snag or affect the positioning of the strings as the arms moved around the tower. For similar reasons, the walls that the CAM motor sits in takes the shape of a trapezoid. The open window panel in front of the CAM, shown in Figure 1c, is where photoresistor is mounted for the encoder system used. Additionally, the open window design allows the audience to see the CAM and follower in motion.

In total, there are 4 motors being used to play the xylophone: 3 stepper motors and 1 motor for the CAM. The circular configuration of the pipes and the centralized tower for the motors allowed us to minimize the number of motors needed to play the xylophone.

III. CAM & Follower

The CAM profile is shown in Figure 2a. This profile is chosen because it translates to a significant drop that allows the hex nuts to make contact with the pipes to produce sounds as well as a quick pull up. The follower was initially 3D printed out of PLA in the shape of a tower and mounted on top of a caster wheel (Fig. 2b). The idea here is to have the tower traverse vertically as the wheel rolls along the profile of the CAM; the tower has multiple eye-bolts on its sides to allow for adjustments to the tensioning of each string, and there is an additional eye-bolt at the top of the tower to gather the strings. Unfortunately, the weight of this follower is too heavy for the CAM to drive, and the friction between the CAM and wheel rotates the follower, preventing it from moving purely vertically (Fig. 2c). Therefore, a new follower was designed to be much lighter and easier to constrain. As shown in Figure 1c, the follower consists of a freely hinged arm that makes contact with the CAM and causes a vertically-constrained arm (piston) to move vertically. The piston is allowed to have some wiggle room laterally to prevent the friction problem encountered with the other follower design. The piston gathers the strings at its tip, and the tensioning of the strings is handled by 3 small screws mounted at the top of the CAM housing, similar to how a guitar is tuned (Fig. 2d).



a) b) c) d)

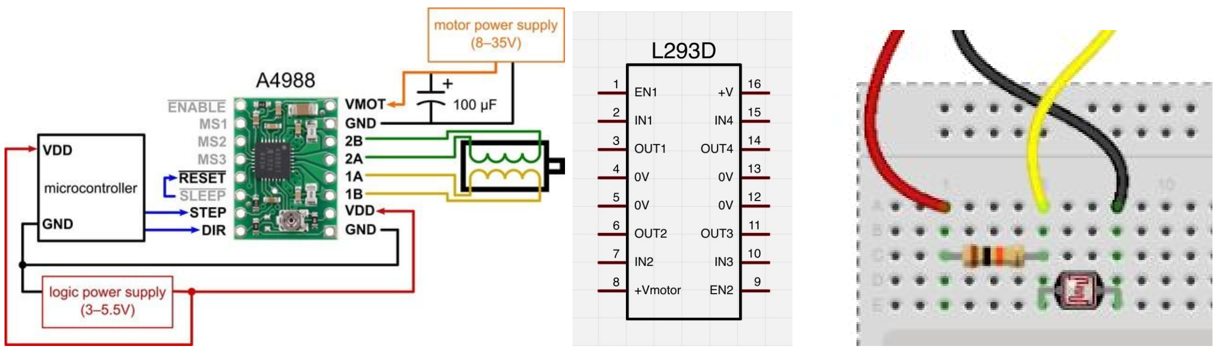
Figure 2: CAM & Follower

IV. ELECTRONICS

Three Adafruit NEMA-17 12V stepper motors are used to drive the three arms because they offer precision and the possibility of open-loop control. Each stepper motor is controlled by a Pololu A4988 Stepper Motor Driver Carrier, which drives the motor with a direction and step input. The angle between notes translates to approximately 8 steps, so no partial stepping is required. Decoupling capacitors were placed close to each of the drivers to protect against power spikes. The motors are then powered in parallel by a 12V power supply with a current limit of 1.5 A. The drivers themselves are powered in parallel by the Arduino.

The CAM motor is a stock DC motor with an experimental operating voltage range between 4-10V. One side of a L293D H-Bridge Motor Driver is used to control the motor. In order to receive feedback and ultimately control the position and speed of the CAM, a pseudo photo-interrupter sensor is made from a photoresistor and an LED. The motor is powered by a 5V power supply, and the driver and photo-interrupter are powered by the Arduino.

An Arduino Mega is used as the mico-controller since this project requires a large amount of I/O pins. The Arduino Mega is connected directly to a laptop that provides it with power and serial communication to determine which notes to play when given an image.



a) b) c)

Figure 3a. Minimal wiring diagram for the A4988 driver [3]. Final wiring was nearly identical.
Figure 3b. L293D wiring diagram for the L293D driver [4]. Only one side of the driver was used.
Figure 3c. Photoresistor half of the pseudo Light-Interrupter [5]. The other half consisted of an LED that would only be detected by the photoresistor if the CAM were out of the way.

V. SOFTWARE

In order to convert an image into a playable song for the device, the RGB values of each pixel are used to create a three-note chord with each of the notes corresponding to one of the red, green, and blue values. To avoid exceedingly long songs with many repeated chords, images are divided into blocks, from which the average RGB values are extracted. These average RGB values are translated into three-note chords according to Table 1. Each chord is then fed via serial communication to the Arduino.

Table 1: RGB pixel value conversion to notes

RGB Value	Note
0-31	Silent
32-63	B
64-95	A
96-127	G
128-159	F
160-191	E
192-223	D
224-255	C

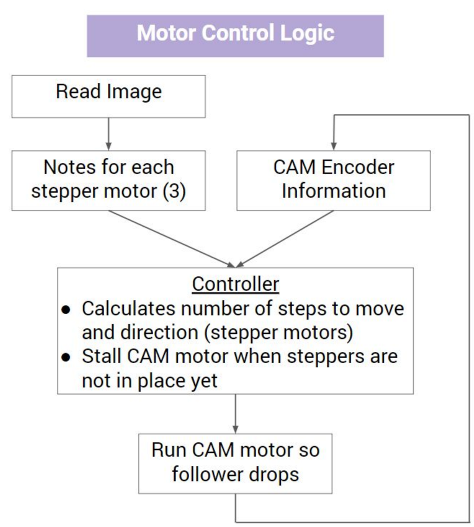


Figure 4. Simplified flowchart of controller logic

A custom SXLibrary (Synesthetic Xylophone Library) is used to control the stepper motors and CAM motor. Inspiration from computer multithreading is used to drive all of the stepper motors and the CAM simultaneously. The controller iterates through each of the motors, running any motors that are active. When the controller receives a new chord, each of the steppers calculates if movement is necessary and flags itself accordingly. The stepper motors move based on relative position in number of steps from the starting position while the CAM motor relies on updates from the photo-interrupter to calculate position. The controller then goes through each of the motors, moving them to their assigned position. Mimicking multithreading on single core processors, the rapid cycle through each of the motors allows the appearance of simultaneous movement of all motors.

All Software can be found at: https://github.com/brandonhuang68/SyntheticXylophone

VI. CONCLUSION

The Synesthetic Xylophone is capable of using the colors in an image to bring relaxing, “wind-chimey” music to an audience. The use of a CAM and hex nuts on fishing wire creates an untraditional but effective way for a xylophone to be played. The electronic components as well as the software created to control the motors is both simplistic and efficient. Lastly, the choice of building materials and design layout gives this instrument a minimalistic, “black-box” aesthetic for the audience to enjoy.

VII. ACKNOWLEDGEMENTS

We would like to thank everyone who helped bring the Synesthetic Xylophone from ideation to creation: Professor Kazerooni, Julia O’Donnell, David Cuban, Tom Clark, and the Design Specialists at the Jacobs Hall of Design and Innovation.

VIII. REFERENCES

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