Music-Visualization and Motion-Controlled LED Cube

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1 Introduction

1.1 Objective

Our project's main inspiration came from a video about an art piece called *Kinetic Rain* at Singapore's Changi Airport. The sculpture cycles over 16 pre-programmed shapes, through fluidlike movement. [1] The construction of the sculpture was made using over 1,200 bronze droplets, steel wires to hold the droplets, and cost several million dollars. [2][3] Although *Kinetic Rain* looks very visually pleasing, we wanted to implement something that not only had visually pleasing animation, but through real time sound input. The *Kinetic Rain* device's engineering seems very complex and cumbersome to fix if there were any issues to arise. Also, we wanted to implement this in a manner that would be very cost effective compared to *Kinetic Rain.*

Our team decided we wanted to build a device that took advantage of LED technology's efficient and aesthetically pleasing properties. An LED grid allows us to display visually pleasing animations by turning off a set of LEDs and keeping others on to mimic the shape that we want. Although there are other LED displays that have music visualization capabilities, ours would not only use a sound's frequency, but its tempo, amplitude, and angle of arrival. Additionally, we'd like to have the user be able to interact with the LED grid to affect the animations within device. By taking something that is traditionally 2-dimensional and implementing a 3-dimensional version, we can show off the benefits of user interaction as well as increase the entertainment factor of the device. We plan on doing this by making a Snake game that uses proximity sensors to control the snake's direction.

1.2 Background

The *Kinetic Rain* sculpture's may be aesthetically pleasing, but that comes at a cost. The sculpture has a price tag of over $7 million and has expensive and unique parts that are hard to replace. [2] Our device would also be more cost efficient and be easy to fix if something were to go wrong with any of the pieces. Additionally, the sculpture took around 2 years to put together. [3] The *Kinetic Rain* was damaged on November 2nd, 2013 by a woman who climbed and hung onto the bronze droplets. The repair took engineers several months and was costly. [4]

With our device, we'd have a low cost and easy to repair LED grid that would use live sound input to affect the animations, so visitors may be exposed to new unique animations each time they visit. Our device would be more scalable because of its modularity and cost. The tax payer burden would also be less if a government municipality were to commission our device versus something like *Kinetic Rain.* Although there are devices that can display aesthetically pleasing animations, ours uses four sources of input to affect the animation. Our device will also have an interactive mode to allow users to affect animations. Even with the LED Cube ECE 445 project from the Fall 2013 semester, they their phone application to affect user input. We will expand on this in terms of number of input as well as improve the way a user interacts with the LEDs.

1.3 High-Level Requirements

- Capture the frequency, amplitude, angle of arrival, and tempo from incoming sound in an accurate manner and make sure each of the sources affect the LEDs appropriately.
- Proximity sensors must be able to pick up motions of user to affect the 6 different directions (Up, Down, Left, Right, Outward, Inward) that the snake can move.
- Make sure the LEDs' colors and off/on states are correct with respect to the mode that the device is in.

2 Design

2.1 Block Diagram & Physical Design

2.1.1 Block Diagram

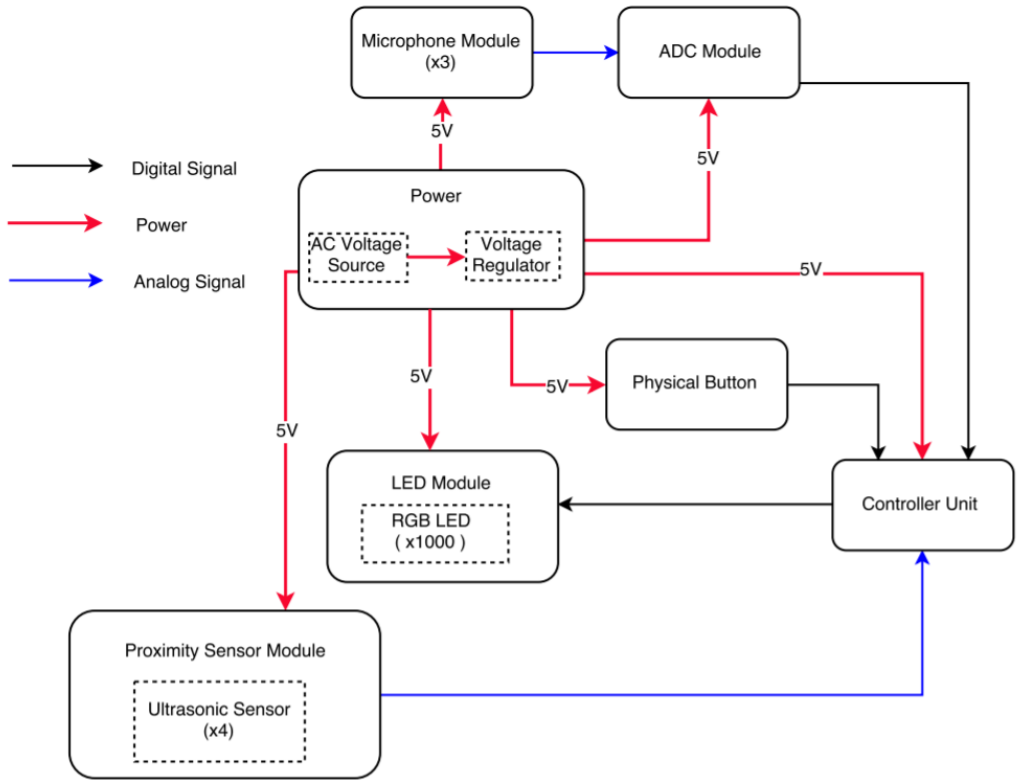

Figure 1

2.1.2 Physical Design

The LED module consists of 1,000 RGB LEDs, which are arranged into a 10x10x10 grid. We plan to arrange the LEDs such that the horizontal and vertical distances between any 2 LEDs is 2 centimeters. This will be placed on a flat rectangular surface that will have our sensors hooked up to. We plan on doing our wiring so that the LEDs remain visible and uncovered by wiring.

2.2 Functional Overview

2.2.1 Power Module

This module is responsible for supplying power to the other components in our design. We estimate a voltage of 5VDC will be needed to power the LEDs, Microcontroller, the sensors,

the microphones, and the analog to digital signal converter. These are estimates and may change depending on model of the parts specified above. The source of the power will be alternating around 120VAC and will need to be converted to 5VDC.

> Requirement: Must power all components of the device, as well as the LEDs, with 5VDC.

2.2.2 Microphone Module

This module is used to collect the sound from the environment. This module contains 3 microphones located at specific positions. These microphones will output an analog signal to the ADC module, which will convert the signal into a digital signal and feed it to the control unit. The microphones must be able to pick up sound with frequencies from 20 Hz to 20 kHz, the frequency range of audible sound.

> Requirement: Must precisely collect sound in the 20 Hz to 20 kHz range.

2.2.3 Proximity Sensor Module

The proximity sensor module is used to pick up how close the user's hand is in order to control the snake when the device is in gaming mode. This proximity sensor module contains 4 ultrasonic sensors arranged at certain positions. These sensors will detect if user's hand is above the sensors and generate analog outputs of 0-10VDC (depending on the model), which will be fed into the control unit. The control unit will then use the signal from the sensors to make decisions about where the snake should move.

> Requirement: Each sensor must detect the hand positions from a range of 3 cm to 1m.
>
> Requirement: Each sensor must detect the position of hand when hand is moving fast.

2.2.4 Control Unit

We will use the microcontroller in this module to take input in from the button that switches between the music visualization and the motion-controlled Snake game mode. The proximity sensor values also feed into the microcontroller to help determine the direction the snake moves in the LED grid. Lastly, the microcontroller uses the ADC as an input value and takes whatever is received from the microphones and runs the appropriate algorithms as needed e.g. FFT. Once the appropriate algorithm is used on the input, the microcontroller feeds what

should be displayed to the LED module. We plan on using an Arduino model to help implement the actions needed to be performed by the microcontroller.

Requirement: Must be able to recognize the motion of user's hand based on the input from the proximity sensor module.

Requirement: Must be able to run the Snake Game based on user's hand motion.

Requirement: Must be able to extract the frequency, tempo, amplitude and output proper signal to drive the LED cube.

Requirement: Must be able to distinguish between which side of the cube the sound comes from (behind, front, left, right).

2.2.5 ADC Module

The analog to digital convertor will be used to take the analog signals received from the microphones and convert it to a digital signal that the microcontroller can use. We plan on using a convertor with 16 to 24 bits of resolution. This will allow us to maximize the possible average signal to noise ratio without using oversampling.

Requirement: Convertor must have a sampling frequency that is at least 44.1 kHz.

2.2.6 LED Module

This module contains a 10x10x10 grid of RGB LEDs. Each LED will be able to display three different colors according to the two different modes, which is controlled by the control unit. The LEDs will be powered directly by power module. For the first mode of our design, music-visualization mode, the purpose of the LEDs is to visually display different sound pieces according to frequency, amplitude, angle of arrival, and tempo. For the second mode of the design, 3D Snake mode, the purpose of LEDs is to show the movement of the snake and the "food" according to the input motion detected by proximity sensors located at the edge of the design.

Requirement: Must be visible to the audience in both modes.

Requirement: Must be able to display all 3 colors (RGB) and determine when change to different colors and change the intensity of the display lighting.

Requirement: Must be able to have the LEDs on/off to have certain animations.

2.2.7 Physical Button

The physical button allows us to change between the two modes our project contains: music-visualization and motion-controlled 3D Snake. The button is directly powered by the

power module and after being pushed, the signal will go to the control unit and the mode will be changed. The LEDs will receive the signal and change accordingly.

> Requirement: must be able to send the signal to the control unit and be able to change the operation mode.

2.3 Risk Analysis

The most difficult part of the project will be making sure all the LEDs in our grid are properly connected and functioning. Because we have so many LEDs, making sure all of them work immaculately is pivotal to our project succeeding. Some LEDs may also be faulty so replacing them could be very cumbersome. Additionally, making sure that the proximity sensors pick up the right signals and that we can translate them to directions for the Snake game will be somewhat difficult due to the nature of a sensor potentially not picking up the correct signal. Lastly, the microphones may not pick up the sound accurately and that could impair the visualizations made on the LED grid.

3 Ethics & Safety

For this project we will abide by IEEE's Code of Ethics [5] and also use our moral judgement when needed. We will respect all intellectual property laws and be honest with all the estimations and results during the entire process of our project.

We will be using an AC wall outlet to power our device so we need to make sure the voltage regulator is working properly. We must never allow a short circuit to occur as this could make the device overheat and potentially make LEDs explode. Our design will contain hundreds of LEDs, which will most likely be wired manually. The glass material and the fact that LEDs could be fragile could make the process challenging and dangerous. Because the device might be viewed by the public, safety and proper containment of the device will be followed. Also, because we might use the soldering iron during the building of the device. We will follow the directions for using the soldering iron with utmost caution.

4 References

[1] ‘Kinetic Rain’, Changai Airport Singapore, 2012. [Online] Available: http://www.changiairport.com/en/airport-experience/attractions-and-services/kinetic-rain.html [Accessed: 2-Feb-2018].

[2] ‘Metalier saves $6.3 million dollars on kinetic sculpture’, Metalier Coatings, 2015. [Online]. Available: https://www.metaliercoatings.com/save6-3m-on-kinetic-sculpture/ [Accessed: 2-Feb-2018].

[3] Emilie Chalcraft, ‘Kinetic Rain by ART+COM’, dezeen, 2012. [Online]. Available: https://www.dezeen.com/2012/07/19/kinetic-rain-artcom/ [Accessed: 2-Feb-2018].

[4] Chai Hung Yin,'Woman arrested for damaging Changi Airport's kinetic rain sculpture', 2013. [Online]. Available: http://www.asiaone.com/singapore/woman-arrested-damaging-changi-airports-kinetic-rain-sculpture [Accessed: 2-Feb-2018].

[5] IEEE.org, "IEEE IEEE Code of Ethics", 2018. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 4-Feb-2018].