Gesture-Based Light Design System

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1 Introduction

1.1 Objective

Currently, there are excellent sophisticated lighting systems in place at almost all venues in order to give proper lighting to design theatrical acts and production for musicians. Unfortunately, the control systems behind these lights can be very expensive, difficult to learn and tough to transport. Particularly for travelling musicians, lugging around a heavy control board could be problematic, and learning someone else's equipment is time consuming in a field where time of the essence. Also, there are few current light systems which gives those on stage the option to be involved in the process; there is almost always someone in the backroom controlling the set.

Our goal is to streamline the process of learning these complex systems, reduce the cost of travel, and offer a new side of production to all types of performers through our gesture-based light design system. Using this system will be much more intuitive and light, changing the way how lighting design is done in the modern world. Instead of learning a series of button and slider combinations that need to be learned, the user will be able to just point in the direction they want the light to face. Furthermore, past utility our project will offer a new type of flare and design to performers on stage. For the first time musicians and actors will be able to take control of the light themselves in a visually appealing way, adding to the showmanship of the whole performance.

1.2 Background

Nearly every modern entertainment venue uses some form of light design to achieve the best overall look for a stage or theater. As stage lighting become more and more complex, it is increasingly necessary to design the stage's lights prior to the show, requiring a multitude of expensive control boards. As if the expense of control boards isn't enough, the complexity of the design system frequently takes away the creativity of the performing artist.

We plan to make our system extremely affordable for an entry level light design. Further, our system will be one of the most intuitive and user-friendly on the market. No need to learn which buttons do what on an expensive board. Instead, the light designer can take full control of the lights by just gesturing his hand.

1.3 High Level Requirements

- The user must be able to walk freely with respect to the Control Unit, but within a distance of 30 feet, and be able to control the Stage Lights with gesture movements.
- The user must be able to select or deselect any single or group of stage lights which they wish to control.
- The system must be able distinguish whether the user is gesturing to control the lights, or if the user is gesturing arbitrarily.

2 Design

2.1 Block Diagram

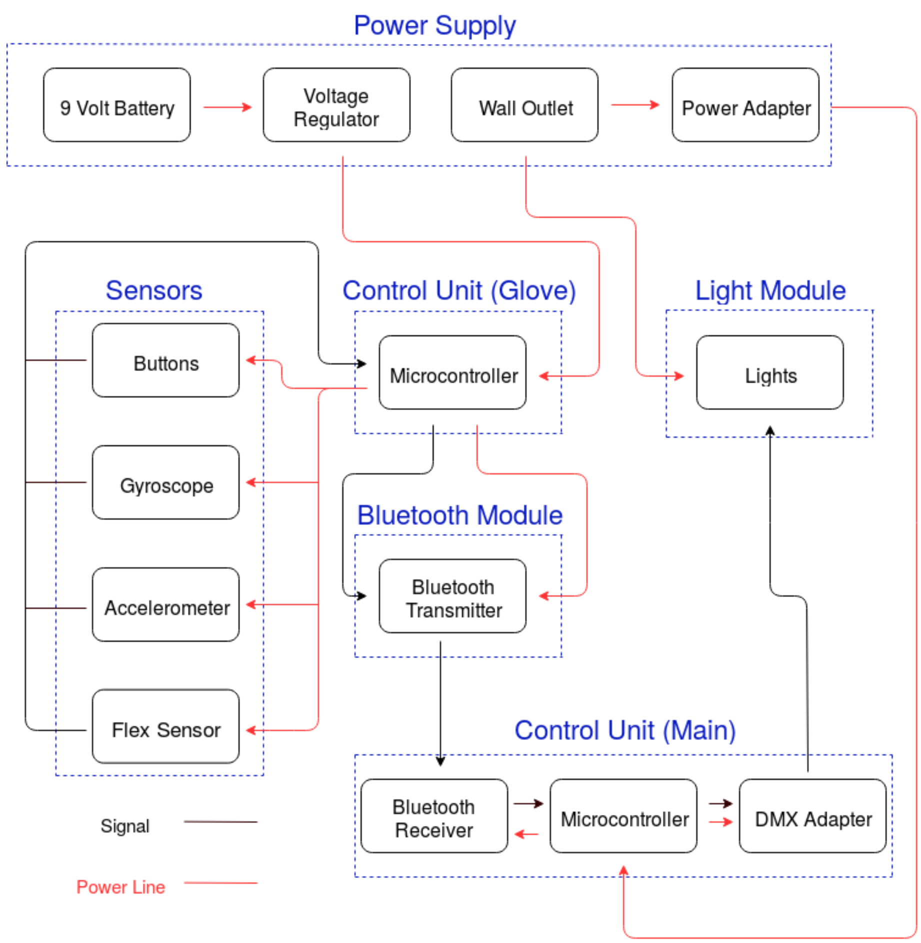

Figure 1. Block diagram of the entire system.

2.2 Physical Design

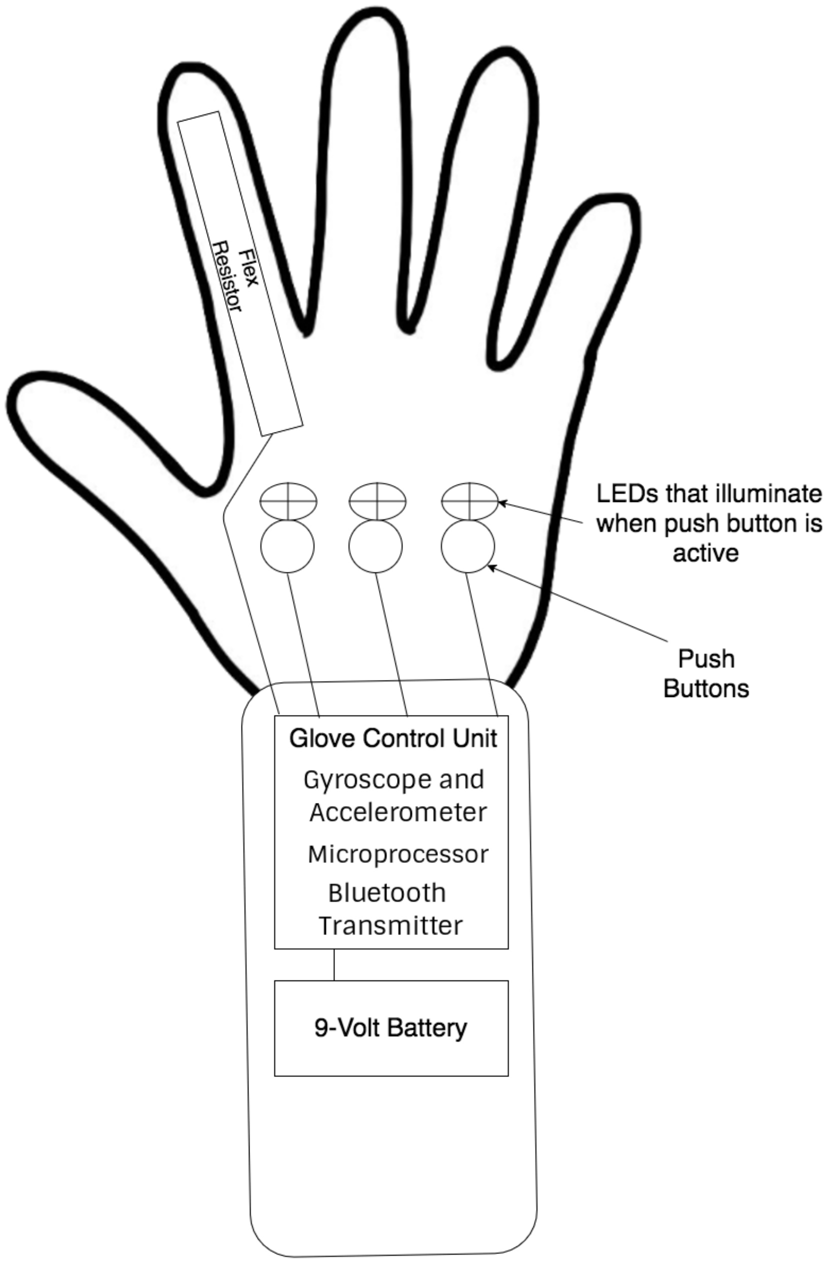

Figure 2. High level physical diagram of the glove.

The biggest reason why we chose to have the glove be powered by a 9 Volt battery and not a rechargeable battery is reliability. In a perfect world, every user would remember to charge their devices. However, in practice, users frequently forget to charge their devices. We want the glove device to be reliable in situations like this. If a user ever needs to use the glove and it happens to be out of battery, the user can easily and quickly swap out the 9 volt battery.

2.3 Functional Overview

2.3.1 Power Supply

9 Volt Battery
A 9 volt battery will be used on the glove to send power to all of the sensors on it. The sensors, microcontroller, and bluetooth module will not be a drawing an overly large amount of energy, so this quantity will suffice for the scope of the project.

Requirement: The battery must provide enough power to keep 4 LED lights, 5 buttons, gyroscope, accelerometer, flex sensor, bluetooth module, and microprocessor active for 5 hours.

Voltage Regulator
A voltage regulator will control the voltage magnitude delivered to the glove control unit in order to protect the microcontroller. The ATmega328P has a voltage range of 1.5 to 5.5 V, so the voltage from the 9V battery must be adjusted to an appropriate level.

Requirement: The voltage regulator must deliver a voltage between 1.5 to 5.5V to the glove's microcontroller.

Wall Outlet
We will power the lights and main control unit through a wall outlet. The main control unit requires DC power, so a power adapter will be necessary.

Requirement: The wall outlet must provide power to the main control microprocessor (through a power adapter) and to the lights.

Power Adapter
An appropriate power adapter will be used in order to convert the AC power from the wall into DC power which can be used by the control board.

Requirement: The power adapter must convert AC power to DC power for the main control microprocessor.

2.3.2 Main Control Unit

Computation Unit

We are planning to use a more powerful computation unit here than on the glove because this processor will be responsible for calculating where the user is gesturing and calculating the correct pattern for the moving-head lights. Because of this higher need in core processing power we plan to use a Broadcom BCM2835 System (Raspberry Pi).

Requirement: This computational unit must be powerful enough for complex processes such as gesture recognition and DMX signal processing. We must be able to use powerful algorithms which can distinguish whether or not the user is truly gesturing or not. If the user is gesturing, we must be able to distinguish which gesture is being enacted.

Bluetooth Receiver

We plan on using a nRF8001 Bluetooth Low Energy Breakout in order to receive information from the bluetooth transmitter on the glove.

Requirement: Must utilize the Bluetooth communication protocol and be compatible with the Broadcom BCM2835 System. It must have enough bandwidth to receive all of the information being sent from the glove unit.

DMX-512 Adapter

We plan on using a FT245RL DMX Interface for the Raspberry Pi in order to deliver information from the main control unit to the lights.

Requirement: Be fully compatible with the Broadcom BCM2835 System and be fully support the DMX-512 communication protocol.

2.3.3 Glove Control Unit

Microcontroller

Chosen to be the ATmega328P. This microcontroller will act to process and route the information through the glove.

Requirement: The microcontroller must be powerful enough to process the information of all of the sensors and deliver it to the main control board via a bluetooth transmitter.

Bluetooth Transmitter
CC2540 SimpleLink Bluetooth Low-Energy Chip. Compatible with the chosen microcontroller, this will enable communication to the Main Control Unit.

Requirement: The bluetooth transmitter must have low enough energy consumption to be powered by a 9 volt battery. The bluetooth transmitter must have a range capability of 30 feet. The bluetooth transmitter must have the bandwidth to deal with the throughput of all of the data from the microprocessor.

2.3.4 Sensors

Buttons
Standard COM-00097 push buttons will suffice. These will allow the user to select or deselect the lights which they would like to have control of.

Requirement: Be able to send high/low signals to the Glove Control Unit, signifying when the button is pushed.

Gyroscope & Accelerometer
MPU-6050. Compatible with the Glove Control Unit's microcontroller. It contains both a gyroscope and an accelerometer.

Requirement: The gyroscope and accelerometer must be able to provide information of how the glove moves in 3-dimensions in order to recognize where the user is pointing and what sort of gestures the user is performing.

Flex Sensor
SEN-10264 2.2" Flex Resistor.

Requirement: Be able to differentiate when the User is point his/her finger to signify that the User intends to control the moving-head lights, and differentiate when the User is not intending to control the lights. This will require significant differences in resistivity from pointed (straight) to flexed (bent).

2.3.5 Moving-Head Lights

Gesture Beam 400
We have access to two Gesture Beam 400s. This is a professional moving-head light that uses the DMX-512 wired communication protocol. The Gesture Beam 400 will take power from the wall outlet and take data in from the Main Control Unit.

Requirement: The moving-head lights must utilize the DMX-512 communication protocol and be able to move in at least 180 degrees of motion. They must also be able to power themselves (from the wall outlet).

2.4 Risk Analysis

The biggest risk factor we are currently considering is the transmission of information to the moving-head lights using the DMX-512 protocol. The area itself is something that is fairly unique and will require a good understanding in order to properly utilize it. In the scope of our project, communicating with it accurately could be difficult. Furthermore, an issue related to this communication is having our gestures map as accurately as possible. Although we may be able to move the light itself relatively feasibly, there might be a degree an error. In the case of lights, a 5% error could result in the light projection being largely displaced.

Further, we are also conducting research in the gesture based feature. Considering that the gesturing is the hallmark of our system, it needs to function well. We are consistently brainstorming ideas on how to most accurately encode what the user is gesturing. For an initial prototype, we plan to experiment gesturing on our own, and hard-code an algorithm using the data from the gyroscope/accelerometer module for common gestures such as 'point lights left/right and up/down'. If this proves highly successful, no further steps will be needed. The risk is that this hard-coded output from the gyroscope/accelerometer will not be accurate enough to control the lights within our desired range. To counteract this potential problem, we are researching machine learning methods to allow the gestures to be understood more accurately which will result in a more ideal control of our lights.

Lastly, it was discussed during our first meeting with Tony Caton that we may run into common issues with the Bluetooth communication. Bluetooth, while relatively straightforward, introduces another area where communication between devices becomes more complex. We are researching common Bluetooth errors and issues to try and mitigate this risk before we begin prototyping.

3 Ethics and Safety

At a quick glance, it seems our project does not have any of the major traditional safety risks that other ECE 445 projects encounter. This is most notably because we are not using a rechargeable battery. However, we have identified areas where ethical and safety questions arise in the following paragraphs.

Although we are not using a rechargeable battery, which are known to explode under improper use, we are using an alkaline battery which still carries the potential to explode [2]. To minimize the risk that any alkaline battery explodes on a user, we will always recommend to follow standard storage and usage procedures for disposable alkaline batteries. To elaborate, there is essentially a nonexistent chance of electrocution by such a small voltage. However, to take full precaution, we will take an additional step and isolate all electrical components of the wearable device from the users skin. No electrical components will be making direct contact with the user.

Next, users of our system may be exposed to high voltages when using standard professional DMX-512 moving-head lights. These lights consume large amounts of electrical power, and are powered directly by the wall outlet. We will communicate this potential electrical hazard to all users of our system through the use of warning labels.

In most cases, the DMX-512 protocol does not include a parity check or an error check [3][4][5]. This means that when using a DMX-512 hardwired system, such as our current approach, there is a potential risk that the wires used to communicate to the lights pick up interference and cause an undesired operation. In the worst case, this means that the moving-head lights move uncontrollably and at incorrect colors/brightness levels until it receives a new correct signal. We will fully disclose this risk to the users of our system and include warning labels. The requirement to use our system will be that all moving lights be in a physical area that gives a full range of movement to the moving-head light with zero possibility of collision or human contact.

We do not suspect interference to be a large problem, but according to IEEE Code of Ethics #1, we must "hold paramount the safety of the public... and disclose promptly the factors that might endanger the public or environment" [6]. We believe we have fully followed this code and all other standards laid forth by the IEEE Code of Ethics.

References

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