ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Mimicry Stage Lighting Control System

Team #445

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1 Introduction

1.1 Problem

Stage lighting engineers are important in scenarios like theaters, concerts, and live houses. They use all kinds of lamps and related equipment to perform artistic lighting to achieve specific effects. However, the current stage lighting work requires tedious programming, while the presented effects are not that ”fascinating”. Sometimes, DJs and performers want to present improvisational movements with the lights or want the lights to move to the rhythm of the music, or just want to guide the audience’s lightstick movement. The preprogrammed and rigid lighting sequence cannot meet this requirement.

Another problem of stage lighting is mobility. Lighting arrays in theaters are mounted on the stage or the ceiling, which is not appropriate in scenarios like a home party. A small, easily controlled prototype is therefore needed.

1.2 Solution

This project aims to build a mimicry stage lighting control system. Generally speaking, the direction control system (usually a robot arm) will imitate the movements of the operator’s arms so that the direction of the light can be controlled arbitrarily. In addition, the color of the light array can be determined by either the operator or the inherent information extracted from the music that is being played. Also, the whole system can be built in small size and can be installed easily, so that it can be deployed in scenarios like home parties.

More specifically, an operator (mostly a presenter or DJ) holds (or wears) a control device, the joystick, in each hand. The joysticks track the movement of each arm and transmit the direction information to the central server. This information is then processed and redirected to the mounted projector light arrays to control the actual direction of beams. Each hand controls each side of the lighting array. The system can also memorize a period of movement and playback. Besides, the color of the lights can be manually determined or be automatically determined by the rhythm or tempo of the music being played. The movement of the light gimbal can even be determined by the inherent feature of music.

1.3 Visual Aid

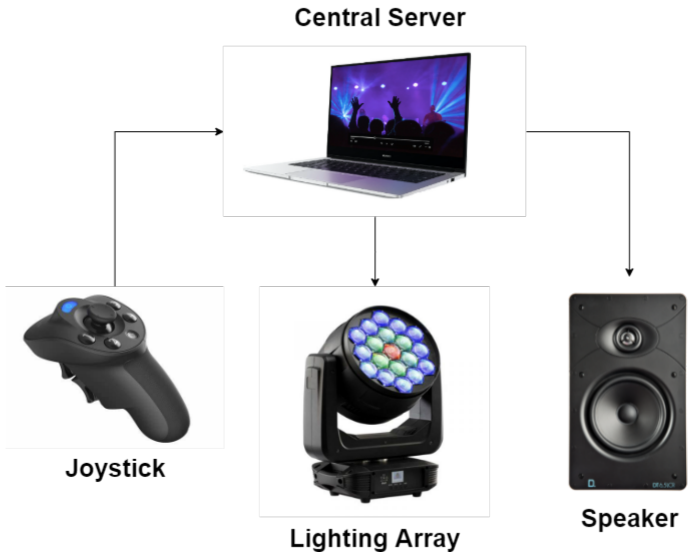

Figure 1: A pictorial representation of project

The overall system consists of four components: a pair of joysticks, an array of lamps, a controlling computer, and a speaker (sometimes the speaker can be integrated into the computer or connected through other means). The controlling computer can also be mobile phones or other personal devices.

1.4 High-level Requirements List

1. Low latency. To achieve a good stage effect, the delay between the movement of the operator and the response of the light array needs to be small enough.
2. Precision. The presented direction of projector light (or more specifically, the gimbal) should be approximately parallel to the actual direction of the operator's arm.
3. Energy Consumption. The overall energy consumption should be reasonably limited. To be more specific, devices like joysticks are usually charged by batteries, which requires certain endurance.

2 Design

2.1 Block Diagram

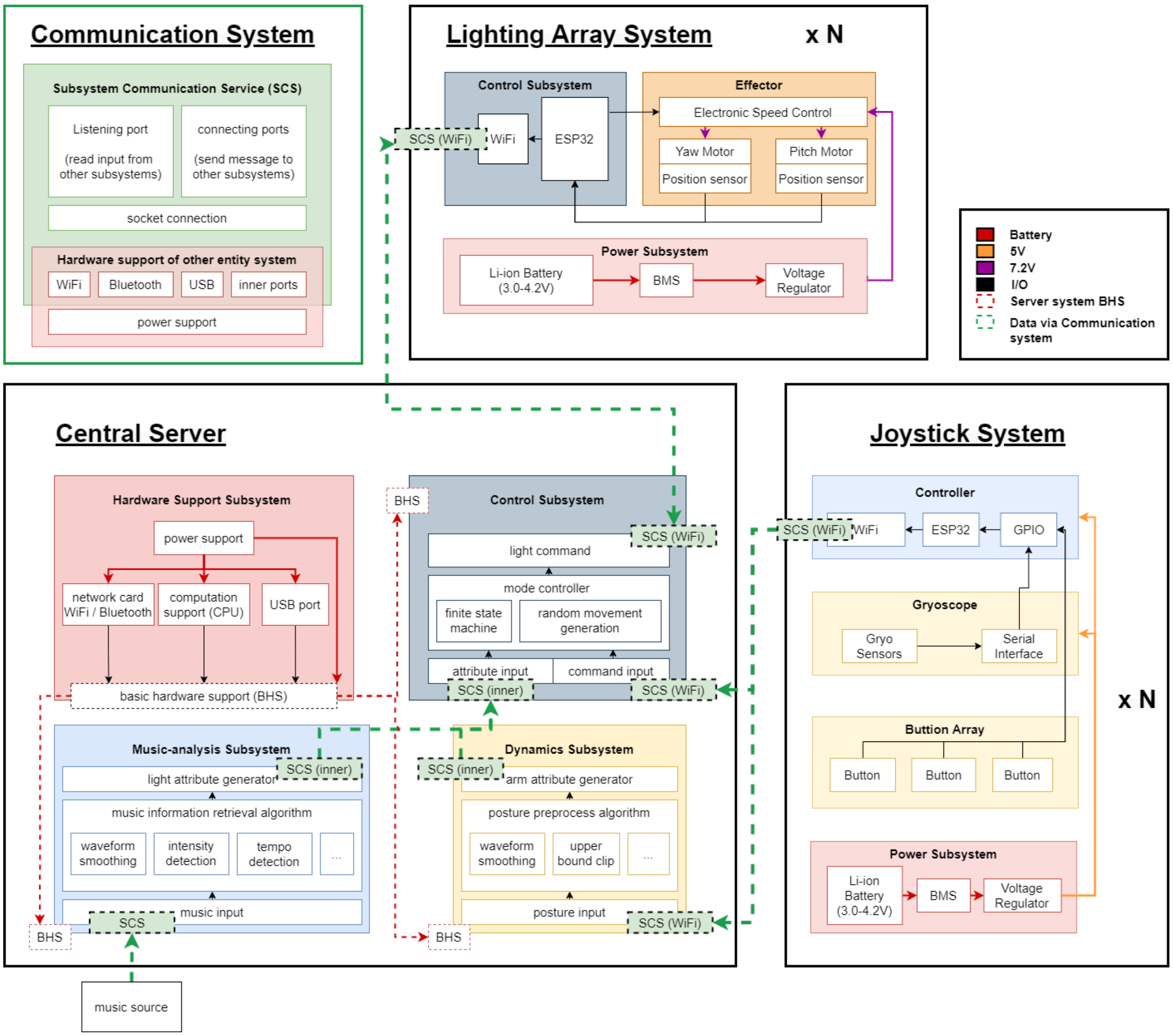

Figure 2: System Block Diagram

2.2 Subsystem Overview

The whole product has four main subsystems as shown on the block diagram above. The joystick system is a stick with controller, gyroscope, button array, and power subsystem. It can transmit the position information to central server.

2.2.1 Joystick Subsystem

The joystick system consists of controller, gyroscope, button array, and power subsystem. It can transmit the position information to central server.

2.2.2 Lighting Array Subsystem

A battery powered two-axis manipulator has YAW and PITCH two degrees of freedom, and is controlled by two stepper motors respectively getting signal form the ESP32 through closed loop PID control.

2.2.3 Communication Subsystem

The communication subsystem handles the connection between subsystems via at least one of WIFI, Bluetooth, USB port or inner ports

2.2.4 Central Server

The central server consists of Hardware Support Subsystem, Control Subsystem, Music-analysis Subsystem, Dynamics Subsystem

2.3 Subsystem Requirements

2.3.1 Joystick Subsystem

The power system should supply 3.3V with a max current greater than 400mA. The MPU-6050 has a built-in gyro sensor, which can automatically detect the value in pitch, rolling, and yaw axis. After conditioning, the signals are encoded and transmitted to ESP32 via the I2C interface. The button array module includes buttons, which control the working model of the robot arm. For example, if we want to record the action of the arm and repeat that, we just need to press the start button and the recording will start. If we want to stop that process, just press the stop button. After pressing the third button our robot arm will repeat the recording action. The power subsystem starts with the 3.0-4.2V battery, and then goes through the battery management system (BMS), which is a rectifier, and finally a voltage regulator. The power applies to the controller. All signals that go into the controller are encoded and transmitted to the central server.

2.3.2 Lighting Array Subsystem

Lighting Array System consists of several independently controlled two-axis robotic arms. Each two-axis manipulator has three parts: control subsystem, manipulator subsystem, and power subsystem.

The control subsystem has an ESP32 chip that receives instructions from the Central Server over WIFI. The PAW and PITCH axis of the manipulator subsystem is controlled by two stepper motors respectively. While receiving the speed control signal from the ESP32, the two stepper motors collect the position signal from the position sensor and transmit it to the ESP32. EPS32 uses PID signal processing technology to control closed-loop feedback based on electrical signals to ensure the accuracy and stability of the manipulator attitude.

The power supply of each manipulator was obtained from Li-ion Battery. The current passes through the Battery Management System (BMS) to prevent backflow and then through the voltage regulator for waveform management.

2.3.3 Communication Subsystem

The communication subsystem is an abstract software layer that handles all the connections between subsystems. It bases on the hardware of its host subsystem, containing the power supply, network hardware, and operating system. The network hardware should cover at least one WiFi, Bluetooth, USB port, or inner ports. With those infrastructures, each subsystem can establish its communication service. There will be a listening port in the service that receives all messages sent to it and many other ports can be utilized to connect with other subsystems.

2.3.4 Central Server

Hardware Support Subsystem

The following three subsystems are abstract software run a central server. Therefore, the basic support for those software is listed here. Varying with different hard platforms such as PC, phone, or server, the value changes a lot. Generally, it requires a network card that supports WiFi or Bluetooth connection, USB ports that help communication and debug through a serial port. Computation support is also needed that makes real-time signal process algorithm possible.

Music-analysis Subsystem

This system takes music signal as input and generates color control signal and gimbal control signal as output. This component is a software algorithm running in the central control server. The algorithm involves traditional spectral analysis, wavelet analysis, or even neural networks. The subsystem adopts technologies of music information retrieval (MIR) to obtain features of tempo, rhythm, strength, melody, and even mood. These features are therefore mapped to color control signal and gimbal control signal.

Dynamics Subsystem

This system receives posture data from the joystick subsystem and does the preprocess like waveform smoothing and upper bound clip for moving angle and distance. Then the preprocessed data will be remapped to the robot arm's dynamic coordinate system and sent to the control subsystem for further processing.

Control Subsystem

This system receives control data from other subsystems and generates control commands to the lighting array system. Specifically, it takes light attributes from the music-analysis subsystem, robot arm attribute from the dynamics subsystem, and button commands from the joystick subsystem. There will also be an inner finite state machine that controls the mode of the whole system, like Mimicking humans, waving according to music characteristics or randomly moving around. It also handles the symmetry behavior and synchronization for the Lighting Array.

2.4 Tolerance Analysis

1. The wireless communication generates inherent delay between each component. The computational center and control system also produces potential delay. These factors jointly contribute to a significant overall delay. However, a certain amount of delay is tolerable, since this whole system is used in scenarios where the human audience is the subject. Therefore, as long as the delay is not noticed by a human observer, it's not important. For example, with the music playing, a 500 ms delay is tolerable.

2. Due to the existence of the base and its lack of freedom, the reachable Angle of the two-axis mechanical arm of this product is smaller than that of the real human arm.The acceptable result is that the workspace of the manipulator meets the stage/room lighting coverage.

3. At the same time, because of the singularity of the mechanical arm, the mechanical arm may be stuck after reaching a certain Angle and unable to move, thus leading to product damage.An acceptable result is to avoid the attitude of the manipulator entering the singularity by setting up a specific mechanical protection structure. While some workspace is sacrificed, structural components are protected to the maximum.

4. The transmission of signal through WIFI between modules could be energy-consuming because the information of button and action is real-time, which means the query is highly frequent. we suggest that the whole system could sustain for an hour without damaging the elements or cause danger, since it is about the time for DJ to perform one show.

3 Ethics and Safety

3.1 Ethics

3.1.1 Ethics of our product

Our group guarantees that the robot will not use strong light that can harm people's eyes by proper controlling of light energy and divergence.

We will reinforce the gimbal and try our best to avoid potential safety hazards caused by the falling of the light during use.

We will do our best to remind our users to avoid using lights late at night, to avoid disturbing others' sleep.

3.1.2 Ethics of research and development

Our group guarantees that the code of this product does not involve any plagiarism

Our group guarantees that this product modeling will not copy any existing modeling solutions

Our group states that this product will not use any solution of existing products on the market.

3.2 Safety

Production safety - our team guarantees that we will have more than two people in the laboratory in the process of production and processing. At the same time, the students participating in the experiment have completed the online safety training of the laboratory and received certificates.

Electricity safety - Our team fully read, understand, and follow the guidelines for the safe use of batteries before using them.

Mechanical structure safety - Our team choose the safest shell shape and mechanical structure.

Material processing safety - Our team pays attention to the safety of production and use when using sheet metal materials and other materials that are easy to cause damage to the human body.