User Adjustable LED for Light Painting Photography

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ECE 445 Project Proposal – Spring 2017
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1 Introduction

1.1 Objective

Light painting is a photographic technique in which a photographer manipulates a hand-held light source, as if it were a paintbrush, to illuminate a subject during a long exposure photograph. This photography practice can produce masterpiece artworks for various purposes. However, in order to excel in light painting, the photographer must expose just the right among of light in different places for aesthetic effects [1]. As with many other photography tools, the equipment used in traditional light painting are often excessively expensive and ungainly large. Our client Rick wants us to design a cost effective, portable LED paint brush that can alter its light settings in delicate detail. The requested functions include: the ability to control the fade/gradient of the light, brightness of the light, and location of the light within the case. Some additional functionalities we would like to add to the project are light temperature variation, and remote controllability. We envision our product to be utilized by many photographers throughout the world to generate jaw dropping light paintings efficiently and cheaply.

1.2 Background

Our client Rick is an engineering minded photographer who likes to solve real world problems. When he started to light paint cars, he ran into a problem because he couldn't find an affordable light source with a light gradient. In an effort to solve the problem, he bought a 4 ft long LED light for $40. Then he took a non-technical approach to creating a gradient; he piled a number of diffusion papers between the LED strip and the outer plexi-glass to improvise a fade. The prototype was effective in producing several quality automobile photographs. However, the prototype was lacking in many ways. In order to change the fade of the LED, the user had to manually allocate multiple layers of diffusion papers in the desired locations. Also, the brightness was not adjustable. Rick also said the power cable could be cumbersome, especially in extremely dark environments where light painting takes place. Also, the power cable limits outdoor light painting practices. Our group will put our head together in order to solve these real-world problems for our client, Rick.

1.2 High Level Requirements

- We must be able to control the brightness and color of each segment of the LED strip in precise detail

- The light source must be bright enough to illuminate the subject during a long exposure photograph
- We must be able to power the LED system using a rechargeable battery for at least 15 minutes

2 Design

Block Diagram and Physical Design

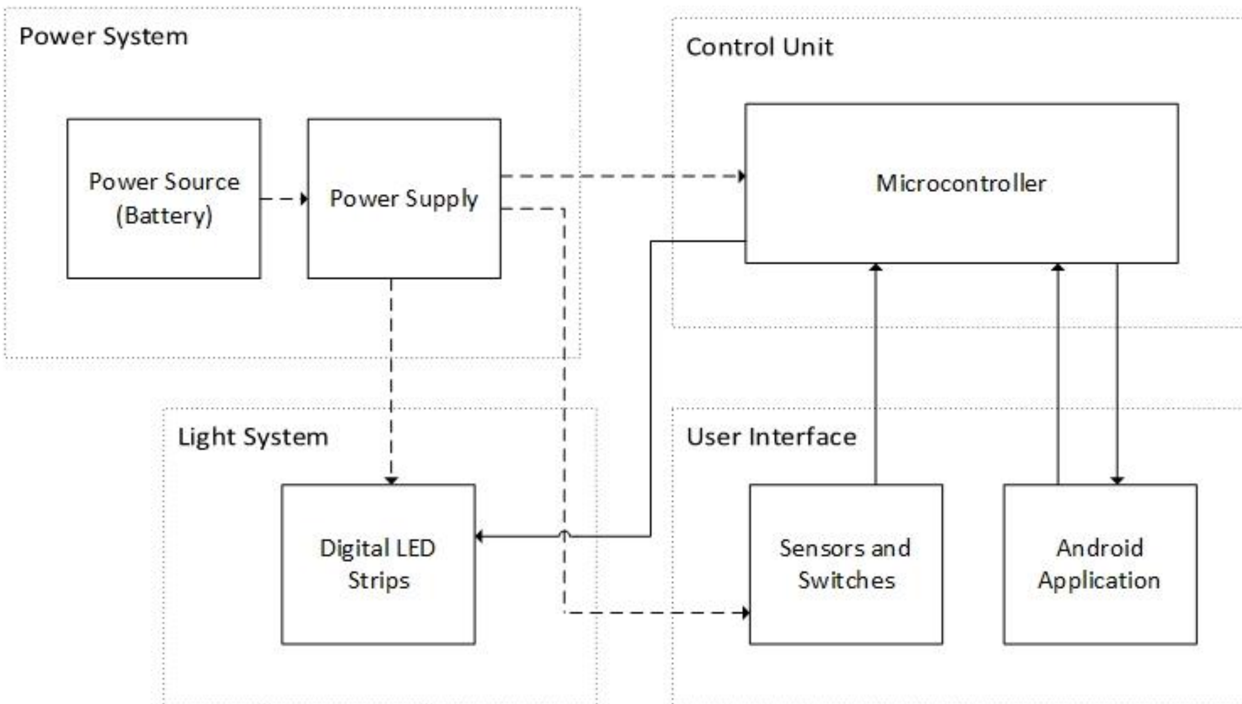

Figure 1. Block Diagram of the Proposed LED Light System

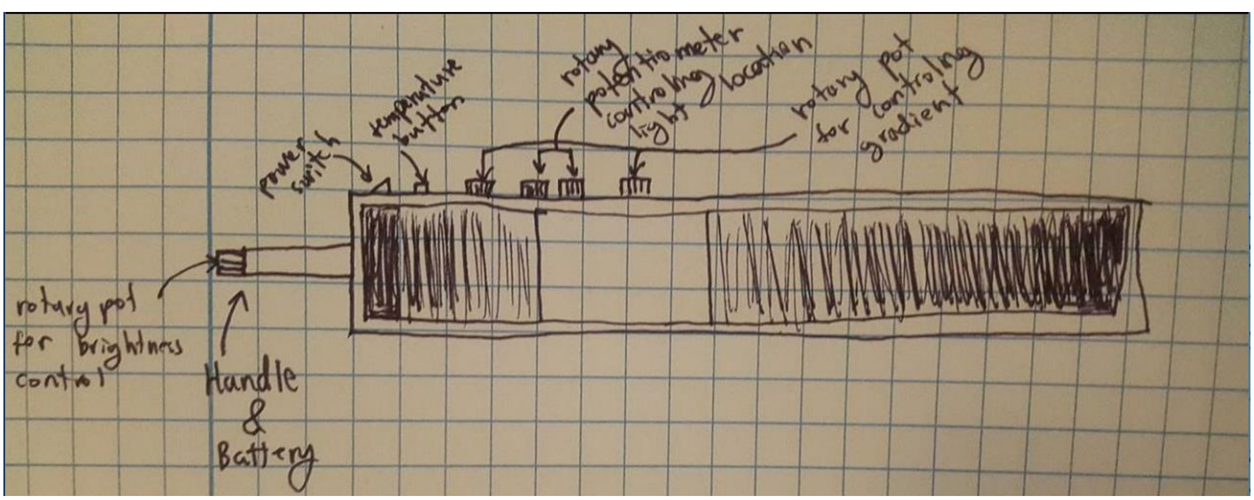

Figure 2. Physical Design of the Proposed LED Light System

The overall shape of the system will be a rectangular prism with dimension 4 ft x 4 in x 4 in. One of the 4 ft x 4 in surface will be a cover made using plexi-glass, while other surfaces will be made using dark metal that can absorb light.

2.1 Power System

2.1.1 Power Source (Battery)

This node consists of a rechargeable lithium-ion battery that powers the circuit steadily. By using battery as the source, the system will not require a power cable plugged into the wall, allowing the users to move the system more easily without worrying about stepping on the power cable.

Requirement 1: The battery must output equal or greater than 18.5mA at 12V DC for at least 15 minutes
Requirement 2: The battery must be mobile enough such that it can be mounted onto the LED case

2.1.2 Voltage Regulation (Power Supply)

The voltage regulation module converts the voltage output of the battery to the voltage input needed by the microcontroller, digital LED strip, and sensors. This component will make sure that the LEDs and micro controller are supplied with a constant voltage of 12V DC.

Requirement 1: The voltage regulator must supply the LEDs with 12V +/- 5%
Requirement 2: The voltage regulator should never supply the microcontroller with more than 12V

2.2 Control Unit

The control unit is responsible for communicating with other sensors and devices within the system to determine the states of the light system which include the location of the gradients, overall brightness, and color temperature. Furthermore, this unit communicates with the SD card to save the state of the overall system before it shuts down, to allow the system to restore its state after restarting.

2.2.1 Microcontroller

The main component of the control unit is the microcontroller, which receives analog signals from the sensor, converts the input to digital signal, and process the data. Also, it will receive and transmit Bluetooth Low Energy (LE) signal to communicate with the Android smartphone application. Based on the data received from the sensor and the smartphone application, the microcontroller transmits digital signals to the LED light system to control the output.

Requirement 1: The microcontroller must have at least 5 analog input pins, and needs to be able to convert the analog signals of range 0-5V to digital values.
Requirement 2: The microcontroller should imbed a low energy bluetooth node with a max range of at least 33 feet.

2.3 Light System

The light system is used to give color temperature description for the painting objects, and have at least three different temperatures of light. Using the strips of LEDs, the device would be able to control the temperature of light manually and wirelessly. Moreover, the device will have function to control only selected parts of the light. In the driving mode, the LED can retain luminance and color temperature even though power supply is less with constant current output.

2.3.1 Digital LED Strips

Our light source must be power efficient and must be individually addressable and digital LED Strips fulfill our needs. The focus of our design is to make the control over the gradient and location of the light as intricate and smooth as possible. In order for that to be possible, the LEDs should be densely packed. Most digital LED strips do not fancy more than 32 LEDs/meter and therefore we will cut and rotate the LEDs to make room for more LEDs within a fixed length. This LED strip receives control signals from the microcontroller and adjusts the color of each LED light bulb accordingly. The LED strip will be reorganized into a 2-D array, where each individual column is controllable by the microcontroller.

Requirement 1: The lights produced by the LEDs must be fully diffused when it reaches the surface of the housing such that it is impossible to spot a single LED.
Requirement 2: There should be at least 100 individually programmable LEDs within the 4 feet case such that the gradients formed by the LEDs are smooth.

2.4 User Interface

2.4.1 Sensors and Switches

Various physical sensors and switches will be mounted onto the LED system such that customizations can be made on the spot. 5 rotary potentiometers will be needed. 1 rotary potentiometer is needed to control the brightness of the overall system. The other 4 rotary potentiometers will be used to alter the location of the light within the LED case and the length of the gradients starting at each edge of the full light. All such values will be sent to the microcontroller, which in turn processes the output values for the individual digital LEDs.

Requirement 1: The power switch should ideally output 5V when on and 0v when off.
Requirement 2: The range of rotation of the rotary potentiometers should be less than 360 degrees

2.4.2 Android Application

An android application software will be developed to allow more complicated user interfaces, such as setting a timer to slowly decrease the brightness of the light and saving the LED system's state for future use of the setting. The software uses the Bluetooth socket to communicate with the microcontroller in order to exchange information about the LED system's current state and how user changed the system's settings using the interface available on the application. Although this application will be developed for Android OS, there are many different versions of the same OS. According to [2] approximately 86.7% of the Android users use the KitKat or newer version of the OS. Hence, for this application, being able to support KitKat or newer OS will be required.

Requirement 1: The application needs to support Android KitKat or newer version of the Android OS.
Requirement 2: The running application needs to use 500MB or less RAM to support most of the Android devices.

2.5 Risk Analysis

The power is the greatest risk factor for our project to be successful. If the power system supplies excessive power into the lighting system, the LEDs can be overheated, and they might shut down and cause a failure in the system. Our device uses a 4 ft LED strip drawing a constant current of 18.5 mA, and there is possibility for power spikes phenomenon or power reverse polarity. In order to reduce the risk, we won't connect more than 100 Ohms resistance in series at the power supply pin of LEDs.

Our customer requested us to build manual control system that offers a variety of lighting/gradient modes. The RGB values of our digital LED's are programmable, and enable us to express more than three different temperatures that our customer requested. However, it could cause our system to fail when manual controlling and remote bluetooth controlling conflict each other. In order to avoid this risk, we will consider allowing user to switch between two types of mode of our device controlling system, one with manual, and the other with Bluetooth control.

As our customer insisted, we will focus on building the device with low budget. The budget could vary depending on our system's functionalities, but it could still limit the quality of the final product by forcing us to use components less stability and quality.

3 Ethics and Safety

There are several potential ethics and safety concerns in this project. First of all, we chose Lead-Acid battery for the power supplier into the system in our design. Even though Lead-acid is a commonly-used material, there are still possibility to put users in danger. Lead is a toxic metal that can be inhaled through mouth with lead-contaminated hands, and it is crucial for human body, especially for people with developing bodies such as children and pregnant women [3]. In order to caution users, we will attach a warning stickers about the battery.

Our product would be left unused most of time. Therefore, it needs to be treated in a proper and good manner. If the battery is left in connection to the power supply system, or to the charger, it could cause a damage in the battery by short-circuiting and overly charging, which could create overheated cells and cause explosion. We also ask customers for special care for the device while in use due to highly drawn power for LEDs.

Furthermore, the device could be used in outdoor depending on one's painting theme and objects. Most of electric machines are vulnerable to moisture, and it could make the nodes to be shorted. People could get electric shock if touched circuit exposed to water. To minimize the possibility of this case, we may cover the circuits with insulated materials, and case.

Beside, LED radiation can cause significant damage to human retinal pigment epithelial cells. More than 100 LEDs will be used in the lighting system in order to paint the objects. This is normally more lights than human's eyes receive in life. Our eyes are not designed to look at light directly, but with light [4].

Following the IEEE Code of Ethics, #1: "To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that endanger the public or the environment" [5]. We are responsible to test and verify all of our design for public health.

Students can be tempted to manipulate data rather than reporting and correcting errors for better grades. This is against the #3 and #7 of the IEEE code of Ethics [5] - the people have to be honest and realistic in stating claims, and seek for honest criticism of technical work to acknowledge and correct errors. We promise to look for TA for any sorts of problems we will confront during the project, and provide realistic and accurate data to obtain proper credits for our contributions and others. It is also important to help colleagues, and co-workers stay out of the violations, and look for further technical development according to the IEEE code of Ethics, #10: "to assist colleagues and co-workers in their professional development and to support them in following this code of ethics" [5].

References

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