Light Management for Healthier Circadian Rhythm

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Project Proposal
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1. Introduction

1.1 Objective

Employee work-from-home numbers have skyrocketed due to Covid19 in the past year. According to Global Workplace Analytics, an estimated 56% of people of current jobholders are compatible with remote work, and 25-30% plan to work from home after the pandemic is over [5]. Potential negative consequences may result for employees' vision, sleep schedules, and electricity bills when they are working with suboptimal lighting throughout the day. A survey done by AJMC shows that 67% of people believed their sleep schedules were healthier before Covid19, 98% had developed new sleep problems, and 53% spent less time sleeping [6]. Electricity bills were also estimated to rise over 10%, which has added thousands of dollars to residents' utility bills. Digital eye strain is also an effect of Covid19, which is caused by harsh and uneven lighting when working on a computer. Because the average U.S. home has between ten to twelve windows, it is a safe assumption that people will try to work next to a window for natural lighting. However, window lighting is not always enough to brighten an entire room, and adding an additional light source can actually do more harm than good if it does not match the first light closely. Working from home is here to stay and we need to mitigate its adverse effects as soon as possible.

Our goal is to promote a healthier at-home lifestyle while conserving energy. We devised an ambient light system that will match a room's color and brightness to the light from the window at any given time. Our light is designed to evenly light up a room with the same intensity, reducing glare on monitors and shadows cast. It will also color correct itself until it finds the perfect match to the color temperature of outdoor lighting. These two features will undoubtedly decrease eye strain and improve one's circadian rhythm and sleep. Furthermore, we will use laser sensors to turn on and off the light for energy conservation.

1.2 Background

There are many different smart lights on the market, but most of them are promoting a more fashionable lifestyle and not a healthier one. The Philips Hue system of lighting is a perfect example of this, as they are themed lighting on timers with voice features. However, lights like these are very user-centered and require a lot of attention for maximal benefit, not to mention they are wifi-dependent and very pricey ($200 for four bulbs and the hub). No current smart light is able to perform ambient light matching and accurate color temperature matching over the range of an entire day, which is important for improving one's natural circadian rhythm. There is currently a gap in the market for a product that is health-geared and adaptive.

1.3 Physical Design

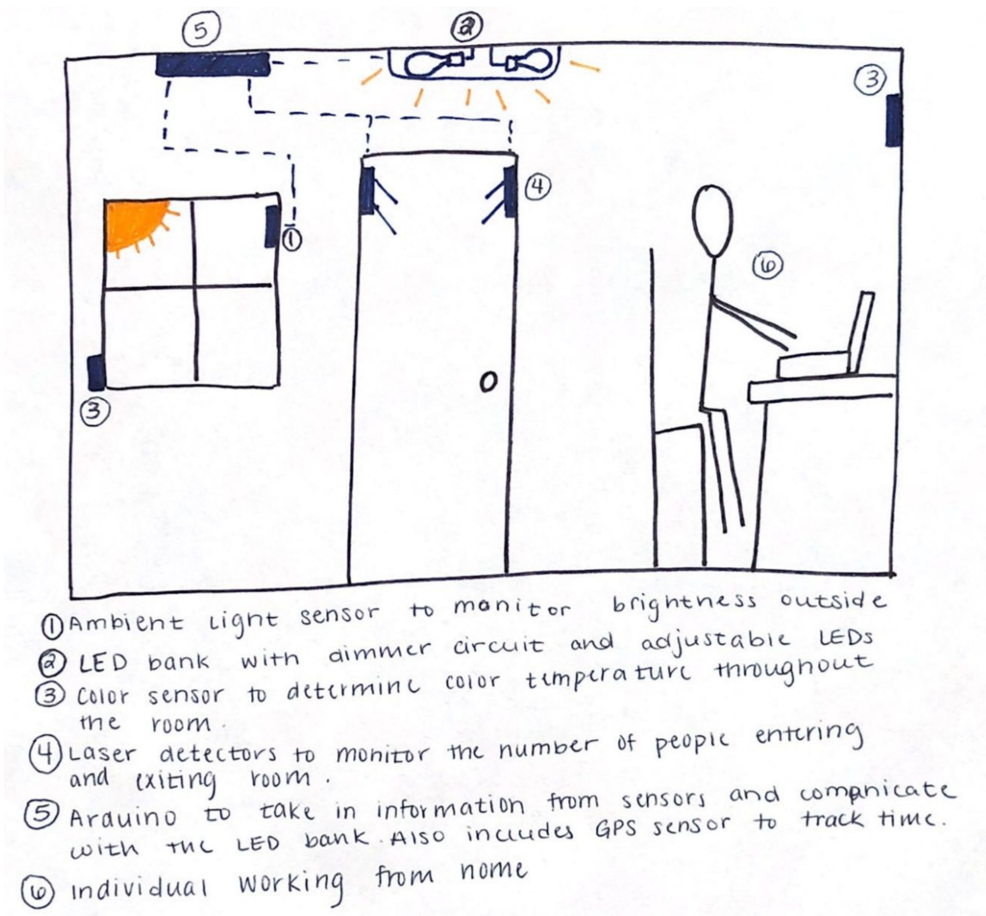

Figure 1: Representation of design with sub components

1.4 High-Level Requirements List

- Using a light sensor set near a window, the lights in a room will adjust the brightness and color to match the outdoor light. The color corrects to ensure that the light in the room matches the color temperature of the outdoor lighting.
- This system will adequately determine when the light in a room drops below a certain threshold and determine when the time is later than a preset "sunset" time. When one of these criteria is met then the yellow light will automatically turn on and adjust accordingly.
- This project will determine when an individual is entering and exiting a room, and based on the amount of light entering the room decide if additional light is required. When a person enters and lights are required, the system will turn on, and when the individual leaves the room the lights will automatically turn off.

2. Design

2.1 Block Diagram

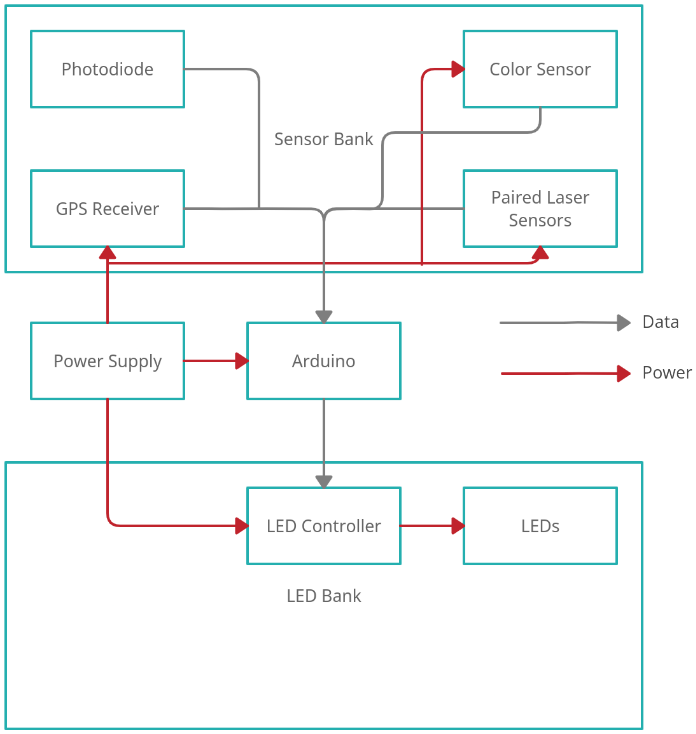

Figure 2: Block Diagram with project's modules and components

The design will be made up of a computational module that takes in information from the multitude of sensors in the sensor bank and calculates the best light settings. It will then send the information to the LED bank to adjust the lighting of the rooms accordingly.

2.2 Functional Overview

- **Sensor Bank:**
  The sensor bank will consist of four different sensors that will monitor various variables inside and outside. The sensors monitoring the outside will be a GPS receiver, a light-dependent resistor (LDR) sensor, and a color recognition sensor. These will sync up time, sense the outdoor lighting intensity, and assess the outdoor color temperature. The laser sensors inside will be used to detect the direction, and as a result, the location of individuals inside.

This module will need to interface with the outside and be connected to the arduino via a wired connection. The wired connection will also carry power as several of the external and internal sensors require power.

- **Arduino:**

An Arduino (Arduino Due) will take information from the Sensor Bank and calculate the best level and color of lighting. It will use information from the color sensor to calculate the color temperature of the outside and combine that with the resistance values from the LDR diode to relay the correct combination of LED controllers to mimic the outside correctly. The Arduino will also take in the time of day from the GPS sensor and use that to begin a late-night mode and morning mode that is set by the user. Data from pairs of laser sensors will be used to track the room location of people within the house and turn on and off the system to conserve power. The data lines will be handled by a wired connection.

- **LED Bank:**

An AC to DC power supply consisting of a rectifier and a current regulator will be constructed for our LED driver. We will also have a heatsink to dissipate heat from our LEDs. Resistance values from the Arduino will be fed into a PWM circuit through a digital potentiometer to adjust brightness.

We will implement two methods of color matching and decide which method is more efficient (cheaper, faster, smallest form factor, etc.). We will either choose from six LED color temperatures, 1000, 2700,3000,4000,5000,6000K, or we will use RGB LEDs and have separate PWM circuits for each leg. There are pros and cons to each method. The first method is able to produce accurate color temperatures, but at the cost of only having six settings. The second method can only approximate white light through RGB, but has more range. For both methods, after a certain sunset time, a 2700K light will be turned on at a set brightness to promote healthier nightlife. At a set bedtime, a 1000K red light will turn on to promote sleep and turn off at a predetermined time. The lights will turn on after reaching a certain light threshold the next day. We cannot use addressable LED protocol because scaling each RGB value does not accurately change brightness, and HSV has its own issues with brightness.

2.3 Block Requirements

- **Sensor Bank:**

Gives consistent readings operating at 5V from Arduino. Must be able to poll data every minute to accurately detect periods of cloudiness, abrupt weather changes, and time.

- **Arduino:**

  Takes sensor signals and output resistance values. Must be able to run python scripts to do color match from RGB values to compute color temperature if using the first method of color matching.

- **LED Bank:**

  Requires a LED driver that can connect to a 120 V outlet and drop it to a constant 12 V DC and minimum current that satisfies our LED ratings. The driver also requires a small but efficient heatsink that can fit inside a lightbulb form factor if possible. The PWM circuit should be current-controlled and able to dim the light from minimum to maximum brightness depending on resistance values from the Arduino. The Arduino must be able to accurately dim the RGB lights without flickering if using the second method. An issue with using PWM is that there is generated electromagnetic interference. To counter this we will try to implement an EMI filter.

2.4 Risk Analysis

A big obstacle for our project is the ease of LED burnout. We anticipate that we will be going through quite a few LEDs before we are able to design a proper power supply and regulator. We are also unsure of the accuracy of our LED's ability to mimic different color temperatures. Lastly, we need to consider how to fit all our components inside a standard lightbulb form factor to make our product real. This will be difficult given we will be designing sensors, drivers, and dimmer circuits ourselves that might be bigger than the industry standard.

3. Ethics and Safety

This project will uphold the "IEEE Code of Ethics" by creating a system that benefits society while ensuring that the safety and well-being of the public is the highest priority [1]. The system will follow the "ACM Code of Ethics" by disclosing all information to the public and ensuring that the consumer is aware of all risks associated with the product [2].

3.1 Privacy Concerns

One part of the IEEE Code of Ethics is to protect the privacy of the public [1]. This system may cause privacy concerns because of the fear an outside source may hack the lighting system. If an individual's home lighting system was compromised then the hacker would be able to turn on and off the lights at any point causing fear for the user's safety and privacy. This project goal is to ensure that situations like this will not occur and an outside source would not be able to access the entire lighting system.

3.2 LED Overheating Hazards

There is a safety issue regarding this problem in the event that the LED lights burn out and start a fire. While LEDs are much safer than the older more traditional light bulbs there is always the possibility of danger. This project deals with the major fire issues that are a concern with incandescent lighting because LEDs do not get as hot or produce heat [4]. Overall, this system will deal with overheating hazards by ensuring that the light system is turned off when not in use and using a proper heatsink.

3.3 Mental Well-being Concerns

Poor or incorrect lighting can cause anxiety, stress, and other mental health issues [3]. There is a concern that this system would increase these issues caused by bad lighting. This project is aiming to correct an individual's everyday light exposure and, through research on the topic, the system will be able to improve the overall health of the user. The lighting that will be used by the system has been researched and proven to improve people's moods and well-being.

3.4 Light Pollution Issues

Light pollution is a huge environmental issue that can also affect an individual's health. The impact of individual households adds to the issue of light pollution, and there is an ethical concern by creating a system that will cause excessive light pollution. While this project does add to the issue, it reduces the amount of pollution that a typical lighting system would emit. This is because our system will sense when additional lighting is necessary and dim or shut off the lights when they are not required.

References

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