UNIVERSITY OF ILLINOIS

Adaptive Lighting

Project Proposal

Jered Greenspan
Madhav Khanna
Sichao Wang

TA: Ryan May
Team 17
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1. Introduction

Motivation: Lighting accounts for a substantial portion of energy consumption in homes and offices worldwide. More importantly, a lot of artificial lighting in use is not necessary. In this project, we attempt to implement a system that will not only reduce energy consumed from lighting by using accurate occupancy sensing, but also provide a more pleasing lighting experience that will achieve one's desired lighting intensity and color.

Objectives:
We propose an adaptive lighting system that responds to the environment in determining the brightness, temperature, and color of light, using occupancy detection and current light levels. A light sensor unit will be set on a table or the area to be illuminated. These sensors will wirelessly transmit to a microcontroller which will control ceiling-mounted LEDs. The feedback from the sensors will keep the desired color and intensity at the area of interest, so that if there is sufficient sunlight, the LEDs need not consume as much power. Occupancy sensors will be mounted near the light and will only turn on the light when a person is detected in the area. We will demonstrate the device with two lights to show that it is adaptable to more fixtures.

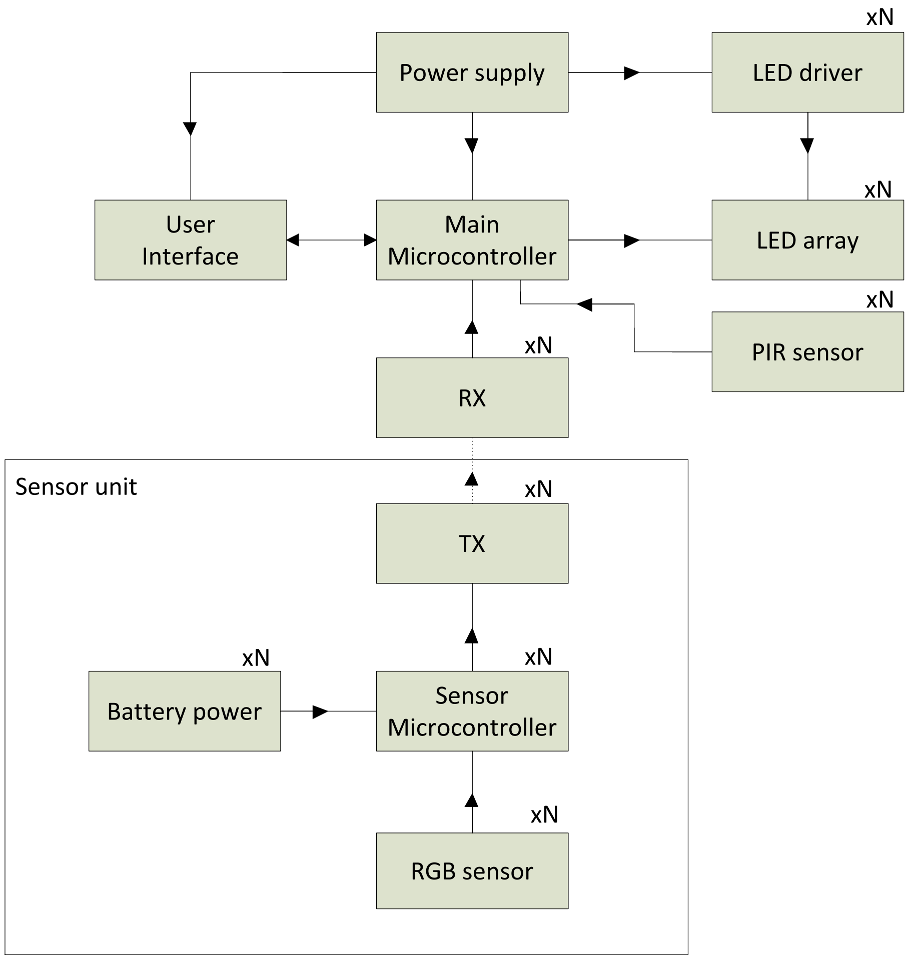
Benefits:

- Reduce lighting energy consumption
- Provide a more pleasing lighting experience (e.g. can replicate sunlight, or have warmer colors at night)

Features:

- User sets desired color by specifying RGB values, or selecting from preset color mixtures
- System accurately senses color intensity for the location, and the main controller adjusts intensities for color channels until the desired setpoint is detected.
- Occupancy sensors will be used to detect if a person is present in a section of the room to switch the light for that section.
- An accessible off switch for each major component.

2. Design



Note: Each block marked with 'xN' means that it will be replicated multiple times. For demonstration purposes, we plan to build 2 lighting and sensor units.

2.1. Block Descriptions

The light sensor unit consists of the RGB Sensor, Sensor Microcontroller, and Transmitter.

RGB sensor

This will be a three-channel photodiode for red, green, and blue frequency ranges. It will output a voltage corresponding to the incident power over each of the frequency ranges to the sensor microcontroller.

Sensor microcontroller
This controller will connect to the RGB sensor output and the transmitter. It will be used to send the sensor data wirelessly to the main controller after A/D conversion.

Receiver / Transmitter
The transmitter will connect to the sensor microcontroller and will transmit the sensor data to the receiver. This allows for the sensor to be placed in a convenient location. The communication link between the sensor and the main controller can tolerate a low delivery ratio for the system to operate properly, and the controller only needs to submit sensor data once per minute for proper functionality, though higher update frequency is preferred.

User interface
The interface will allow the user to select a setpoint intensity for the three color channels red, green, and blue. An LCD will display the value that the user has selected. There will be a four button navigation pad. This is the primary interaction of the user with the system.

Main microcontroller
This is the "brains" of the system. It receives sensor data from the light sensor, the user interface, and the PIR sensor. It will read the serial data from the receiver(s) and process it. It will also process the data from the PIR sensor in deciding whether a person is present. It will determine the PWM duty cycle for each of channels of the LED arrays.

LED array
We plan to use 10 RGB LED modules for each light, giving a total luminous flux of about 500 lumens. The LEDs will be driven by LED drivers

LED drivers
The LEDs will need to be current-limited. The PWM signal from the main microcontroller will connect to these drivers each capable of driving multiple LEDs. The light intensity will change slowly so as to not discomfort the user.

PIR sensor
This passive-infrared sensor will be used to detect the presence of a person in the area to be lit. It will be connected directly to pins on the main microcontroller. It will be mounted near the LED to detect a person from above. The PIR sensor should accurately detect the presence of a person in a particular section of the room.

Power Supply
The power supply will consist of AC to DC conversion to power the main microcontroller, the display for the user interface, and the LED driver circuitry.

Battery Power
This will power the light sensor unit, which includes the microcontroller and the transmitter.

Note that the LED lighting enclosure will be mounted together with the PIR occupancy sensor and the main microcontroller.

2.2. Performance Requirement:

- In a given day, the energy consumption of the device should not exceed the total savings due to decreased lighting use. The energy consumed by the entire system—including lighting—should be less than 80% of the energy usage without the system in place.
- The range between the transmitter and receiver should be at least 10ft.

3. Verification

3.1. Testing Procedures:

3.1.1. RGB Color Sensor Testing:

The first step of our testing procedure will be to determine how effectively our sensor is able to measure the light produced by our bulbs and whether the measurement of each of the three channels (i.e. Red, Green and Blue) are within the parameters required. We will take these measurements initially in a classroom during different times of the day and then to check for individual colors we will test the sensor with individual red, green and blue LED's.

3.1.2. Wireless Communication Testing

As we will be using RF chips we will need to check our range parameters to identify what is the ideal placement of all devices within the system. We will verify that serial data can be sent with from one microcontroller to another with the RF chips, by sending packets. We will then place the transmitter at various distances and locations and verify what percent of packets are not received.

3.1.3. User Interface Testing

We will also need to test our user interface and make sure the design we create is dynamic enough to incorporate any user needs. This will include testing our LCD screen and work around with user setting to see if the design is able to handle any and all user demands. First, we will test that we can send data from the microcontroller and it will display correctly on the LCD screen. Second, we will test that all button presses are received correctly (no bouncing). Once the code for the user interface is complete, we will see that the correct button presses lead to what we expect for the changes in outputs. The user should be able to change the red, green, and blue setpoints from 0 to 100% or select from predefined setpoints.

3.1.4. Occupancy Sensing Testing

As our system includes motion sensing technology we will have to evaluate our motion sensors and see whether it responds to movements. We will also have to take into account edge cases where there may be single occupancy in the room and set appropriate clock time so as to make this efficient and remove the need for continuously moving for the lights to remain on. We will test the performance by observing the percentage the sensor correctly detects a person.

3.2. Tolerance Analysis

The RGB light sensor is the most critical part of the system. For our system to behave properly, the RGB sensor needs to have a precision so that the lighting can closely track the desired illumination. We will test the light sensor against a commercial photometer for various color mixtures. We will test that the output we get from our sensor after analog to digital conversion should match that of a quality commercial meter with an error of less than 10% for the frequency spectrum of interest.

4. Cost and Schedule

4.1. Cost Analysis

4.1.1. Labor

Person	Rate	Hours	Total	Total x 2.5
Jered Greenspan	$35/hr.	200	$7000	$17,500
Madhav Khanna	$35/hr.	200	$7000	$17,500
Sichao Wang	$35/hr.	200	$7000	$17,500
			Total	$52,500

4.1.2. Parts

Part	Unit cost($)	Quantity	Cost
RGB photodiode	8.80	2	17.60
RF transmitter	3.95	2	3.95
RF receiver	4.95	2	4.95
PIR sensor	2.71	2	5.42
Power supply	40	1	40
LED drivers	15	1	15
LEDs/Lenses/enclosures	60	1	60
LCD display	20	1	20
Sensor microcontroller	5	2	10
Main microcontroller	15	1	15
		Total	$200.82

Grand Total = Labor + Parts = $52,690.82

4.2. Schedule

6-Feb	Finish proposal	All
	Design control system logic	Jered
	Search for LED parts	Madhav
	Design LED driver circuit	Sichao
13-Feb	Prepare for design review	All
	Simulate the control algorithm	Madhav
	Select microcontrollers	Sichao
	Order parts	Jered
20-Feb	**Design Review**	
	Finalize and order parts	Jered
	Test RGB sensor	Sichao
	Build LED driver circuit	Madhav
27-Feb	Test RF link between two microcontrollers	Jered
	Program microcontroller to control LED dimming and color mixing	Sichao
	Build simple user interface	Madhav
5-Mar	Test PIR sensor	Jered
	Program control system on microcontroller, test with a simulated system	Sichao
	Test interface between components	Madhav
12-Mar	Test user interface	Jered
	Build second sensor unit and light	Sichao
	Integrate all system components	Jered, Madhav
19-Mar	**Spring break**	
26-Mar	**Mock-Up Demo**	
	Prepare for mock-up presentation	Madhav
	Integrate second sensor unit and light	Jered
	Calibrate overall system	Sichao
2-Apr	**Mock-Up presentations**	
	Test motion detection performance	Madhav
	Test color mixing performance	Sichao
	Measure energy savings	Jered
9-Apr	Prepare for final demo	Sichao
	Begin writing written report	Jered, Madhav
16-Apr	Prepare for final demo	Madhav
	Continue writing written report	Jered, Sichao
23-Apr	**Final Demo**	
	Prepare a final presentation	All
	Finish written report	All
30-Apr	**Presentation**	