MODULAR AUTONOMOUS HOME LIGHT

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Project Proposal for ECE 445, Senior Design, Spring 2020

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13 February 2020

Project No. 52

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1. Introduction

1.1 Objective

Currently, there is no cheap, modular solution for autonomous lighting that can be used with older buildings without having to open up the walls and rewire the internal circuitry. We propose a solution which can be implemented on manual light switches to automatically turn off and on lights without needing to rewire a building's circuitry. This way, typical individuals and families can afford to have autonomous lighting installed without needing to hire an electrician to install motion sensors.

1.2 Background

In the bustle of everyday life, it is often easy to forget to turn off the lights. Energy and money are wasted when lights are left on. On average, a household uses $200 a year for electricity on lighting, not including the cost of bulbs used overtime. [1] Some modern buildings have motion detectors installed which are connected to a room's circuitry and can shut off the lights and power in a room when no one is occupying it. However, for older buildings, this requires hiring an electrician and rewiring the circuitry. There are modular solutions. However, they are very expensive, have a lacking user experience, and are inaccurate. These are all barriers for the typical family who wants to save on lights and be conscious of their environmental impact.

In addition, current solutions for occupancy detection which focus on full room motion detection, there is a significant failure rate for still occupants. Therefore, we aim to implement our occupancy detection using a sensor unit focused on the entrance to detect as people enter and leave the room instead of the motion in the entire room. The sensor unit will communicate with a central computing unit through Bluetooth. After an entry is detected, the computer will increment its count by one. When someone leaves, the device will count down one. At zero, the device will know that there are currently no occupants in the room.

1.3 Physical Design

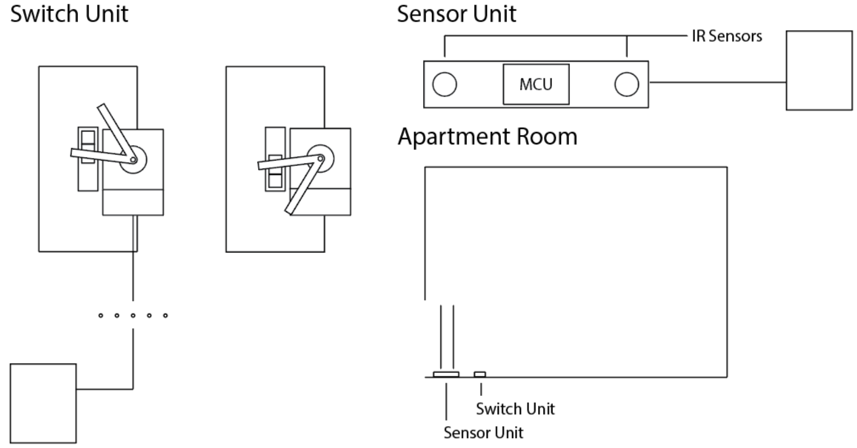

Figure 1: Physical Design

On the left side of figure 1, we can see the switch unit and the design of how the motor will turn the switch on and off. On the top right of the figure is the sensor unit design. There are two infrared sensors on each side so the system will be able to figure out if the person left or entered the room based on which sensor triggers first. The placement of the sensor can be seen in the lower right side of the figure. The gap represents the door and the sensor unit will be placed near the door in order to detect people.

1.4 High Level Requirements List

- Both infrared sensors need to be able to detect people entering and leaving the room and send that signal to the main microcontroller, so the microcontroller can correctly send that Bluetooth signal to the mechanical component.
- The mechanical component must be able to receive the correct Bluetooth signal from the main microcontroller, and the servo motor must be able to have enough force to flip the switch.
- The phone must be able to communicate with the Wi-Fi module, so the main microcontroller can send the Bluetooth signal to the mechanical unit to flip the switch.

2. Design

2.1 Block Diagram

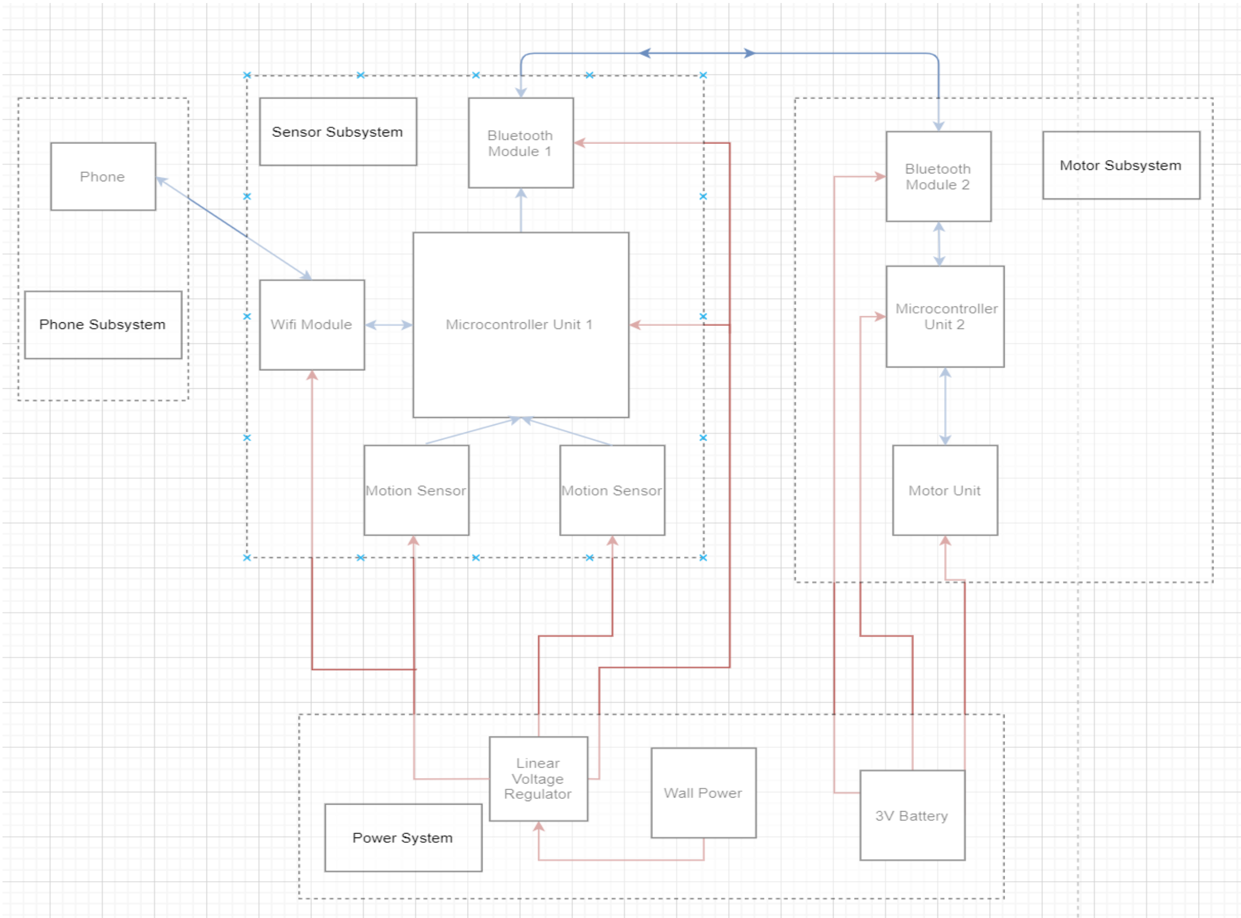

Figure 2: Block Diagram

Our block diagram has 4 subsystems - the phone subsystem, the power system, the sensor subsystem, and the motor subsystem. The power subsystem's job is to power up all the components of the other subsystems, except for the phone subsystem. There are 2 motion sensors that will be able to detect people entering or leaving and give that information to the Microcontroller Unit 1, which will then send a switch command to the Bluetooth Module 2 via Bluetooth Module 1. The motor subsystem will then flip the switch based on that information. The phone subsystem also can give commands to the Microcontroller Unit 1, which then will send a switch command to the motor subsystem. All of these subsystems are needed to fulfill our high-level requirements.

2.2 Functional Overview

Motion Sensor:
We will be using a HC-SR501 PIR Sensor. A PIR sensor is designed to detect infrared radiation. All objects with a temperature above Absolute Zero emit heat energy in the form of infrared radiation, including human bodies. The hotter an object is, the more radiation it emits. The responsibility of this sensor will be to track people entering and leaving the room.

Battery (1.5V per battery):
To power our motor subsystem we will be using 2 AA batteries for the motor subsystem. These two batteries will be put in series so we can have a total of 3 V and 2400 mAh.

Servo Motor:
A servo contains a small DC motor which is connected to the output shaft through gears. The output shaft drives a servo arm that is also connected to a potentiometer. The potentiometer provides position feedback to the servo control unit where the current position of the motor is compared to the target position. Then depending on the amount of error, the control unit corrects the actual position of the motor so that it matches the target position. This servo motor in conjunction with additional mechanical fixtures will be what turns the switch on and off.

Wi-Fi Module:
We will be using the ESP8266 Wi-Fi module. This Wi-Fi module allows you to connect to your Wi-Fi network, connect to the Internet, host a web server with real web pages, and it allows your smartphone to connect to it. Microcontroller unit will send motion sensor data to the Wi-Fi module and then the Wi-Fi module will transmit that data to the mobile application. The Wi-Fi module will also take in data from the mobile phone app which will allow the user to turn the lights on and off.

Microcontroller:
A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. In our block diagram we have two microcontrollers. The first one is used to process data from the motion sensors and send that data to the Bluetooth module which then transmit that data to another Bluetooth module. This Bluetooth module then sends that data to our second microcontroller which is responsible for controlling the servo motor. The first microcontroller unit will send motion sensor data to the Wi-Fi module which will then send that data to our mobile phone.

Bluetooth Module:
We will be using the HC-05 module which uses a Bluetooth Serial Port Protocol which is designed for wireless serial connection setup. The Bluetooth module will be responsible for communication between the sensor subsystem and the motor subsystem.

Linear Voltage Regulator: We are using a L7805 voltage regulator. Our sensor subsystem will be powered from a wall outlet so the linear voltage regulator will make sure only 5V is outputted to our sensor subsystem.

Phone
The mobile app that we create will allow users to track the occupancy levels of people in the room. From the phone, users can also turn on and off the lights.

2.3 Block Requirements

3V Battery:
These batteries should be able to supply a steady amount of power to power our mechanical component.

Wi-Fi Module:
This module should allow us to connect to Wi-Fi in order to communicate motion sensor information to the mobile application. The Wi-Fi Module should also be able to receive messages from the mobile application and send that back to Microcontroller Unit 1.

Bluetooth Module 1:
This module should be able to take in information from Microcontroller Unit 1 and send that information over Bluetooth to Bluetooth Module 2.

Motion Sensor 2x:
This module should allow us to detect whether people are leaving or entering the room.

Microcontroller Unit 1:
This module should allow us to process in the motion sensor data and communicate to both the Wi-Fi Module and Bluetooth Module 1.

Microcontroller Unit 2:
This module should be able to take in information from Bluetooth Module 2 and from that information control the Servo Motor.

Bluetooth Module 2:
This module will receive information over Bluetooth from Bluetooth Module 1 and transfer that information to Microcontroller Unit 2.

Linear Voltage Regulator:
This module should be able to take the voltage output from the wall outlet and output a stable 5V.

Wall Power:
This block should output a steady voltage to power our sensor subsystem.

Servo Motor:
This block should be able to rotate depending on whatever direction the Microcontroller Unit 2 dictates in order to turn on/off the light

Phone:
Our mobile application should be able to receive motion sensor data from the Wi-Fi Module and send turn off/turn on commands to the Wi-Fi Module

2.4 Risk Analysis

The block that poses the greatest risk to the completion of the project is the sensor unit. Most occupancy detection units operate by continuously checking for motion in a given space. However, our occupancy detector will focus on tracking movement at the entrance to the room. It will assume that a room will always be occupied once someone enters the room until it detects someone exiting the room again. If they don't leave, the lights will remain on regardless of how still the occupant is. In addition, this unit is the core of our project. If it doesn't work reliably, it will really undermine our project's value.

3. Ethics and Safety

Regarding ethics and safety, we have identified a few potential ethics and safety risks. The first safety concern is the location of the PCB. Being an electrical device that will be present in rooms, there is a chance that the pcb could fry and users could harm themselves. In order to protect against this, we must ensure that there are adequate protections against electrostatic discharge.

In addition, due to the multisystem aspect of our project, there are privacy considerations regarding the communication protocols between subsystems that we need to address in order to follow ACM's General Ethics Principles 1.6. For connection between the sensor and switch units, information is sent and received using Bluetooth. Steps should be taken to ensure that the Bluetooth unit cannot be eavesdropped on or be taken control of by a third party. Otherwise, they will have access to information on the comings and goings of people in their own homes. They would also be able to take control of the lights controlled by the switch unit. [2]

For collaboration during the project, our group will adhere to IEEE Code of Ethics Rule 7: we will make sure throughout the entire design process that we will always seek honest feedback from one another. [3] In addition, being a project related to energy efficiency. Our project is following the ACM General Ethics Principle 1.1, which is to contribute to humanity and well-being, by helping the environment. [4]

References

[1] "How Much Money Can You Save by Turning Off the Lights?," Mr. Electric. [Online]. Available: https://mrelectric.com/blog/turn-off-lights-save-money. [Accessed: 14-Feb-2020].

[2] Mdpi.com. (2020). [online] Available at: https://www.mdpi.com/1999-5903/11/9/194/pdf [Accessed 14 Feb. 2020].

[3] "IEEE Code of Ethics," IEEE. [Online]. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 14-Feb-2020].

[4] "The Code affirms an obligation of computing professionals to use their skills for the benefit of society.," Code of Ethics. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 14-Feb-2020]