ECE 445

Fall 2023

Senior Design Project Proposal

Smart Availability Indicator for ECEB Study Rooms

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1. Introduction

1.1 Problem

The Electrical and Computer Engineering Building (ECEB) offers a limited number of study and discussion rooms across its five floors, which prove invaluable for students aiming to collaborate on assignments, prepare for exams, or engage in general study sessions. There is currently no system in place to identify vacant rooms and as a result, each day students tirelessly go back and forth, scouring each floor in hopes of finding an empty study room. Worse still, there are also many students who travel all the way to the ECEB only to discover that all rooms are occupied forcing them to then seek alternatives in different buildings.

1.2 Solution

Our proposal presents a solution aimed at enabling students to easily and conveniently check room availability via a website. We plan to implement a system that will replace the existing motion sensor and automation infrastructure. Our proposed system not only retains the current capabilities of automatically controlling room lighting based on occupancy and adjusting brightness levels but will also seamlessly transmit real-time occupancy data to a central server using Wi-Fi, allowing students to conveniently view room availability information from their smartphones or laptops on a website anytime/anywhere.

1.3 Visual Aid

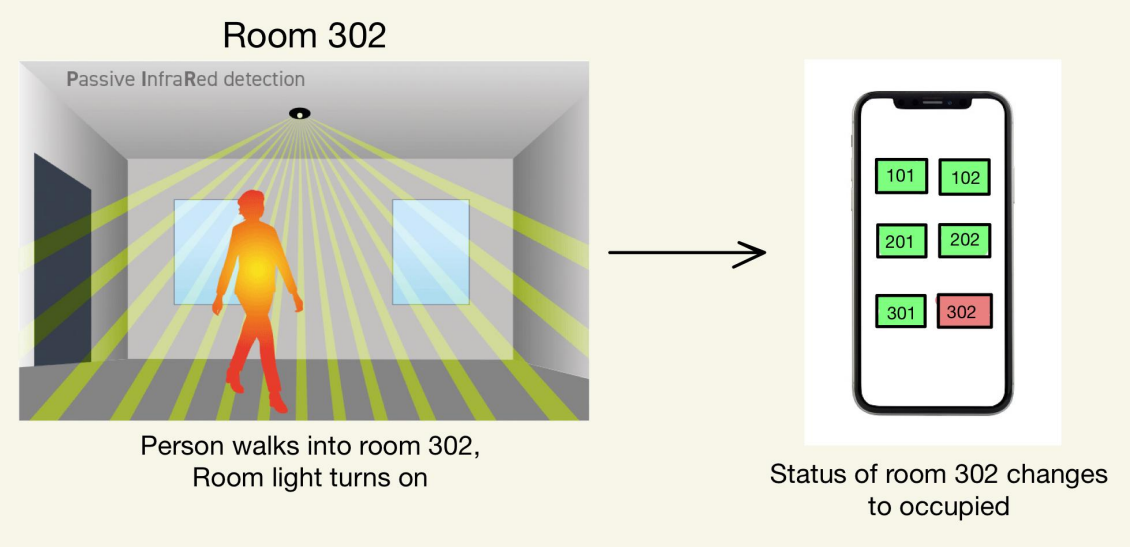

Figure 1: High-level illustration of our project [1][2]

1.4 High-Level requirements

- The lighting system should activate within 2 seconds (±1 sec) upon detecting the presence of a user in the room. The light should turn off automatically after a five-minute period when the user leaves the room.
- User should be able to adjust the light's brightness from dim to its maximum intensity using a dial/slider. (Demonstrable by displaying three distinct brightness levels: dim, intermediate, and bright.)
- Any changes in room availability should be reflected on the webpage within 10 seconds.

2. Design

2.1 Block Diagram

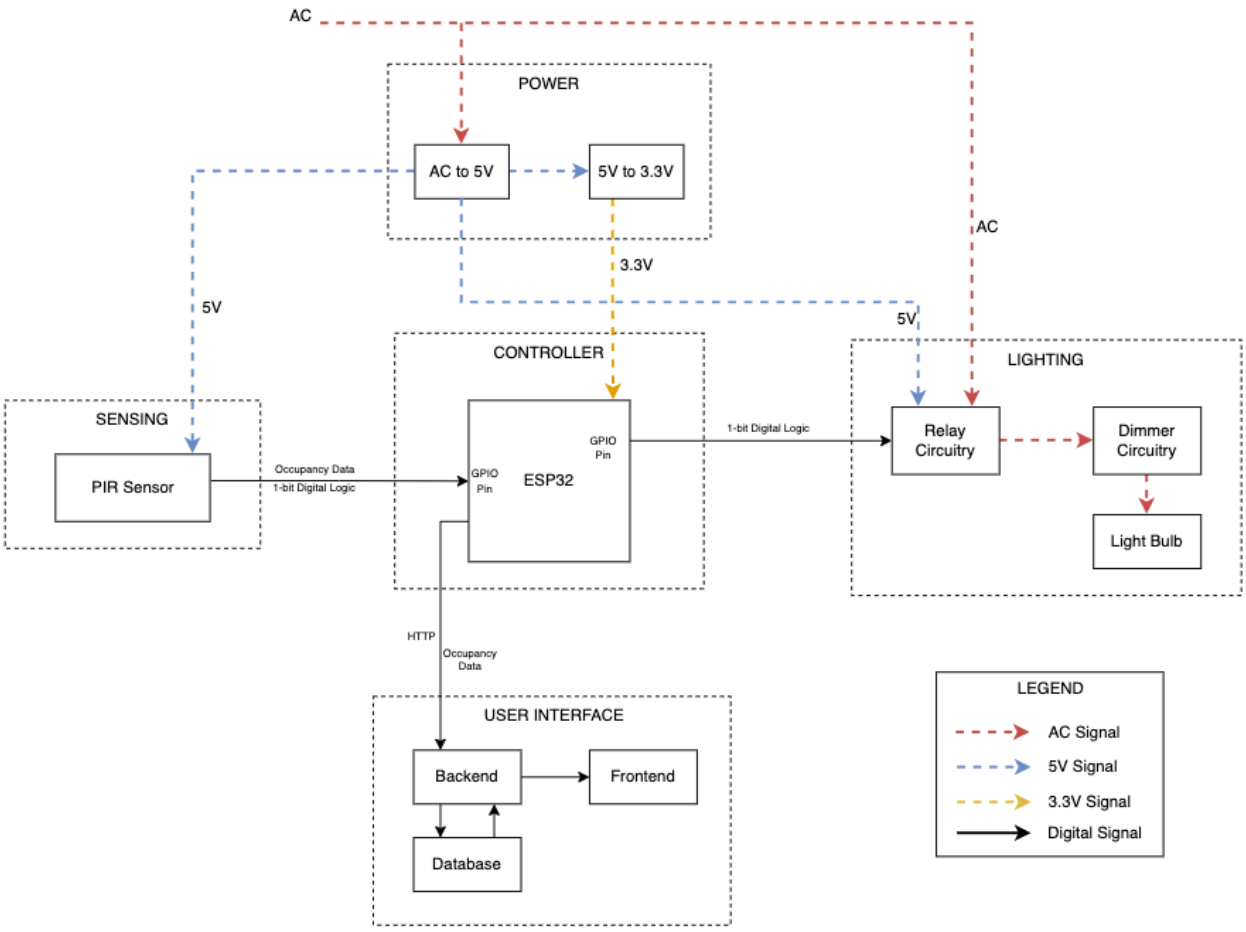

Figure 2: Block diagram depicting interactions between modules

2.2 Subsystem Overview & Requirements

- Power
    - This subsystem powers the hardware subsystems of this project (Sensing, Controller, Lighting). For the prototype, the system will be powered by an AC power outlet. The power subsystem will use an AC-DC buck to create a 5V rail. The 5 V output will then be inputted to another buck to create a 3.3 V rail. The 5 V and 3.3 V rails will be used to power various components such as the ESP 32 and PIR Sensor. Additionally, the submodule will route AC supply to the Lighting submodule to power the Light Bulb
    - Requirements:
        - AC-DC Buck should be able to output 5 V (±0.3V).
        - 5V-3.3V converter should be able to output 3.3 V (±0.3V).
- Sensing
    - The sensing sub-system is responsible for determining room availability. It makes use of a PIR sensor to detect changes in heat energy emitted by humans. When a human is detected, the PIR sensor will send a 3.3 V Digital Pulse to a GPIO Pin on the ESP-32
    - Requirements:
        - The sensor should output 0 V when there is no human present
        - The sensor should output 3.3 V (±0.3V) digital pulse when a human is detected
- Controller
    - The ESP 32 microcontroller receives availability status data from the PIR Sensor. It will then send a 3.3 V/0V Digital Logic signal to the Lighting submodule to toggle the light. It will also update availability information on a database using HTTP
    - Requirements:
        - Upon receiving 3.3 V pulse from the PIR sensor, the ESP32 should output a 3.3V digital signal to the relay to turn on the light for 5 minutes
        - After not receiving a pulse for 5 minutes, the ESP32 should output a 0 V digital signal to the relay to turn the light off

- Lighting
    - This submodule is responsible for turning on/off the lightbulb and allowing the user to adjust its brightness using a potentiometer. The potentiometer value is read by the GPIO pin of the ESP32, which subsequently sends a 1-bit digital signal back to the lighting module. When this signal is received by the Diac in the lighting module, power is supplied to the lightbulb until the zero-crossing of the alternating current. By increasing the potentiometer value, the microcontroller could be told to send the signal at an earlier phase in the current wave, thereby supplying more power to the bulb and making it shine brighter.

    - Requirements:
        - Tuning the Potentiometer modifies the duty cycle of the output leading to the lightbulb from low to high

- User Interface
    - This subsystem consists of an online server with a database and a website that presents this data to the user. The ESP32 will post occupancy data via the HTTP Protocol to the website's backend. This data would be in the form of a tuple with the first element being the room number and the second being whether the room is occupied or not. The backend will then store this data in the online database. Lastly, the backend will pass this information onto the frontend section of the website which will format the occupancy data for the user to view.

    - Requirements:
        - Once information is posted to the backend by the microcontroller, the change should be reflected in the frontend within 10 seconds.

2.3 Tolerance Analysis

One aspect of our design that could pose a risk to successful completion of our project is the PIR sensor. Our PIR sensors have a field-of-view of approximately 120 degrees. This could lead to movement in the corners of the room being undetected.

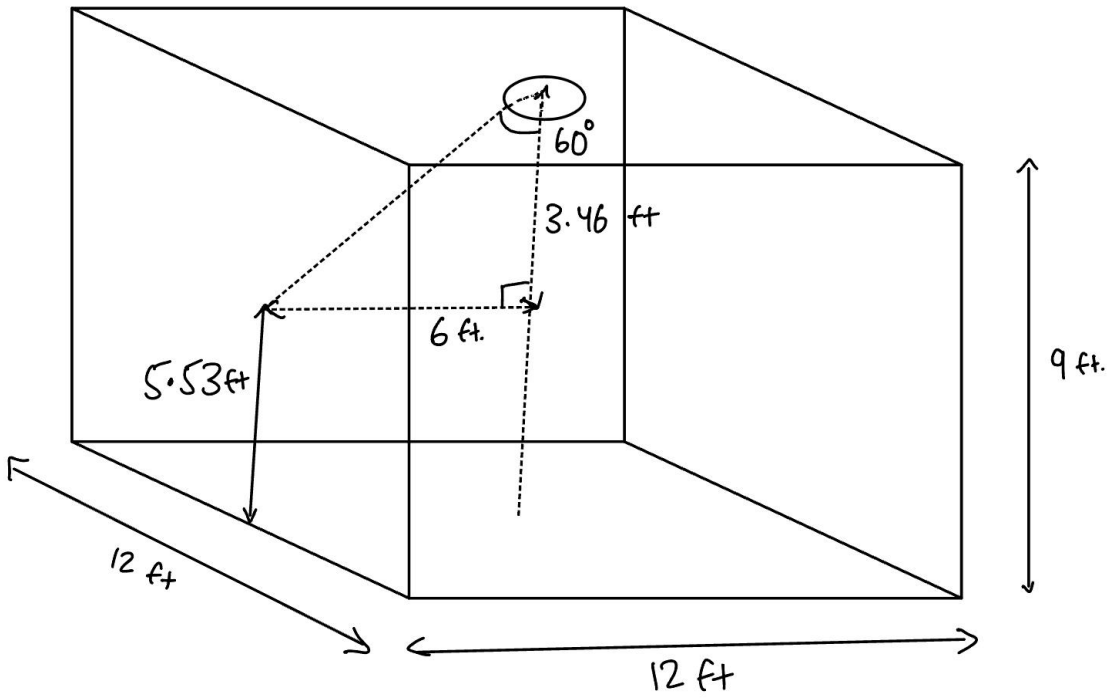

Figure 3: Cone of view of the PIR sensor in an average study room

The approximate dimensions of the ECEB study rooms are indicated in the diagram above. The field of view of the sensor can be depicted as a cone of angle 120 degrees (and height 3-7 meters). The edge of the room is a horizontal distance of 6 feet away from the sensor. We can then calculate the height at which the beam intersects with the wall (= 6ft / tan(60) = 3.46 ft). Thus we know that the sensor will detect movement even at the edge of the room below a height 9 - 3.46 = 5.53 ft. This height should be sufficient to detect movement by most individuals in all corners of the room.

Additionally, we suspect that the dimmer circuitry portion of our project poses the greatest risk, largely because neither of us have worked with this hardware before. Varying current to the bulb using a series resistor (rheostat, potentiometer) leads to far too much energy loss. Ideally there would be zero energy loss, but an acceptable loss would be if we are able to integrate a Triac Switch in our design.

3. Ethics and Safety

On the surface, our project does not seem to present an ethical problem. However, a problem could arise if this project were expanded to be more accurate using computer vision. This would violate the privacy of the individuals using the study room (taken from the IEEE Code of Ethics [3]). Hence, we will focus our efforts into making the PIR sensing system as accurate as possible. Additionally, this system should easily integrate with the existing power lines in the ECEB study and not pose a risk (electrocution, fire) to the users in the case of failure. Lastly, all team members will be undergoing High-Voltage Training so we will be adequately trained to handle the 110V coming from the main power line.

4. References

[1] Pippa, “Pir Vs microwave sensors: Which do you need?,” Green Lighting, https://greenlighting.co.uk/pir-vs-microwave-sensors-need/ (accessed Sep. 14, 2023).

[2] Bombuscreative, “The new Apple iPhone X Silver Color 256GB model with white blank...,” iStock, https://www.istockphoto.com/photo/apple-iphone-x-silver-white-blank-screen-gm892510910-247013254 (accessed Sep. 14, 2023).

[3] “IEEE code of Ethics,” IEEE, https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Sep. 14, 2023).