

Occupancy Counter

ECE 445 Design Document

Team #73

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Introduction

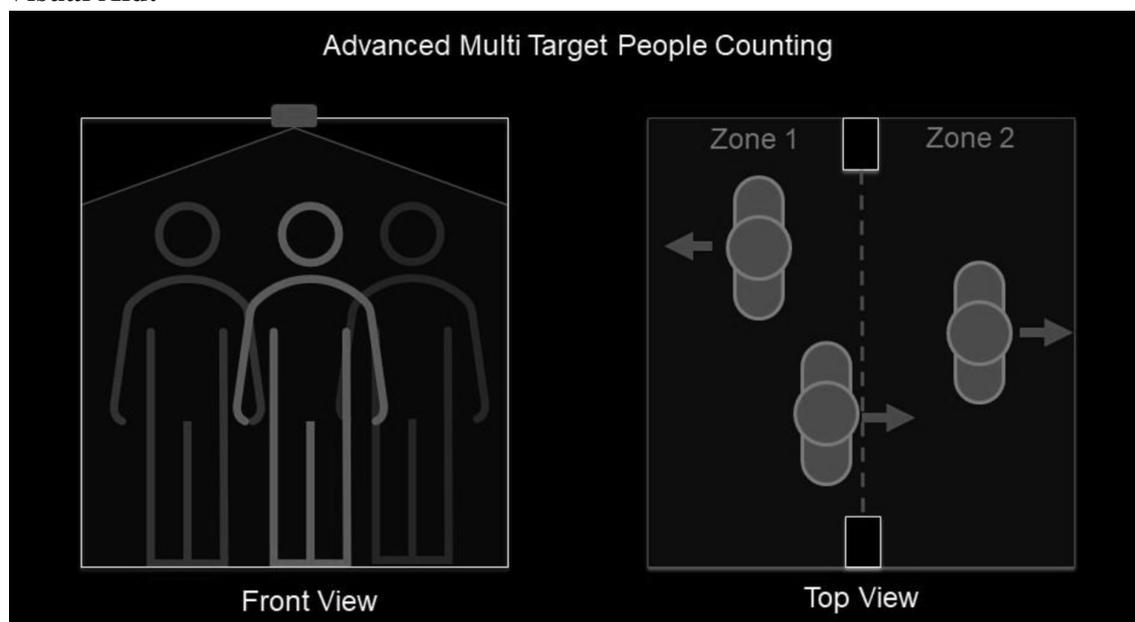
Problem:

In large building environments, managing energy consumption efficiently, particularly for heating, ventilation, and air conditioning (HVAC) systems, presents a significant challenge. HVAC systems often operate on a fixed schedule, with little regard for the actual occupancy of a space, leading to unnecessary energy use and increased operational costs. This inefficiency is especially pronounced in spaces like offices or small meeting rooms due to constant movement. The motivation for the occupancy counter project is to enable more intelligent and adaptive HVAC control by accurately tracking the number of people in a given space. Our experience in the ECE391 Lab (ECEB3026) was a perfect example of HVAC not recognizing the amount of students working late in the lab, with temperature fluctuating constantly. By aligning HVAC operations with real-time occupancy levels, this technology aims to significantly reduce energy consumption and operational costs for large buildings. Achieving precise occupancy counts allows for the HVAC system to adapt its output to the current need, ensuring that energy is not wasted heating, cooling, or ventilating spaces that are not in use or are only partially occupied. Additionally, this system supports a more sustainable approach to building management by reducing the carbon footprint associated with unnecessary energy use.

Solution:

Our project is an occupancy counter for rooms. It will utilize [a] Time of Flight Sensor Module(s) for the recognition of room occupants, where we will either use one module, splitting between two zones, or use two modules in order to determine whether the target is entering or exiting the room. The brains behind the sensor will be a WiFi-enabled Arduino Board that will decide the direction of the person's transit, keeping track of how many people are present in the room. It will update a web interface that can be connected to by any user. The whole device will be powered by USB power brick(s).

Visual Aid:

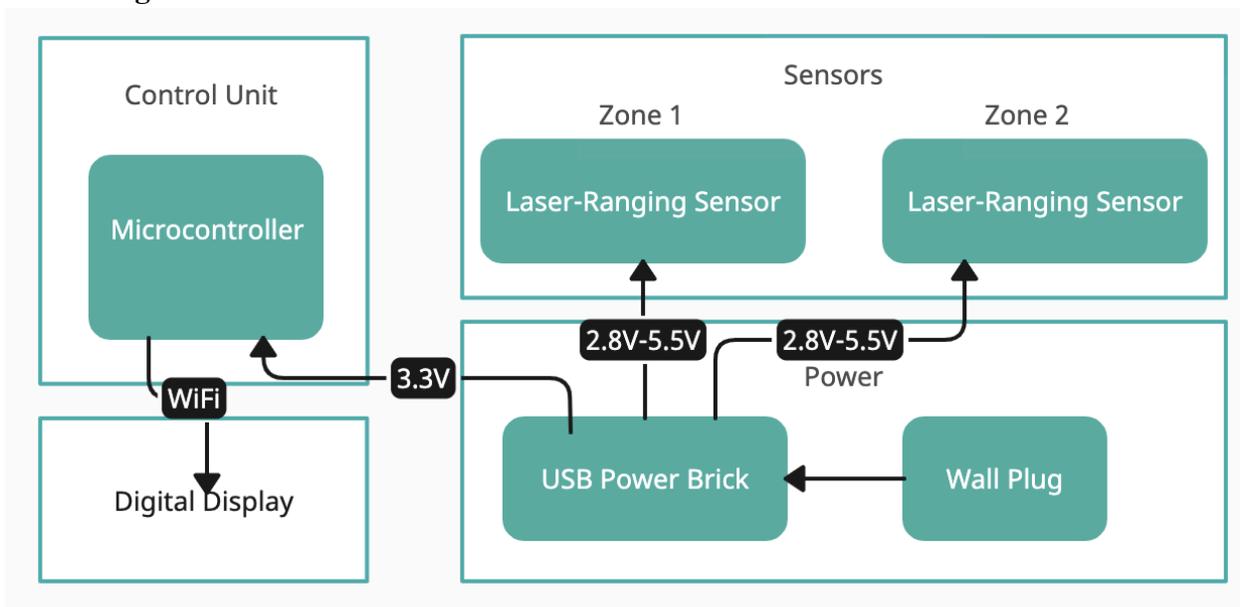


High-Level Requirements:

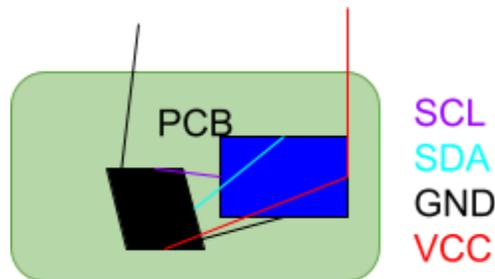
1. Exactness/error of count: the count must be exact for up to six occupants, and correct within plus/minus of one person for up to twelve. Since this project is being used as a dependency for a much bigger system, precision and accuracy are important.
2. The actual display should update between two to ten times per minute. This is to ensure that our count is considered live and makes an impact on the energy-saving and HVAC procedures that will ensue.
3. Output data will be transferred via a wireless (WiFi) connection to a display. The sensor we are using has a built-in web interface that can be enabled during setup which will allow for universal access for users of the project.

Design

Block Diagram:



Physical Design:



Control Unit Subsystem:

Description:

“The ESP8266 is a high-performance wireless SOC that offers maximum utility at the lowest cost and unlimited possibilities for embedding WiFi functionality into other systems.” This

module will be the brain and mouth of our project, where data received will be broken down into a few key components, calculated, and sent out as a summary. The data will be analyzed to decide whether the target is moving from Zone 1 to Zone 2 or conversely. From there, the brain will add or subtract to the room count. Once this is complete, the data will be beamed via WiFi to a digital display (monitor, tablet, phone).

Requirements	Verification
<p>The ESP8266 should maintain an accurate count of how many people are in the room. The count must be exact for up to six occupants, and correct within plus/minus of one person for up to twelve.</p>	<ul style="list-style-type: none"> ● Simulate movements between zone 1 and 2 and verify that the room count adjusts accordingly ● Test edge cases such as rapid movements or simultaneous movements from multiple targets
<p>Data summaries must be transmitted over WiFi to a digital display device. The actual display should update between two to ten times per minute.</p>	<ul style="list-style-type: none"> ● Ensure reliable and secure data transmission ● Test the stability and speed of WiFi transmission under various network conditions ● Conduct stress tests to ensure system can handle a high volume of data transmissions

Sensor Subsystem:

Description:

“The VL53L1X is a state-of-the-art, Time-of-Flight (ToF), laser-ranging sensor, enhancing the ST FlightSense™ product family. It is the fastest miniature ToF sensor on the market with accuracy ranging up to 4 m and fast ranging frequency up to 50 Hz.” This module acts as the eyes for our project, where the timing of a person crossing the tracked region will be acted upon using a state machine to see the current status.

Requirements	Verification
<p>The VL53L1X sensor must accurately detect individuals within a range of up to 4 meters, catering to small to medium-sized rooms. The detection error has to be minimal to ensure precision</p>	<p>We will conduct field tests to test out the sensor's detection range and accuracy, by having individuals moving at different speeds and distances up to 4 meters to verify the sensor's performance.</p>
<p>The sensor needs to be able to accurately capture a fast ranging frequency of up to 50</p>	<p>We will simulate scenarios where individuals cross the detection zone rapidly, and measure</p>

Hz.	sensor response time to see if it satisfies the 50 Hz requirement
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Power Subsystem:

Description:

We will use a USB-enabled power brick to provide power to the modules and connect it through a slim and long USB cable. The power for the VL53L1X will be between 2.8V to 5.5V, with the voltage properly regulated by the sensor carrier board while the power for the ESP8266 will be a standard 3.3V input, both powered by DC current. This is arguably the simplest but most important part of the build, as the power must be supplied to both the sensors and the control unit in order for working functionality of the project.

Requirements	Verification
The sensor carrier board must regulate the voltage supplied to the VL53L1X sensor within the specified range (2.8V to 5.5V).	<ul style="list-style-type: none"> ● Measure the voltage output of the sensor carrier board to ensure it falls within the specified range for the VL53L1X sensor. ● Verify that the ESP8266 module receives an average of around 3.3V input voltage. ● Test the voltage regulation circuit under different load conditions to ensure stability and reliability.
Ensure the USB cable provides reliable power transmission without any significant voltage drops/interruptions.	<ul style="list-style-type: none"> ● Inspect the USB cable for any physical damage or defects before permanent installation. ● Test the cable for continuity and proper power transmission. ● Perform stress tests by bending and flexing the cable to see if it has the proper durability and longevity.

Tolerance Analysis:

We will be focusing on sensor accuracy tolerance analysis since if our sensor accuracy degrades, our entire project fails.

Time of Flight Sensor with Voltage Regulator Board

- Accuracy: +/- 25mm
- Maximum range: 4m

- Input voltage range for the board: 2.6V to 5.5V
- Board includes a 2.8V linear regulator

We'll assume a general tolerance for the linear regulator of about 1%, which is a common value for precision regulators, although the exact value would be in the sensor's datasheet.

Voltage Output Lower Limit = $2.8V - (2.8V \times 1\%)$

Voltage Output Upper Limit = $2.8V + (2.8 \times 1\%)$

This will help us understand if the provided voltage stays within the operational range of the sensor, ensuring accuracy.

Assuming the output voltage range of the sensor's built-in linear regulator is 2.8V, with a 1% tolerance, this is between 2.772V and 2.828V. This is well within the sensor's operational voltage range of 2.6V to 5.5V, indicating that even with the maximum expected tolerance of the voltage regulator, the sensor should operate correctly and maintain its accuracy.

Worst-case error = Accuracy + (Accuracy \times Regulator Tolerance)

Worst-case error = 25mm + (25mm \times 1%)

This will give us the worst-case error at the lower and upper voltage limits provided by the regulator. The worst-case error for the sensor, with a 1% voltage regulator tolerance, would be 25.25mm. This is slightly better than the previous general analysis and remains within the specified accuracy tolerance of +/- 25mm for distances up to 4m.

We do recognize that this analysis assumes a direct correlation between the voltage regulator's output tolerance and sensor accuracy. In practice, the sensor's accuracy might not degrade linearly with voltage, and other factors like temperature, target reflectivity, and ambient light conditions could also impact accuracy.

Cost

Cost Analysis:

Wi-Fi Enabled Chip - \$5.12 USD

ToF Sensor - \$2.78 USD

PCB and wires - provided, estimated <\$10 USD

Discussion of Ethics and Safety

Ethics:

With this project, we aim to mitigate potential ethical and safety concerns that could arise. We are improving the effectiveness of safety standards, which corresponds to IEEE's Code of Ethics Section I.1, which is "to hold paramount the safety, health, and welfare of the public...". The data obtained through this project is to be processed externally while scanning for people both entering and exiting an environment. It is important to respect the privacy of individuals and

their whereabouts, as IEEE's Code of Ethics Section I.1 mentions how crucial it is, "to protect the privacy of others...". Our device will detect people who enter or exit a room but will not store or scan any information that could pose any harm to anyone. In order to sustain our functionality while abiding by IEEE's Code of Ethics Section I.3, which is "to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist, we decided that this was the best course of action".

Safety:

As always, safety is a very critical aspect that our group will consider, so that we can protect everyone's wellbeing and work smoothly towards a successful and meaningful project. This project involves the use of electronic components such as the ESP8266 module and the VL53L1X sensor, so we have to keep in mind electrical safety. All of our connections should be properly insulated to prevent short circuits or electrical shocks. We will be sure to pay careful attention to the USB power bricks and cables to ensure they meet safety standards and regulations. Moreover, our team will be cautious when handling live circuits and power sources. While the project primarily deals with low-voltage components, there is still a risk of fire if components are faulty or improperly connected. To mitigate this risk, all components should be checked for proper functioning before installation, and connections should be securely made to prevent overheating or arcing. Moreover, fire extinguishing equipment should be readily available in the event of an electrical fire.

During the installation of the occupancy counter system, care should be taken to ensure that mounting brackets or fixtures do not compromise the structural integrity of the building. Heavy-duty adhesive tapes or non-destructive mounting methods should be considered to avoid damage to walls or ceilings. Regular inspections of the installation site should be conducted to detect any signs of structural stress or instability.

Citations

[1] "VL53L1X." STMicroelectronics, www.st.com/en/imaging-and-photonics-solutions/vl53l1x.html. Accessed 22 Feb. 2024.

[2] "ESP-12F ESP8266 Serial WIFI Transceiver Wireless Module COM52, R16." Faranux Electronics, 16 Nov. 2023, www.faranux.com/product/esp-12f-wifi-module/#:~:text=separate%20network%20controllers.-,The%20ESP8266%20is%20a%20high%2Dperformance%20wireless%20SOC%20that%20offers,running%20on%20other%20host%20MCUs.

[3] "IEEE Code of Ethics." IEEE,
www.ieee.org/about/corporate/governance/p7-8.html. Accessed 22 Feb. 2024.