ECE 445 Project Proposal
Occupancy Counter

Team #73
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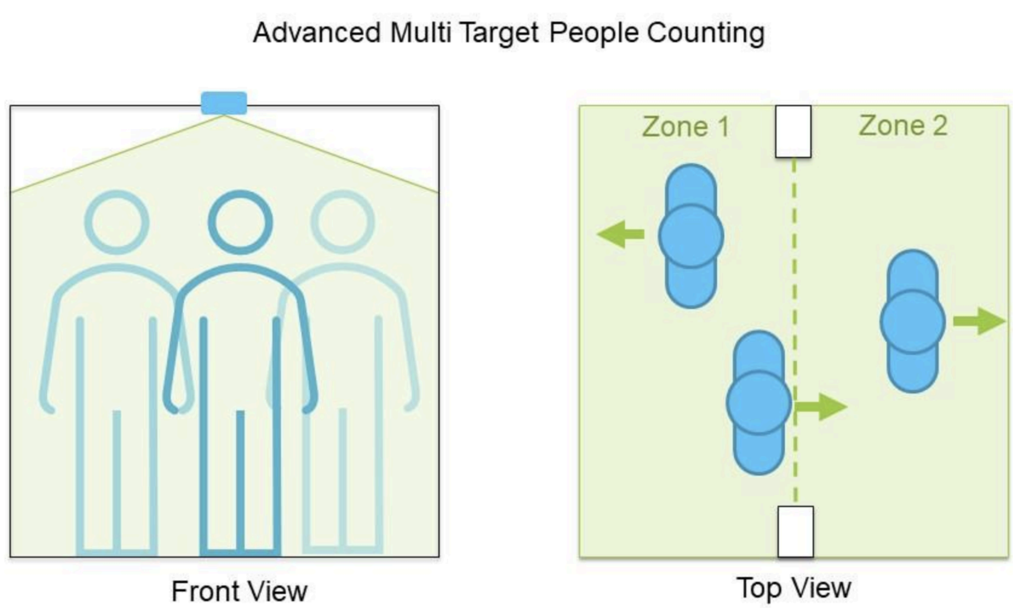
Introduction

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:

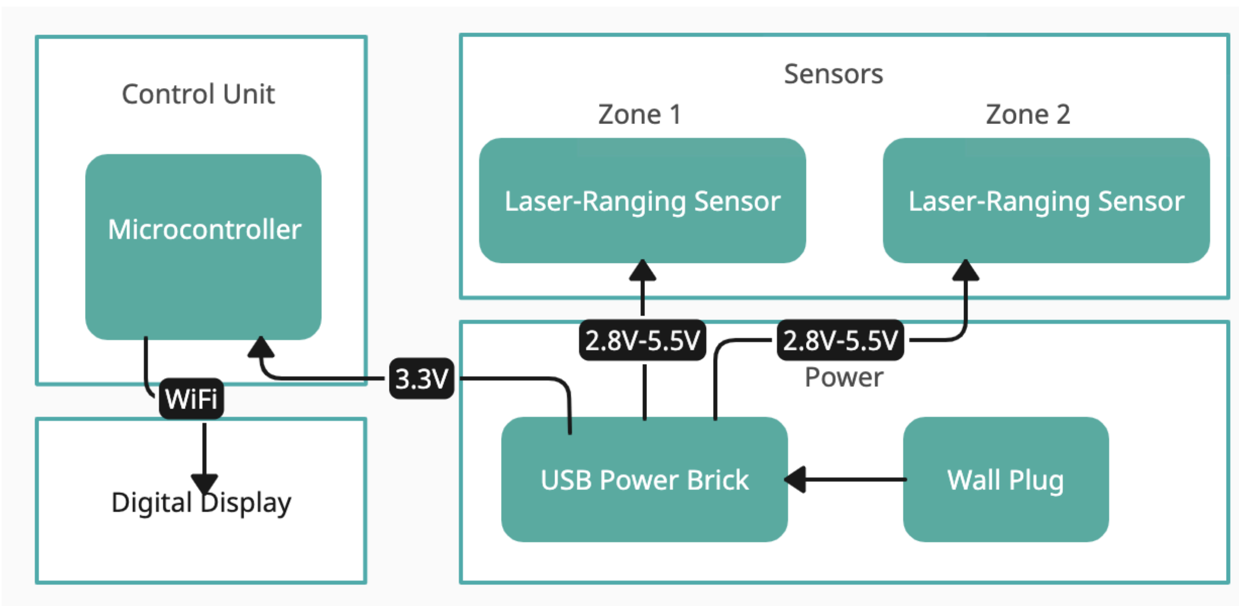


High-Level Requirements List:

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:



Subsystem Overview:

Control Unit

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.

Sensor(s)

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.

Power

This is the simplest part of the build, where we will use a USB-enabled power brick to provide power to the modules and connect it through a slim and long USB cable.

Subsystem Requirements:
Control Unit:

- Microcontroller:
    - Block Description: The microcontroller is the central processing unit of the system, interfacing with sensors and the digital display, managing WiFi communication, and executing the people-counting algorithm.
    - Interface Requirements: Our control unit must have GPIO pins compatible with digital/analog signals from sensors; a WiFi module for communication; and be able to interface with a 3.3V power supply.
    - Our subsystem Requirements:
        - Must provide stable 3.3V power to the digital display.
        - Requires a minimum of 4M bytes of flash memory for program storage.
        - Must have a WiFi interface capable of HTTP communication.
        - Must process sensor data with a latency less than 100ms for real-time counting.

Sensor(s)

- Laser-Ranging Sensor with Voltage Regulator:
    - Block Description: The sensor provides accurate distance measurements using Time of Flight (ToF) technology, crucial for the people-counting task. The integrated voltage regulator ensures stable operation across varying power supplies.
    - Interface Requirements: Our sensor(s) must be capable of interfacing with microcontrollers via I^2C protocol; operates effectively over an input voltage range of 2.6V to 5.5V.
    - Subsystem Requirements:
        - The regulator must ensure a steady 2.8V output despite input fluctuations between 2.6V and 5.5V.
        - Sensor accuracy must remain within +/- 25mm for distances up to 4m.
        - Must have a programmable ROI to adapt to different environmental conditions.
        - Response time should allow for a measurement rate sufficient for counting people in motion, typically around 50Hz.

Power

- USB Power Brick & Wall Plug:
    - Block Description: These components supply power to the sensors and indirectly to other subsystems.
    - Interface Requirements: Our power unit must output a voltage compatible with the sensors (2.8V-5.5V).
    - Subsystem Requirements:
        - Must supply at least 500mA continuously to each sensor.

- Output voltage must be 5V with a tolerance of +/- 0.1V to ensure sensor accuracy.
- Should have over-current and short-circuit protection to safeguard the system.

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 × 1%)
Voltage Output Upper Limit = 2.8V + (2.8 × 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 × Regulator Tolerance)
Worst-case error = 25mm + (25mm × 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.

Ethics and Safety

Ethical Issues:

Since the data 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. 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.

Safety Issues:

The sensors and microcontrollers that use external electrical devices could pose an electrical or fire risk. However, we ensure there is no risk with our minimal voltage and compact design.

Ethics and Safety References:

Clause 3 of the IEEE Code of Ethics discusses respecting peoples' privacy. Our product will make sure to not abuse anyone's privacy as it just detects motion of the appropriate zones. Principle 1.6 of the ACM Code of Ethics talks about ensuring the safety of the product's intended usage.