GymHive Tracker

ECE 445 Project Proposal

Team 28

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Date: 02-13-2025

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1. Introduction

1.1 Problem

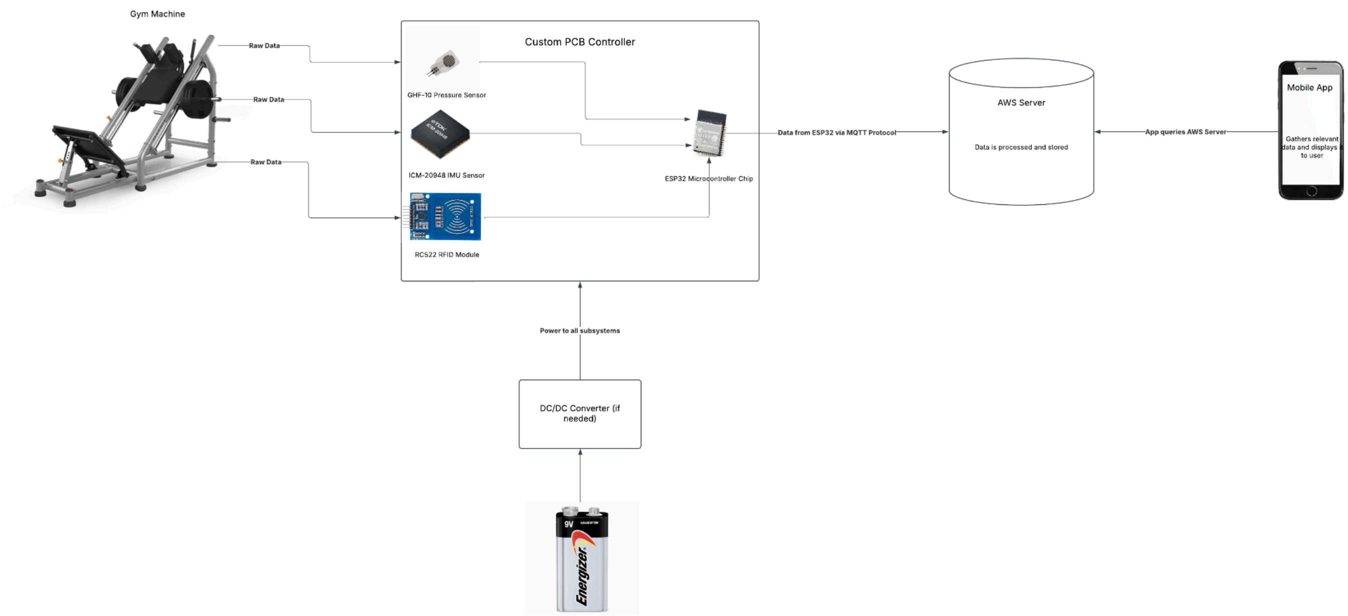
During peak gym times, equipment tends to get occupied quickly, which leads to long wait times and disrupted workout routines. Many gym-goers rely on consistent machines to track their progress weekly, but delays caused by occupied machines tend to force them to wait or alter their regimens. This inefficiency wastes time and reduces overall workout effectiveness for the athlete.

1.2 Solution

Our solution to this obstacle for gym-goers is the GymHive Tracker, a sensor-based system that monitors gym equipment utilization and provides individuals with real-time availability updates. We place our tracker at key contact points - such as pads, seats, or standing areas - and our system detects when a machine is occupied. To further optimize user satisfaction, we plan to implement a queue system where users can “check-in” via an app by scanning an RFID-enabled tag on each machine. Once checked in, users input their planned sets and reps, enabling the system to estimate wait times for those in line.

Our sensor utilizes an IMU (Inertial Measurement Unit) to track movement patterns and automatically log reps, eliminating the need for manual user input [9]. The system will notify the next gym-goer in the queue when the current user finishes their last set, minimizing wasted time. Each gym machine will have a dedicated PCB with an ESP32 microcontroller chip that transmits data remotely to a central AWS server for processing [6]. Users can access this data through a mobile app by hovering their RFID-enabled phone over the machine, allowing for a seamless process [8]. By integrating features such as real-time tracking, automatic rep counting, and estimated wait times, the GymHive Tracker will enhance workout efficiency and promote optimized gym operations.

1.3 Visual Aid

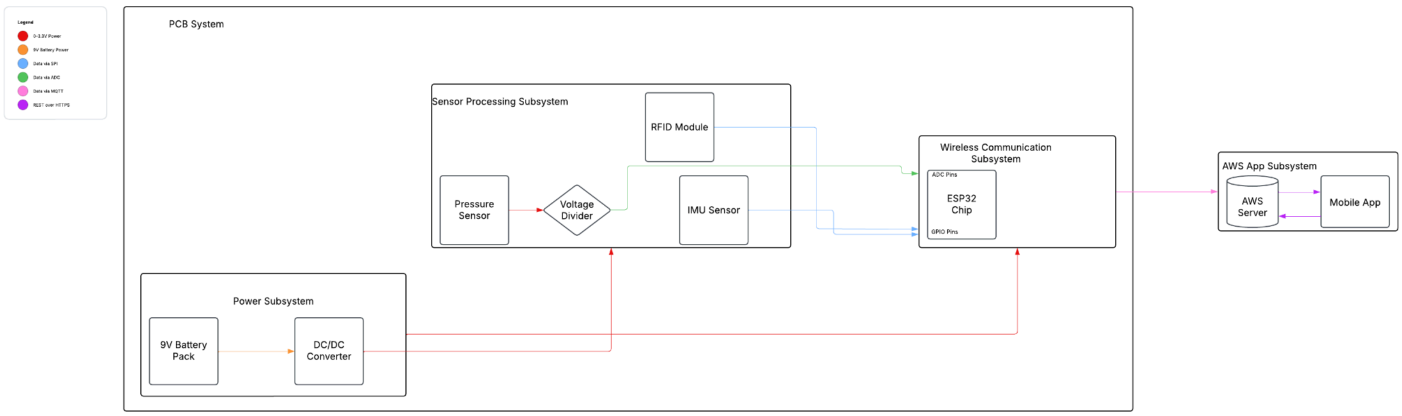


1.4 High-Level Requirements

1. **Real-Time Equipment Monitoring:** The PCB Controller must detect gym equipment occupancy with at least 95% accuracy (+/- 5lb discrepancy for acceptance), filtering out random weight fluctuations.
2. **Efficient Data Transmission and Display:** Sensor data must update the interface with real-time availability and wait times within 1 second of an occupancy change.
3. **Queue Management and User Notifications:** The system must estimate wait times within a 20±3% error margin using user input for sets and reps along with motion tracking.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview & Requirements

Pressure Sensing Module

- **Description:** This module detects whether the gym equipment is occupied. It used a pressure sensor to check when weight was applied to the machine.
- **Component:** GHF-10 [1]
- **Requirement:**
    - Must detect applied weight within ±5 lbs accuracy.
    - Must maintain 95% accuracy in distinguishing actual occupancy from fluctuations in sensor readings.

Microcontroller Chip

- **Description:** The Microcontroller Chip will be a part of the custom PCB we design, which will process the sensor data, handle communication via the RFID chip, and transmit data to an AWS server
- **Component:** ESP32 [4]
- **Requirement:**
    - The ESP32's ADC (Analog-to-Digital Converter) must read the signal and process occupancy data within 500 milliseconds to ensure real-time updates.

RFID Communication

- **Description:** This module allows for the ability of the user to use their smartphone to simply hover over the gym machine and be presented with the app to join and view the queue.
- **Component:** RC522 [3]
- **Requirement:**
    - Must recognize RFID tags within 1 second of the scan.

Inertial Measurement Unit

- **Description:** This module allows our PCB to detect reps based on motion data. This will allow for real-time updates to an equipment's availability without any user action.
- **Component:** ICM-20948 [2]
- **Requirement:**
    - Must detect reps with at least 90% accuracy.
    - Process and transmit motion data within 1 second of detection.

Mobile App

- **Description:** The app is designed to provide users with real-time equipment status and input/output functionality for them to "check in" to the machine.
- **Requirement:**
    - Display real-time occupancy updates.
    - Accurately track user check-ins and queue management.

Power Supply

- **Description:** This module powers the sensors and other hardware.
- **Component:** Rechargeable 9V lithium-ion battery along with a DC-DC converter.
- **Requirement:**
    - All hardware must function correctly after 40 hours of operation in a simulated gym environment.

2.3 Tolerance Analysis

When utilizing a pressure sensing module embedded within common points of contact in a gym machine, it is critical to be able to determine whether the equipment is truly being occupied. It is therefore important to consider the accuracy and reliability of the

GHF-10 to ensure that it does not pick up random weight fluctuations and throw a false positive. As listed in our high-level requirements, our accuracy threshold is +/- 5lbs, leaving us little room for error when detecting miscellaneous environmental factors or other movement patterns that may throw our sensor off.

In response to this, we analyze the feasibility of this component, by evaluating the sensor response to applied weight and movement fluctuations using mathematical analysis:

We model the force applied on the sensor as:

$$F_{total} = F_{user} + F_{machine} + F_{fluctuation}$$

where:

- F_{user} is the force exerted by the gym-goer,
- $F_{machine}$ accounts for the resting weight of the equipment/padding onto the sensor that may affect sensor readings,
- $F_{fluctuation}$ represents noise due to minor weight shifts, mechanical vibrations, and temporary pressure variations.

The pressure sensor must differentiate between actual occupancy and these fluctuations. The sensor outputs a voltage proportional to the applied force:

$$V_{out} = kF_{total}$$

where k is a sensitivity constant specific to the sensor.

Given the specifications of the **GHF-10 pressure sensor**, the output readings could fluctuate with repeatability and hysteresis of ±2%, which translates to a weight fluctuation threshold of approximately 2-3 lbs. So we need to ensure a ±5 lbs accuracy requirement so that $\left|F_{fluctuation}\right| < 5$

We implement signal filtering techniques such as:

- Low-pass filtering to smooth transient noise. [5]
- Kalman filtering to predict and correct erratic fluctuations. [7]

3. Ethics & Safety

- **User Data Privacy and Security**

  According to the IEEE Code of Ethics Section 1.1 [10], the intent of engineers should be to "hold paramount the safety, health, and welfare of the public". By collecting and transmitting user data between the ESP32 microcontroller, AWS server, and mobile app, it is vital to encrypt this information using standard AES-256 encryption. Our goal will be to store as little personally identifiable information as needed, all of which will be securely encrypted.

- **Physical Safety of Equipment and Users**

  According to the ACM Code 1.2 [11], the goal of an engineer should be to "avoid harm… negative consequences, especially when those consequences are significant and unjust… include unjustified physical or mental injury, unjustified destruction…". With this in mind, we understand how the custom PCB composed of pressure sensors and IMU modules must not only interfere with the intended use of the gym equipment but also not pose any risk to the gym-goers. We will ensure that each electrical component is securely enclosed to mitigate exposure to electrical or flammable hazards. Our PCB operates at a low voltage from 0 - 3.3V, which already reduces risks of any electric shock or fire hazards. This will severely minimize any risk of harm to either the gym goers themselves, the equipment, or the gym establishment.

- **Support each other in maintaining Ethical Standards**

  According to the IEEE Code of Ethics 7.8.III.10 [10], we must support our team members in following this code of ethics, and support them in reporting violations without fear of retaliation, ensuring both transparency and accountability. We will make sure to put this in our team contract to ensure we all agree on this.

4. References

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[11] ACM, "ACM Code of Ethics and Professional Conduct," ACM, 2018. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 13-Feb-2025].