Power Rack Occupancy System

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1 Introduction

1.1 Objective

Power racks are often the most important piece of equipment at a gym for an individual's work out routine. Due to the popularity of the equipment, it is rare to find an empty rack at either CRCE or the ARC at convenient workout times. Busy students who can only go to the gym on a tight schedule are often met with the frustration of just standing around waiting for a rack to open up with no knowledge of who just started their workout or who is almost finished. As it stands, there is no system in place to monitor the occupancy of the power racks, no system for being notified when there are empty power racks, and no way of determining how long someone's been using a power rack.

We propose a network of sensors installed onto power racks in a gym to detect occupancy of the power rack, how long a power rack has been used, and to provide an online interface for viewing this information for all the equipped power racks at the gym. We believe that by designing a system that can be installed on any power rack with minimal hardware modification that is connected to a central processing unit with an arbitrary amount of connections, modern gyms would find this as a realistic service to implement. By making this information available to students, our system can provide the following quality of life improvements to the gym-going experience:

- Gauge how many racks are available for use
- Be politely notified of when they are using the power rack for an inordinate amount of time
- Have access to a method of being notified when there are available power racks

1.2 Background

When going to the gym at busy times, it can be extremely time consuming to have to walk all the way down to check if a rack is free, then go back to see if anyone is close to finishing up. It's also frustrating to think you finally found a free rack, only to see someone's phone on the bench and weights still on the bar. Additionally, at peak hours, the walkway across the gym floor is impeded severely by multiple groups waiting for racks. Somewhat inspired by the occupancy sensors in parking garages and how they made parking much more convenient, we envision a more convenient gym experience as well, by freeing up gym floor space, and saving gym goers time.

1.3 Physical Design

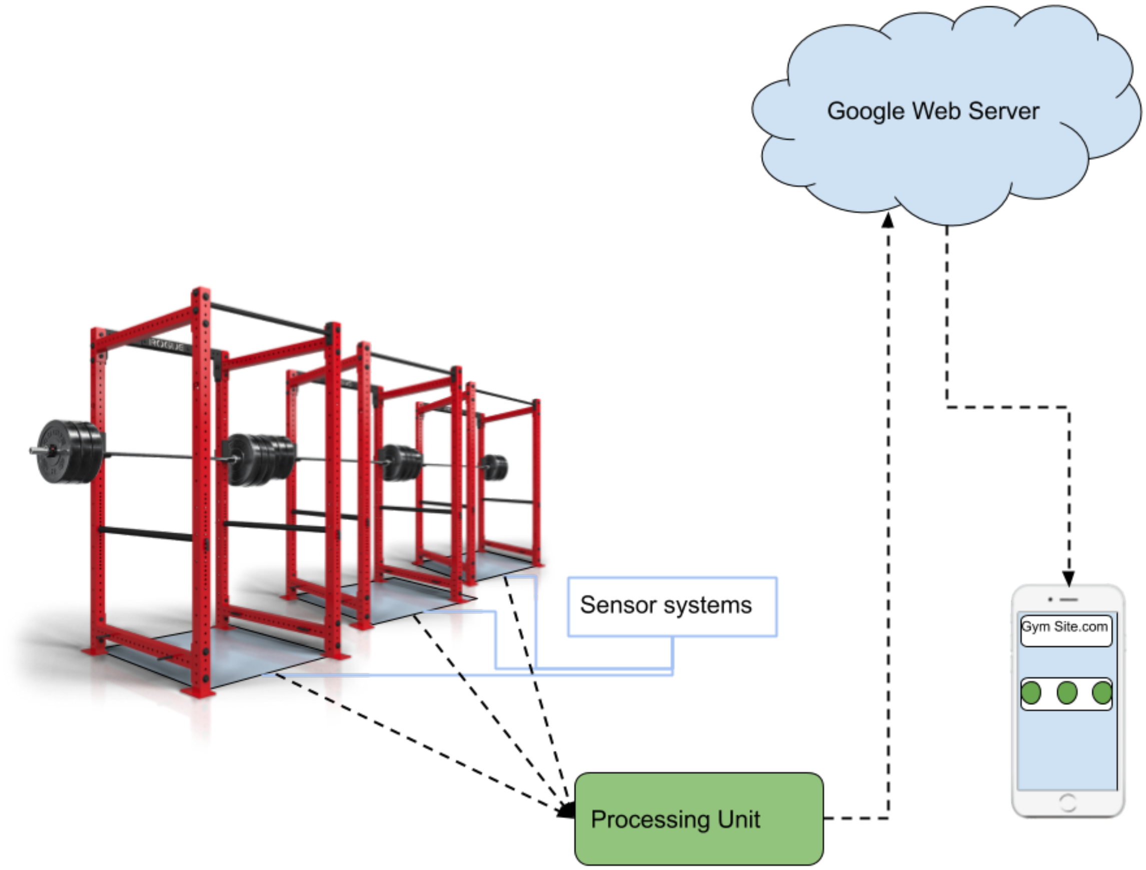

Figure 1. Physical Design Diagram

1.4 High-Level Requirements

- Sensor system must be able to detect occupancy within 1 minute of start of use of power rack
- System must accurately update online server with occupancy data for at least 2 power racks
- Users must be notified of power rack vacancy within 1 minute of registered vacancy

2 Design

2.1 Block Diagram

We have divided our power occupancy system into three primary subsystems: the system of sensors to be installed on each power rack, the central control system to aggregate the data and interface with the online server, and the server/web framework to provide a point of access to the data for the consumer. To contrast the wired connections shown in black, wireless connections between/within the subsystems are marked in blue. The central control system will be interfacing with several power rack sensor systems to wrap up the data to send to the online server.

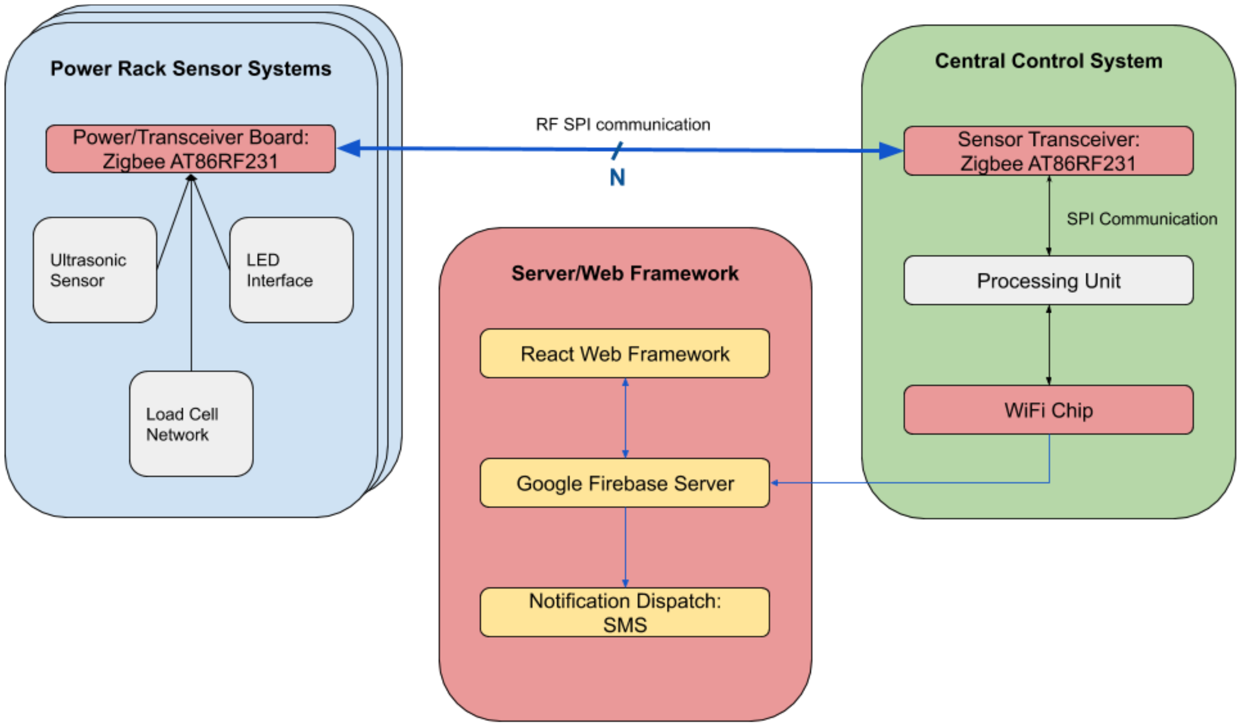

Figure 2. Block Diagram

2.2 Physical Design(s)

The relevant physical design of our system only really pertains to how the sensors will be installed on the power racks. This is because the server/web framework subsystem is virtual and the central control subsystem simply has to enclose the necessary electronics and will simply be a box.

In the interest of the most absolute versatility between types of power racks, we are choosing to install staggered load sensors at the base of the power rack. By having a series of weight load measures at the front and back of the power rack, we believe that we will be able to ascertain rack occupancy as well as some measure of weight is being used. In order to protect the sensitive mechanical design of the load cells in the system, Shown in the figure below is a diagram of sensor placement.

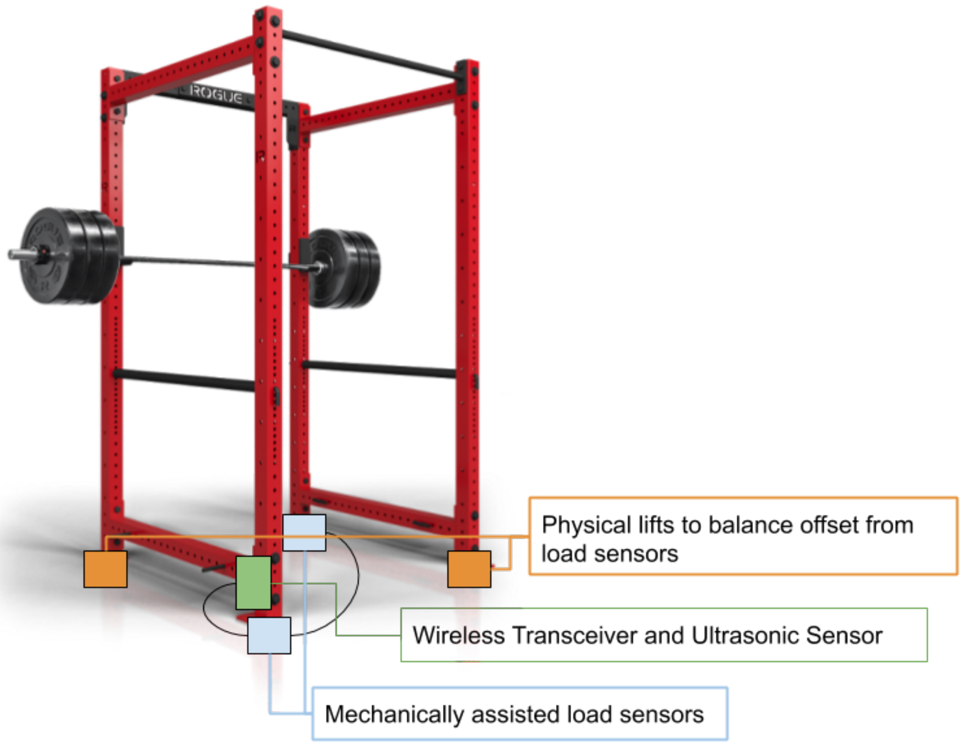

Figure 3. Sensor Placement Diagram

2.3 Functional Overview

2.3.1 Power Rack Sensor System Power/Transceiver Board

Each sensor in the power rack sensor network will be piped to a single board per power rack that will provide power and interface with the central control system. This board will house the wireless transmission chip, the Zigbee AT86RF231, the battery power supply, and implement the SPI communication protocol from the RF transceiver to each of the sensors. By designing each power rack to be able to individually be able to interface with the central control system wirelessly, we believe it gives consumers of the system great flexibility in terms of modularity and not having to route additional wirings.

2.3.2 Power Rack Load Cell Network

The load cells in the power rack sensor systems are heavy lifters in more ways than one. The primary advantage of the power rack is its flexibility in where the barbell can be stably supported-- it can be placed along an adjustable height axis on one or both sides of the rack or the bar can be placed along the safety crossbars that extend from front to back. This uncertainty in measurement from not knowing where the bar may be placed is amplified when the power rack had holder bars for additional plates to be stored along the side of the power rack. By having two load cells staggered at the base of the power rack, tremendous insight is given into how weight is being transferred or hung around the rack.

2.3.3 Power Rack Ultrasonic Sensor

As a supplement to the detection of how weight is being transferred around the power rack, we have also decided to utilize an ultrasonic sensor to provide a sense of what is inside the power rack. The benefits are two-fold: the presence of a large static object likely denotes the presence of a bench for something like the bench press and it also gives an added security to detecting if the power rack is being used for something that does not involve unloading and reloading weight onto the rack.

2.3.4 Central Control System Sensor Data Transceiver

In this design, we have opted to use the same wireless data transceiver for both the central control system and the power rack sensor systems: the Zigbee AT86RF231. This chip is designed for SPI communication and supports the queuing of data in a buffer for transmission which is helpful to collect time series data from the required sensors for analysis.

2.3.5 Central Control System Processing Unit

For the sake of modularity and cost efficiency, we are piping all raw sensor data to a single processing unit to be processed, wrapped up, and sent to the online server. In the absence of real data, the exact processing needed is unclear. Our system will initially be prototyped using a fully featured single board computer like a Raspberry Pi but the final implementation of the processing unit will surely require some rudimentary time series analysis/filtering, the ability to authenticate and interact with the Google Firebase server, and have sufficient memory to record short term sensor statistics for occupancy and type of usage decisions.

2.3.6 Central Control System WiFi Chip

It is not certain if the central control system processing unit that fits best into the system will inherently have the ability to connect with the internet. Should the processing unit not have this capability, a WiFi chip will have to be installed and put into the data pipeline since access to the internet is critical to making the occupancy data available from remote locations.

2.3.7 Google Firebase Server

Our Firebase server will be hosting our React frontend, which will allow gym-goers to access the site as long as they have internet. Our Firebase server will also utilize Google's NoSQL database, Firestore, to store data sent from our sensor networks and keep track of the users currently subscribed to our power rack vacancy notification service.

2.3.8 React Web Framework

Our React code, which is being hosted by Google Firebase, is our main software component that connects everything together. Users can view the real-time vacancy of the power racks at the gym and can subscribe or unsubscribe to our notification service. The React code will be reading and writing to our database when viewing occupancy and subscribing/unsubscribing to our service.

2.3.9 Notification Dispatch

Once our system has detected that a power rack is vacant, we will send a SMS text to all users currently subscribed to our service, notifying them of the vacancy. We will go through our database and gather all the numbers of our users and send them a SMS text utilizing Twilio's API.

2.4 Block Requirements

2.4.1 Power Rack Sensor System

This subsystem is solely responsible for collection of data relevant to determining occupancy and how the power rack is being used. The relevant sensors are at least two load cells and an ultrasonic sensor. A single board will be designed for a power rack to implement SPI communication between all relevant sensors and the Zigbee AT86RF231 wireless transceiver. These subsystems will be battery powered.

The sensor subsystem must be able to do the following:

- Support the weight of the power rack without being overloaded in a variety of use cases
- Poll each sensor at a frequency of at least once every 5 seconds
- Have an operational battery life of at least 3 days

2.4.2 Central Processing Unit

This subsystem acts as the brains of our project, interfacing between the sensors and the web framework. It will interpret the data obtained wirelessly from the load cells and ultrasonic sensors, process whether that means the rack is free, and display the info on our web interface.

The central processing/control subsystem must be able to the following:

- Be able to communicate with multiple power rack sensor systems in parallel (at least 2)
- Be able to update the server in less than 1 second

2.4.3 Server/Web Framework

This subsystem acts as the communication hub between our occupancy data and our gym-goers. This subsystem allows users to add or remove themselves from the subscription pool, allows users to view the vacancy of the power racks at the gym through our user interface, and sends notifications to the users who are subscribed whenever a power rack vacancy is detected.

The server/web framework must be able to do the following:

- When the user presses subscribe, the user's information should be inserted into the database and should begin receiving notifications.

- When the user presses unsubscribe, the user's information should be deleted from the database and should no longer be receiving notifications.
- Must update the status of the power racks whenever a status change is detected within the database and should notify the subscribed users if a power rack is vacant.
- Website to view power rack occupancy must be formatted for both mobile and desktop viewing

2.5 Risk Analysis

The central control system would be the component that poses the biggest risk to the completion of our project. Compared to the power rack sensor systems and the web framework, which only communicate with one other component, the central control system communicates with two. Without the central control system, there would be no way for each power rack sensor system to transmit data to our database, which means our user interface would have no updates and no ways of communicating with each power rack system. In other words, it ties our whole project together. Furthermore, we have little to no experience with setting up a transceiver system that communicates over WIFI, whereas we do have experience with sensor systems and web servers.

3 Safety and Ethics

One possible safety concern would be the increased risk of injury following improper installation. If not properly secured, the rack could become unbalanced and tip over, causing serious bodily harm or death, due to the heavy weights it holds. Another safety issue we must take care to address is how spills will affect our system. The load cells that we plan on using are IP66 certified, which should be more than adequate to protect against any accidental spillage of water or other liquids. For any parts near the power rack that are not IP certified, we plan on using conformal spray to protect against liquid.

In regard to ethics, we believe our project has no conflicts with either the ACM Code of Ethics nor the IEEE Code of Ethics, given that fair access to the data is given to the involved parties.