ENGR 697

San Francisco State University

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Team MejjiMEC

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I. Problem Statement and Background

Today, many Americans go to the gym, for a variety of reasons, such as, to stay in shape, be healthy, get stronger, or for competitive reasons. According to Statista, The United States has an estimated 64.19 million gym memberships, the most of any country. Meaning that at least 64.19 million people have gone to a gym to use the exercise machines, weights, and other equipment for their workout. Although each workout is unique, each piece of equipment is used at least once in a gym facility, and among that equipment is a rowing machine etc. The use of these machines can be strenuous activity. During any form of exercise, your heart beats faster. According to the CDC, for vigorous-intensity physical activity, your target heart rate should be between 77% and 93%, [1] of your maximum heart rate. Rowing has been growing in popularity and has been represented with the greatest year-over-year growth of 5.9% (TBD). This can be due to the many benefits such as improved cardiovascular health, increased muscle strength and endurance, and weight loss. But, no matter how good of an exercise rowing is, there is always the risk of injury. Many injuries come from applying too much tension across a specific muscle or tendon. Few injuries that can occur is lower back pain, shoulder injuries, knee pain, and overuse injuries. When exercising, you are always pushing yourself, to go further so that you can be stronger. You are always pushing your limit. This is when you have to be the safest. A gym-goer is only consumed by their exercise and only has one goal, to keep going. Losing concentration may stop you from finishing a rep. Constantly depleting your energy bar can lead to fatigue, which causes brain fog. You forget what rep or set you ended up doing. Many repetitions of an exercise are no longer as perfect as the first time. Which is why it is important to have good form. However, the more fatigue you get, the more brain fog you have, and the harder it is to have good form. All of these factors can lead to hunching, leading too far back, overextending etc, which can lead to injury. The 2 problems that need to be addressed are form correction and brain fog.

The first aspect to consider is the amount of injuries that can be caused by a rowing machine. Rowing machines are already low impact, but because users may not know the correct form, they are more likely to get hurt. Incorrect form on a rowing machine means that you are either relying too much or too little on your back. Or you are trying to over extend your arms. You could even bend your knees too early. Which can lead to back, knee and shoulder pains. Rowing is a full-body workout that requires significant strength, endurance, and cardiovascular fitness. It involves using the legs, core, arms for an extended period of time and because of this, if you have a single error, it may lead to several different injuries. To avoid this issue, our solution is to track the gym-goers performance at the gym while rowing with a phone application that is built with the To the rowing machine. The application will have a calibration setting with instructions of correct form. The calibration setting that will notify the user to do one slow repetition of the rowing and will keep track of the distance of the handles throughout the workout based on the initial calibration.

The second issue is mental fatigue. “Mental fatigue can be defined as a psychobiological state caused by prolonged exertion that has the potential to reduce cognitive performance and exercise performance. [5].” Prolonged exertion is overtraining for a sport or physical fitness. Overtraining can be associated with any type of sports or fitness program. As shown in table 3, the symptoms of overtraining syndrome for rowing are sympathetic alterations and a lack of mental concentration. Table 3, shows that there is a correlation between exercise and cognitive performance. In order to prevent and put an end to overtraining, our solution is to track the gym-goers performance at the gym while rowing with a web page that is built with the rowing machine.. The webpage will be able to track stores, power exertion, form, and repetitions. These features will solve many issues that are caused by mental fatigue.

Symptoms of overtraining syndrome.

Parasympathetic Alterations[a]	**Sympathetic Alterations**[b]	**Other**
Fatigue	Insomnia	Anorexia
Depression	Irritability	Weight loss
Bradycardia	Agitation	Lack of mental concentration
Loss of motivation	Tachycardia	Heavy, sore, stiff muscles
	Hypertension	Anxiety
	Restlessness	Awakening unrefreshed

[a]More common in aerobic sports.

[b]More common in anaerobic sports.

Table 1: Overtraining Symptoms

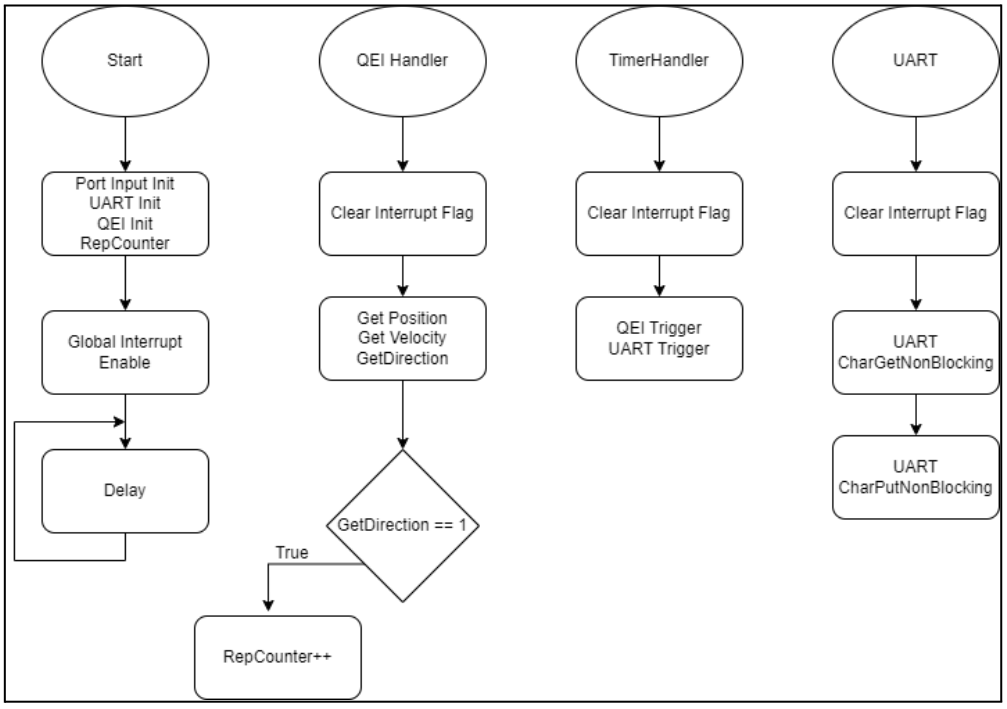
The objective of this project is to enhance gym-goers' workout experience by enabling them to monitor their performance in real-time while using exercise equipment. To achieve this, we propose to develop an additional device that works in tandem with equipment such as lifting and rowing machines, providing users with immediate performance feedback. The collection of data from exercise equipment has been shown to have numerous benefits, including tracking performance over time, setting achievable goals, promoting self-motivation, ensuring proper equipment use for safety, and improving overall experience.

II. Proposed Solutions and Design (include 1 annotated schematic)

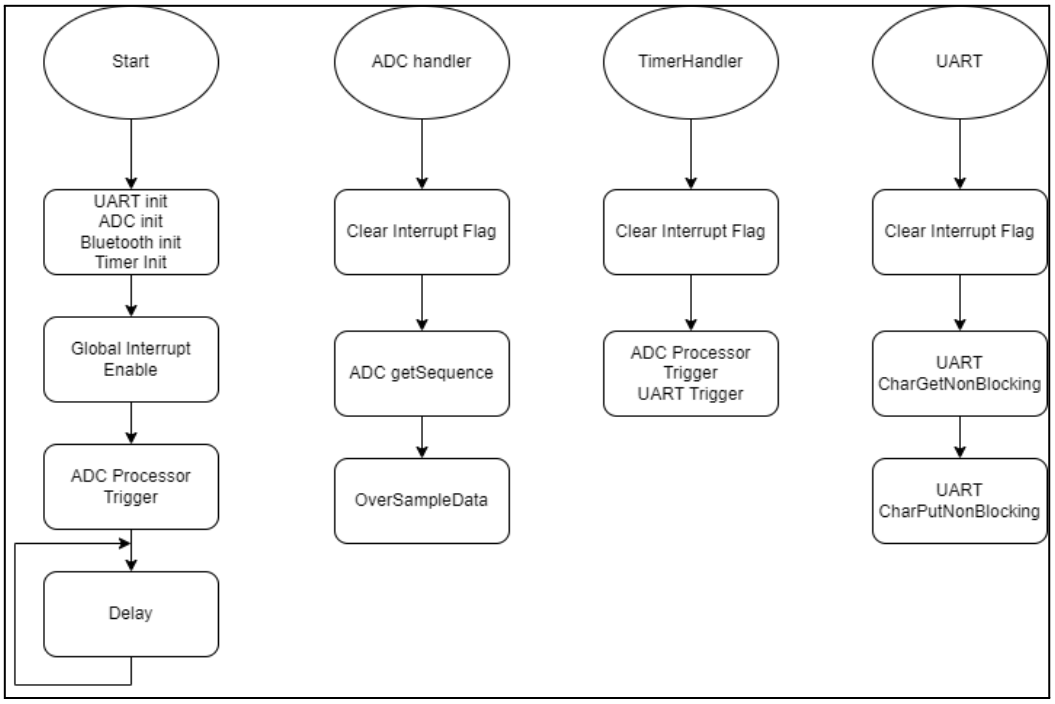
The user's performance on a rowing machine can be tracked using rotary encoders and force sensors. To do this, the encoder is attached to the rotating shaft of the machine, and pre-calibrated optimal rowing parameters are established beforehand to ensure proper equipment use and correct

form. Additionally, force sensors are placed at each foothold on the machine to determine proper weight distribution. To attach the encoder, a 3D printed mount is designed to read the rotating shaft while the equipment is in use. We will be working with the Concept 2 rowing machine provided to us by San Francisco State University, which currently has non-functioning performance units that we will manipulate and adjust to demonstrate our justification.

Our main goal for the implementation is to take the data we need, and redirect it. Starting from the rotary encoder, we know that our selected incremental optical rotary encoder is a digital system that can be implemented using the hardware. To interface with the encoder, many microcontrollers use a Quadrature Encoder (QEI) API function. The QEI contains a collection of functions for working with the Quadrature Encoder. There are functions that can help us register a QEI interrupt handler, configure and read the position and velocity captures, and deal with QEI interrupt masking/clearing [6]. We also have a series of interrupts that will work together when we have completed a cycle of data retrieval. When there is a value that has been read into the microcontroller (MCU), we want to trigger the interrupt flag and use the Universal Asynchronous Receiver/Transmitter (UART) API. It provides a set of functions for using the Tiva UART modules. Functions are provided to configure and control the UART modules, to send and receive data, and to manage interrupts for the UART modules. It performs serial-to-parallel data conversion on data received from a peripheral device and parallel-to-serial conversion on data transmitted to a peripheral device [6]. UART will be used to interface with WiFi. Wifi does not involve a shared clock signal, so it is asynchronous, which allows us to send data through UART to the WiFi module. By reading the position of the encoder and capturing the velocity, and interfacing with UART to send our data through wifi, we are able to implement most of our intended functions in our project.

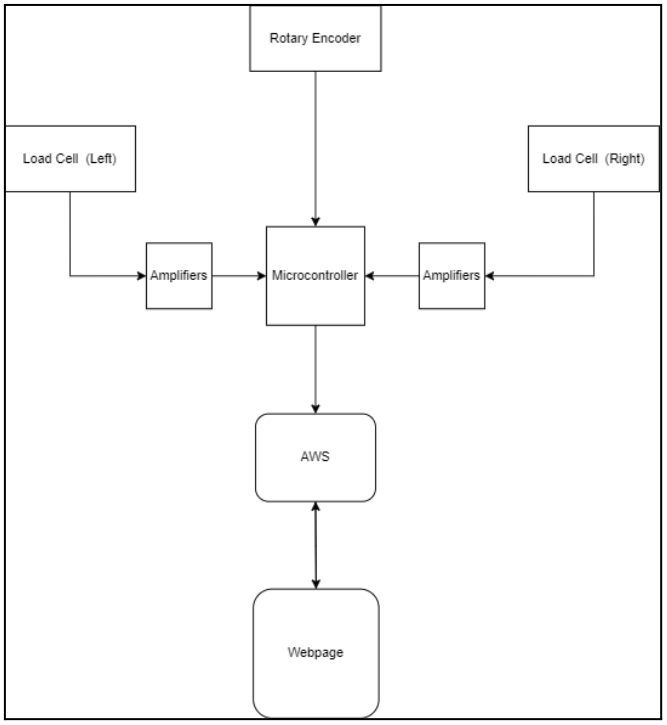


Rotary Encoder Implementation

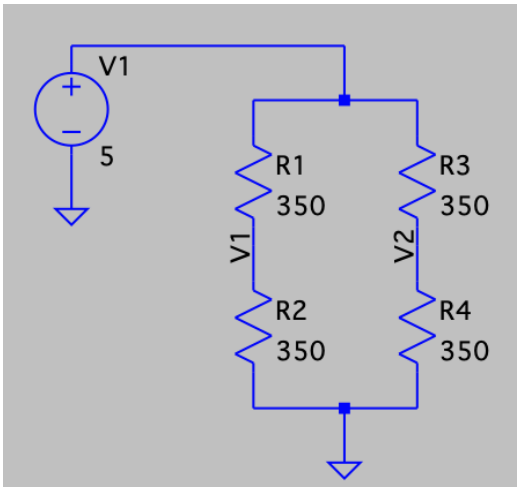


Load Cell Implementation

The final portion of our implementation includes a web page which will display performance data after the microcontroller has calculated the metrics. The data transfer between the web page and the microcontroller will use MQTT protocols, which are well-suited for real-time messaging in low-bandwidth and high-latency networks commonly used in IoT applications like our project. To make the web page accessible from any device with an internet connection, it will be hosted on Amazon Web Services (AWS). This will enable real-time data processing and analysis by connecting the microcontroller to the cloud. We plan to use the Arduino IDE, which is compatible with the AWS IoT Core library.



Full Implementation



Schematic of load cell: with source of 5 V and a resistance of 350 Ohm. Output will be the difference between V1 and V2, which will be sent to the amplifier then to the microcontroller.

III. Bill of Materials (BOM)

Item	Quantity	Unit Price	Shipping	Tax	Final Price
ESP32 Huzzah Feather Board	1	$21.95	$13.20	$2.17	$37.32
Mongoose OS & Google loT Core Pack - Feather Huzzah32	1	54.95	$17.70	$5.43	$78.08
6-Pin Cable	1	$5.08	-	$0.50	$5.58
S-Type Beam Load Cell	2	$35.69	-	$7.04	$78.42
SparkFun Qwiic Scale - NAU7802	2	$16.50	-	-	$16.50
Incremental Rotary Encoder	1	$56.99	$12.95	$5.63	$75.47
Total					**$291.37**

IV. Material Justification

In order to track the performance of users on the rowing machine, it was identified that several components listed in the BOM (Bill of Materials) would be necessary. The rotary encoder will be employed to monitor the speed of the exercise, while force sensors will be utilized to ascertain whether the user is appropriately distributing weight on the machine's footholds. Additionally, a load cell amplifier will be used to enhance the force sensor's output, allowing it to be interpreted by the microcontroller.

The button load cell is vital for application on the foot holder of the roller without requiring major modification. Its size range is enough to hold any individual and accurately track the force applied. The limit on the load cell is 200 kg. The load cell can also function in all gym environments as its maximum temperature is 55º C.

The US Digital E8T-250-250-N-S-D-H Hollow Shaft Encoder is good for tracking the performance of the Concept 2 rowing machine because it is accurate, tough, and cheap. It gives precise information about position and speed, and its sturdy design protects it from harsh environments, guaranteeing it will work well for a long time and it is reasonably priced compared to other encoders that have similar accuracy and rigidity.

Item Number: E8T-360-315-D-H-G-2
Specifications:

Resolution	315 CPR
Output Type	Differential Line Driver (A, B, Z)
Supply Voltage	4.75 - 5.25 VDC
Output Voltage	-1.0 V min , 1.0 V max

Operating Temperature Range	-40 - 100 C
Maximum Shaft Speed	10,000 RPM
Encoder Size	2” Diameter x 1.38” Depth
Shaft Size	0.375’ Diameter, Hollow
Housing Material	Aluminum
Protection Rating	Protection Rating

To accurately measure the input signals from the rotary encoder and load cell, the microcontroller must detect a minimum voltage of 0.244mV. This requires a 10-bit ADC to handle a range of 1,024 values and a minimum of 15 bits for necessary calculations. The ESP-32 Huzzah Feather Board meets these requirements and features built-in WiFi and Bluetooth capabilities, a 12-bit ADC resolution, and a 32-bit microcontroller based on the Xtensa LX6 processor. With 19 GPIO pins, a micro-USB port, and a LiPo battery connector, it supports various communication protocols and can be programmed using the Arduino IDE. Its efficient processing capabilities enable it to handle complex calculations and process large amounts of data.

MCU	Rotary Encoder	Reason	Load Cell	Reason
ADC Resolution	10-bit Range: 0-1024 Minimum voltage read: 0.244mV	- Needed to convert data from the load cells	N/A	N/A
Wifi module	Required	Sends data to app.	Required	Sends data to app.
Interface	QEI & UART	- QEI interfaces with the encoder - Uart interfaces with WiFi	UART	- Uart interfaces with WiFi
Bits	15-bit Range: 0-32768	30,000 counts per revolution	9-bit Range: 0 - 512	Max weight: 300lbs
Memory size	<400 bytes	- Sending Data, not storing	<400 bytes	- Sending Data, not storing

Material Purchase Links

ESP32 Huzzah Feather Board (1):
https://www.adafruit.com/product/3619

Mongoose OS & Google loT Core Pack - Feather Huzzah 32 (1):
https://www.adafruit.com/product/3606

6-Pin Cable (1):
https://www.amazon.com/dp/B09K4TD8KF?psc=1&ref=ppx_yo2ov_dt_b_product_details

S-Type Beam Load Cell (2):
https://www.amazon.com/dp/B082MPLRCS?psc=1&ref=ppx_yo2ov_dt_b_product_details

SparkFun Qwiic Scale - NAU7802 (2):
https://www.amazon.com/dp/B082MPLRCS?psc=1&ref=ppx_yo2ov_dt_b_product_details

Incremental Rotary Encoder (1):
https://www.digikey.com/en/products/detail/us-digital/E8T-512-197-S-D-D-2/15786522