IntelliGYM

Justin Naal, Daniel Rymut, Srinija Kakumanu

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1 Introduction

1.1 Objective

It was estimated in November 2020 that 25% of health and fitness clubs would have closed due to Covid-19 (Rodriguez). “Fitness is a $34 billion industry, and an estimated 20% of Americans have a membership to some kind of fitness club, according to the International Health, Racquet & Sportsclub Association (IHRSA)” (Eschner). That means 20% of all Americans were forced to pivot to at-home workouts due to COVID-19. And “one of the [in-person] gym’s big appeals—besides easy access to equipment and workout space, two things that are expensive and may not be available at home—is access to both the expert knowledge of trainers and class instructors and the community knowledge and support of other people working out” (Eschner).

So, while at home workouts are an excellent way to stay healthy, you do not have access to trainers or spotters. This means that you could be performing exercises poorly and over time this would result in injury or strain. Additionally, working out at home means it is harder to stay consistent and motivated.

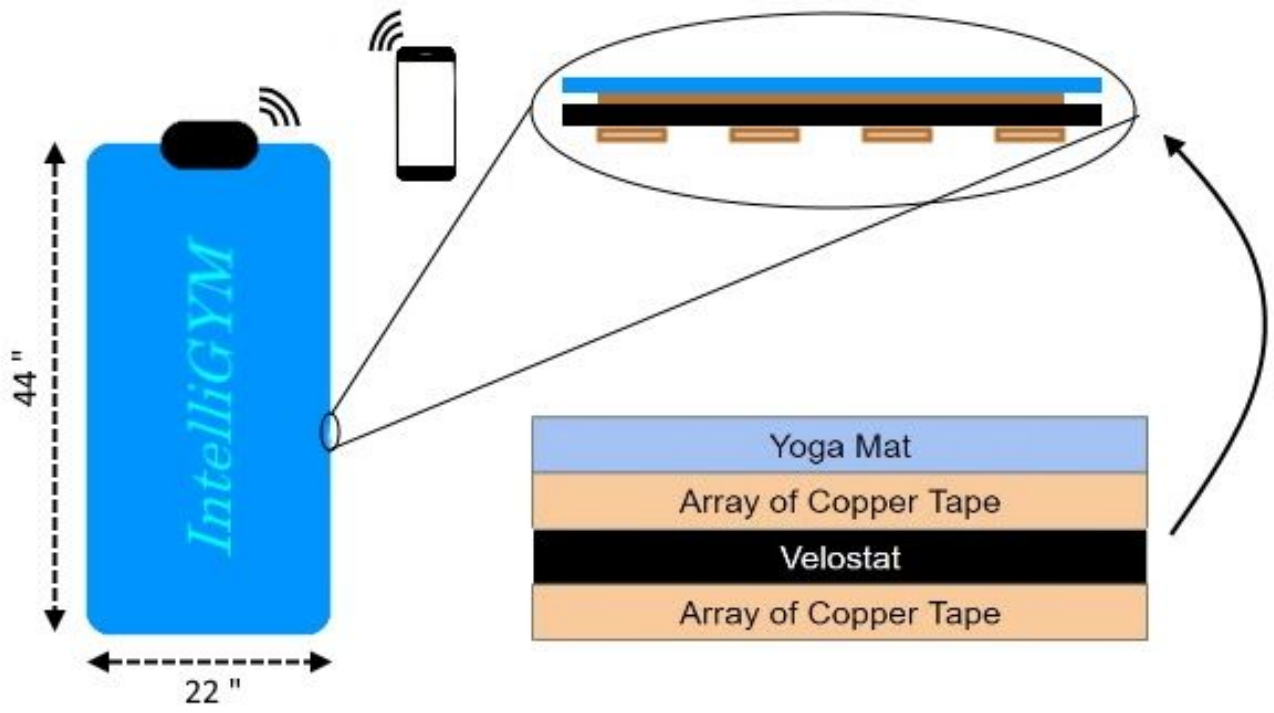
The way to address these problems is to give people a way to collect and examine data from their workouts. Our proposed solution is to build a smart exercise mat and companion mobile app to help at-home workouts. The mat would use pressure to analyze form while performing sets of exercise and the app would be used to build circuits of exercises and analyze performance data.

1.2 Background

We feel there is a strong need for a product such as ours because the number of people who had to pivot to at home workouts skyrocketed due to COVID-19. But the need for IntelliGYM goes beyond COVID. There is a huge portion of Americans who want to exercise but cannot afford trainers or gym memberships. Our product would address both displaced gym-goers and novice exercisers by giving them a standalone tool to improve their performance without high recurring cost.

IntelliGYM does not require a user to have anything besides their smartphone. Users would only be performing bodyweight exercises. By creating an ecosystem where people can collect and study their data as well as build custom workouts, we are addressing the issue of ineffective and potentially strenuous exercises.

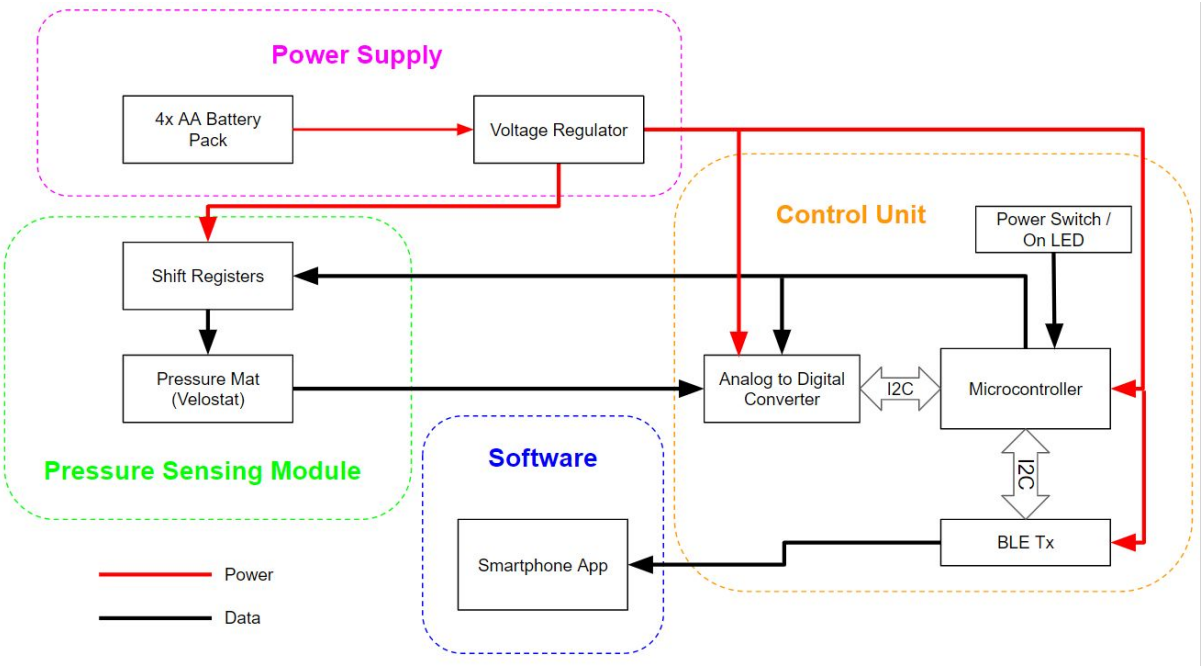
1.3 Physical Design



1.4 High-Level Requirement

1. The mat is able to distinguish between the phases of the following exercises:
    a. Push-up
    b. Lunge
    c. Squat
    d. Crunch
    e. Plank
2. The mat is able to count reps of the aforementioned exercises within 90% accuracy.
3. The mat is able to differentiate between 2 different exercises (tell a push-up from a lunge)
4. The mat is able to differentiate between 2 different qualities of exercises (a well-performed push-up and poorly-performed push-up

2 Design



2.1 Pressure Sensing Module

The pressure sensing module comprises the hardware that measures user input data. An array of copper cells separated by a piezoresistive material create varying current pulls, and these values are read sequentially using serially connected shift registers.

2.1.1 Pressure Mat (Velostat)

An array of pressure sensors is created through rows and columns of ¼ inch copper tape. The columns are separated from the rows by a thin layer of velostat, whose resistance values range from 800 Ω to 100 Ω between 0 and ~1100 grams. The shift registers are responsible for activating each column, and the analog signal is fed to the control unit through the ADC converter.

Requirement 1: Pressure mat is capable of differentiating ~100 gram changes in pressure.

Requirement 2: The analog signal has time to settle between ADC read periods.

2.1.2 Shift Registers

A system of 8-bit shift registers are serially connected to make an 88-bit circular shift register. Only one bit is high while the rest are low, and the high bit powers a column of the pressure mat array. The high bit indefinitely circles the register allowing continuous reads of the pressure mat array.

Requirement 1: The shift register supplies the column of copper tape with [5.5,4.5] V

Requirement 2: Only one bit is active at any given time.

2.2 Power Supply

Our power supply is planned so that our product can be more mobile and not need to be next to an outlet during use.

2.2.1 4x AA Battery Pack

Using 4 1.5V AA batteries which are connected in series, we can obtain a 6V output which will need to be regulated in order to power all other modules at the needed power levels.
Requirement: Securely holds 4 batteries and provides a constant 6V DC output

2.2.2 Voltage Regulator

The modules and components of the PCB will require either a 5V or 3.3V power supply, so we will need to step down the voltage to two different levels.
Requirement 1: Step down to 5V output
Requirement 2: Step down to 3.3 V output

2.3 Control Unit

The control unit module will be responsible for all control and clock signals being sent to the other modules. It will also need to send the data from the pressure mat to the phone.

2.3.1 Analog to Digital Converter (ADC)

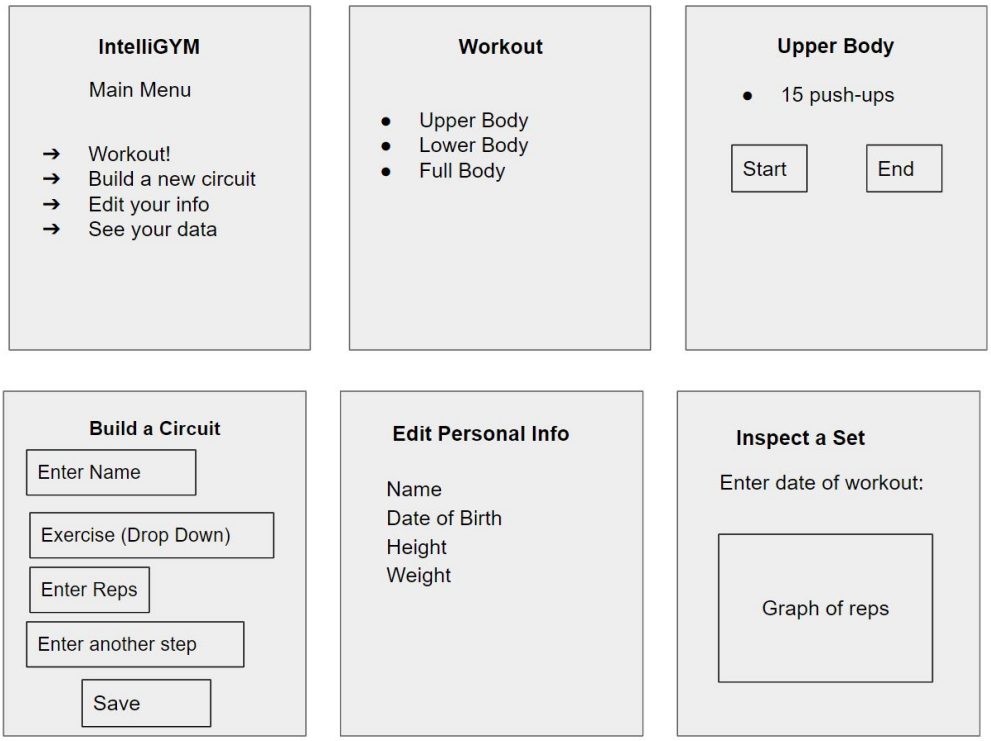
The data that comes from the pressure mat will be an analog signal. In order to process this data it will be converted to a digital signal by the ADC. The most critical aspect of this module is getting it to be as fast as possible while maintaining accuracy.
Requirement 1: Be able to process at least 4k SPS
Requirement 2: Have at least 8 bits of accuracy

2.3.2 Microcontroller

The microcontroller will be responsible for sending out all control and clock signals to other components. It must also have the ability to quickly process data and send it to the BLE transmitter.
Requirement 1: Have sufficient amount of I/O pins for the system

2.4 Software

The smartphone app will be where the user can build circuits, look at their data and complete new workouts. The app will communicate with the mat using Bluetooth connection. We plan to use either the BeeWare or Kivy framework to develop the application.
Wireframes for App Pages:



2.5 Risk Analysis

The exercise mat is the most significant risk to the successful completion of this project. There are not many available resources that provide information on using velostat as a pressure sensor. So we will need to run some preliminary tests to see how accurate and consistent the data will be. Properly implementing our proposed design of about 3,800 sensors in order to achieve a detailed pressure mapping will be met with many potential challenges along the way. The amount of power needed to obtain a reading is another unknown factor that may affect the design as a whole. Our hope is that this will be an accurate, efficient, and reliable method for producing a cost effective pressure mapping; however, we expect to have some challenges as we learn to use this material that has primarily been used as an electrically conductive packing material.

3 Safety and Ethics

The primary ethical concern of IntelliGYM is privacy. In order for this product to use the pressure data as effectively as possible, we will need to know the users size, weight, and height. For many people, especially those trying to get in shape, this may be sensitive information. We must ensure that the data that is put into their smartphone will not be used or distributed in any way that may be a breach of privacy. In other words, we must ensure that we adhere to principle 1.6 of the ACM Code of Ethics, “Respect Privacy”.

References

[1] K. Eschner, “COVID-19 has changed how people exercise, but that doesn't mean gyms are going away,” *Fortune*, 12-Jun-2020. [Online]. Available: https://fortune.com/2020/06/11/coronavirus-gyms-workouts-fitness-apps-reopening/. [Accessed: 17-Feb-2021].

[2] “One in Four Health & Fitness Clubs Could Close by Year-End,” *IHRSA*. [Online]. Available: https://www.ihrsa.org/about/media-center/press-releases/15-of-health-fitness-clubs-in-the-u-s-permanently-closed/. [Accessed: 17-Feb-2021].

[3] S. Dufresne, “Hi-Res, Body-Sized Pressure Sensor Mat,” *Hackaday*, 29-Oct-2017. [Online]. Available: https://hackaday.com/2017/10/29/hi-res-body-sized-pressure-sensor-mat/. [Accessed: 17-Feb-2021].