BarPro

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1 Introduction

1.1 Objective

A common issue among weightlifters, regardless of experience, is bad form when doing exercises. This occurs from a beginning lifter not understanding the correct motion or an experienced lifter wearing out when reaching the end of their set. Muscles begin to give out and when exercises are performed with two hands (bench press, squats, deadlifts, for example), the stronger hand compensates for the other and the bar can, unbeknownst to the user, become unlevel, leading to asymmetrical strain on the body. This issue can be mitigated if the user is doing a workout on a Smith machine or is partnered with a spotter; but these machines have their drawbacks which we will not elaborate on here for the sake of space, and with the ongoing Covid-19 atmosphere and the difficulty of consistently aligning gym schedules between people, users more often now than ever find themselves at the gym alone.

So our group presents the BarPro, a strap designed for weightlifters of all skill ranges, to assist in monitoring good form and managing sets/reps for a user throughout his or her workout. With its (hopefully soon to be) built-in accelerometer and ultrasonic sensor for level and height measurement, respectively, it uses these sensors to measure level and output discrepancies to an LED display for the user to see real-time, and measure height to count reps throughout a user's workout.

1.2 Background

Uneven barbell positioning could result in serious injuries, especially when lifting heavy weights. This uneven positioning causes uneven weight distribution on muscles and joints such as shoulders [2] during the bench press exercise. In order to reduce the risk of these injuries, a weightlifter has to make sure they are keeping their barbell level at all times. Although a

weightlifter can sometimes notice an uneven barbell themselves, oftentimes people go through an entire motion with an uneven barbell unnoticed. A spotter or partner can definitely notice an uneven barbell, but a lot of gym-goers work out alone, especially now during the COVID-19 pandemic where social distancing measures are enforced. The BarPro device will have the ability to be that spotter or partner and notify the weightlifter when the barbell is uneven. It will perform even better than a human being by using an accelerometer to know exactly when a barbell is not positioned evenly.

Exercises such as the bench press and squat require full motion to activate the desired muscle groups. When full motion is not completed by the weightlifter, maximum efficiency is not reached from the workout and some muscles may undergo minimum usage. To eliminate the possibility of doing exercises with incomplete motion, weightlifters should practice proper form with little weights to create the muscle memory needed for a proper lift. The BarPro device can aid in this process by allowing the user to calibrate their full range of motion for their workout and notifying the user if they are not completing a full repetition of motion by using an ultrasonic height sensor.

Finally, keeping track of repetitions and sets is an important factor of every weightlifting session. Different repetitions and sets are executed by the weightlifter depending on what their goal in working out is. Some people want to build muscle strength and size so they stay in the lower range of repetitions, while others want to build muscle endurance and train with higher repetitions. It is actually recommended to train with less weight and more repetitions if reducing the risk of injuries is desired [3]. Although mentally keeping track of repetitions and sets may be a fairly easy process, lifting heavy weights for a long duration of time does lead to fatigue that may cause a weightlifter to forget what set they are on or how many reps they have completed. BarPro will have the ability to keep track of these repetitions and sets so the user can focus on weightlifting and not worry about doing too little or too many repetitions and sets.

1.3 High-Level Requirements

- Accurately count repetitions of motion during a workout (+/- 1 rep).

- Accurately read the user's barbell tilt angle (~30°) to be set during initial testing.

- Measure the height of motion (bench press: +/- 2cm, squats/deadlifts: +/- 5cm) during a workout.

- Intuitive user interface with buttons and LEDs displays reps and level of bar.

2 Design

The BarPro will require five main component areas to operate as desired. These include the power module, sensing module, control module, user interface and LEDs. The power module will supply the power to run the components of the device. The sensing module contains the accelerometer and ultrasonic sensors needed for device operation. The control module will send and receive data to control various device components. Lastly, the user interface will contain the buttons and LEDs for the user to read and also provide input to the device.

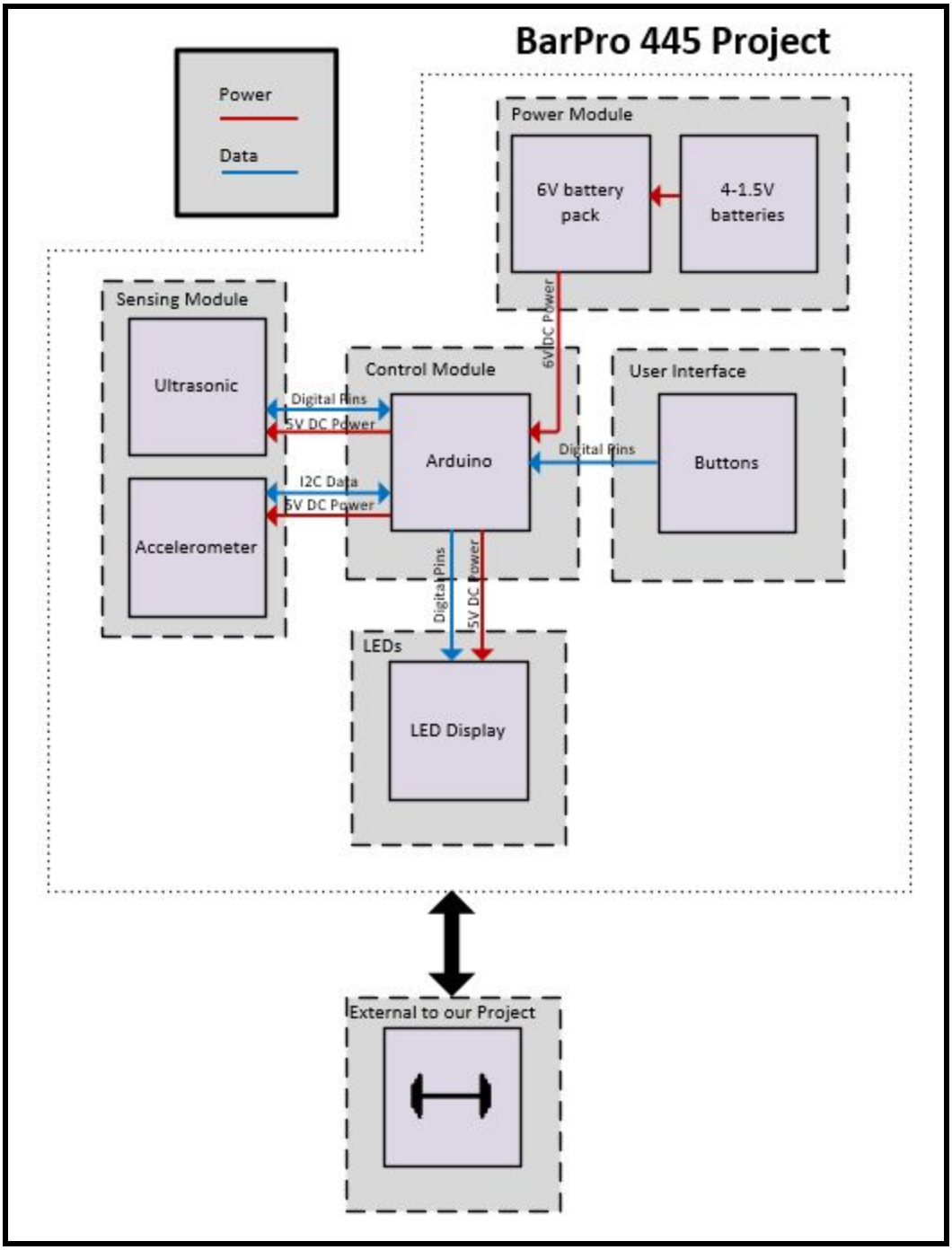

Figure 1. Block Diagram

2.1.1 Power Module

This module is clearly providing the power for the rest of our system. Since we are not working with high voltages or magnetism, this module is simplified to strictly low voltage DC power. The Arduino needs a range of 5-12V to operate, and we currently have 6V battery packs for 4-1.5V

AA batteries, so that was our inspiration for this module. It is possible we will be limited on space implementing it this way, so we might transition to a smaller battery to power our system. There is no data transfer between the power module and the rest of the system, so there will only be two wires leaving this module.

2.1.2 Control Module

This is the entire brain of our system, and we will begin with using a version of an Arduino board for our prototype; depending on the complexity of our program and memory space, this will either likely be a Nano or Uno board. This module will receive 6V DC power from the power module and distribute 5V DC power to the rest of the modules that need it.

Regarding data, the digital IO pins will be used for the majority of our system. Every other module will be connected through digital pins, with the exception that the accelerometer will communicate with the control module with additional I2C protocol. It will have a strict input from user interface, strict output to our LEDs, and input/output to our sensing module.

2.1.3 Sensing Module

Our sensing module is currently composed of two sensors: the accelerometer and ultrasonic sensor. This is where the reps a user is doing will be counted, and the movement/level will be tracked and sent back to the control module for interpretation. The sensors in the sensing module will be wired in parallel to the control module receiving 5V DC power. In terms of data transfer, the sensors will receive a data request from the control module and send back data, one sensor after the other. Both sensors will communicate through digital IO pins, with additional I2C protocol for the accelerometer.

2.1.4 User Interface

This module consists of buttons allowing the user to interact with the control module. It will have a calibration button when beginning a workout, a start/stop button for counting reps,

2.1.5 LEDs

This module will primarily allow the user to see the level of the bar in real-time. Our current idea is to use two RGY SMD LEDs on either side to illuminate to the user the level of the bar. Same idea on both sides, if the bar is under 5° it will show green, 5-10° will show yellow, and >10° will show red. We could also increase the resolution to show smaller increments by displaying together green-yellow and yellow-red lights or blinking the LEDs. Aside from showing level, the LEDs will output an initial pattern of colors to show the BarPro is on when the user turns it on.

2.2 Subsystem Requirements

Subsystem	Requirements
Subsystem #1 - Level Sensor: An accelerometer will be used to measure the level of the barbell. If an unlevel position is measured, an LED will light up and notify the lifter.	1.) If barbell is not level during workout, a notification will be given to user with a sound/beep 2.) If barbell is kept perfectly level or within a set threshold of error, a notification will not be give to user since they are properly doing the workout
Subsystem #2 - Full Repetition Sensor: An ultrasonic or infrared distance sensor will be used to measure the height of the barbell from the ground/body during repetitions. The sensor will first be calibrated by the lifter during a repetition with no weight, and then	1.) User will be able to calibrate minimum and maximum heights of a workout 2.) Device will notify user if they are above or below the set threshold, indicating they are not doing the

that calibration will be used to check if the lifter is having their barbell reach the calibrated maximum and minimum heights.	proper full repetition
Subsystem #3 - LED/LCD Rep/Sets Indicator: LEDs or a LCD screen will be used to display the reps/sets from the data measured by the accelerometer.	1.) Either LEDs or an LCD screen will display the reps/sets that the user has completed during the workout 2.) The user can reset the counter when they start a new workout

2.3 Risk Analysis

Our greatest threat to a successful final project will be a malfunctioning sensing module. The entire system relies on the accuracy of the sensors within it to send back accurate information to the control module for correct parsing and data interpretation. The user interface is very difficult to mess up because it is primarily passive buttons. Faulty LEDs are easily replaceable and programming them comes very easy. The control module accepts a wide range of voltages (5-12V), so the power module providing the wrong power is not a big issue. Arduinos are very reliable, but the control module can malfunction if the code implemented on ours is not optimized or written correctly. This can be an issue, but regardless if our sensors do not have a high tolerance our code (whether written well or not) will not work anyway. So that is how we decided our sensor module is the riskiest module to combine into our system.

3 Safety and Ethics

The product that emerges from completing this project has the possibility of being a fantastic aid to the general public that enhances workouts and body fitness goals. This also comes at the cost of possible misuse causing issues with safety. We do not recognize any ethical issues with the BarPro product. It is simply a device to aid beginners on their workout journey by stopping bad habits with form. To avoid safety issues regarding the BarPro product, only very light weight

will be used for testing purposes. Using light weights will minimize the possibility of injury during testing. When the BarPro is used at the gym, individuals need to make smart decisions about the weight they workout with. The BarPro is only present to ensure proper motion and data tracking, it will not stop a careless individual from pushing their limits too far. This product will have warnings regarding the use of heavy weights which will hopefully steer individuals in the right direction and promote safety measures. These precautions are in line with rule #9 in the IEEE Code of Ethics regarding the requirement to never injure individuals.

References

[1] Ieee.org. 2020. *IEEE Code Of Ethics*. [online] Available at: <https://www.ieee.org/about/corporate/governance/p7-8.html> [Accessed 18 September 2020].

[2] Issaonline.com. 2020. *Shoulder Injuries | ISSA*. [online] Available at: <https://www.issaonline.com/blog/index.cfm/2011/2/11/shoulder-injuries> [Accessed 18 September 2020].

[3] ScienceDaily. 2020. *Military Surgeons Report 'Alarming Frequency' Of Bench Press Injuries*. [online] Available at: <https://www.sciencedaily.com/releases/2018/03/180322124948.htm> [Accessed 18 September 2020].