BENCH PRESS SMART HELPER

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1. Introduction

1.1. Problem

The bench press is by default the best compound exercise to build the chest, triceps and shoulders. It is also the powerlifting exercise to which more injuries are attributed to. A recent study conducted over sub-elite to elite powerlifters showed that up to 46 % of their injuries were caused by the bench press [1], accounting for almost half in some athletes. In order to avoid damage and be able to work out the chest and shoulders, one tends to either lower the intensity of the bench press, or choose other exercises that are not as prone to causing injuries. However, this is far from ideal, as other practices and movements do not encompass all the benefits of the bench press; and clearly, performing this exercise at half intensity does not optimize growth and strength in any way.

Aiming to perform the bench press with a good intensity, one ends up seeking external help, which generally comes from other people at the gym, and is usually deficient and very inconsistent. Aside from this, it is very important to track everything we do during our workouts with numbers, and unpredictable and unstable help from other people is unquantifiable. Furthermore, even if there are individuals who can provide good and consistent aid, it is still not ideal to rely on people to have a good workout at all. Finally, when performing the bench press with a certain amount of weight, going to failure does not necessarily mean not being able to complete more repetitions with the allocated weight. A few more repetitions can always be squeezed out with some help, and that extra effort is essential in maximizing muscle use. Our aim is to guarantee the possibility of putting that extra effort with customized, quantifiable help.

1.2. Solution

Our design will solve three issues: the first one, the reliance on another person when performing the bench press with good intensity and minimized risk of injury; the second one, the unquantifiability and inconsistency of human help; the third one, the inability of going to failure without having to stop performing the exercise, lowering the weight, and going at it again.

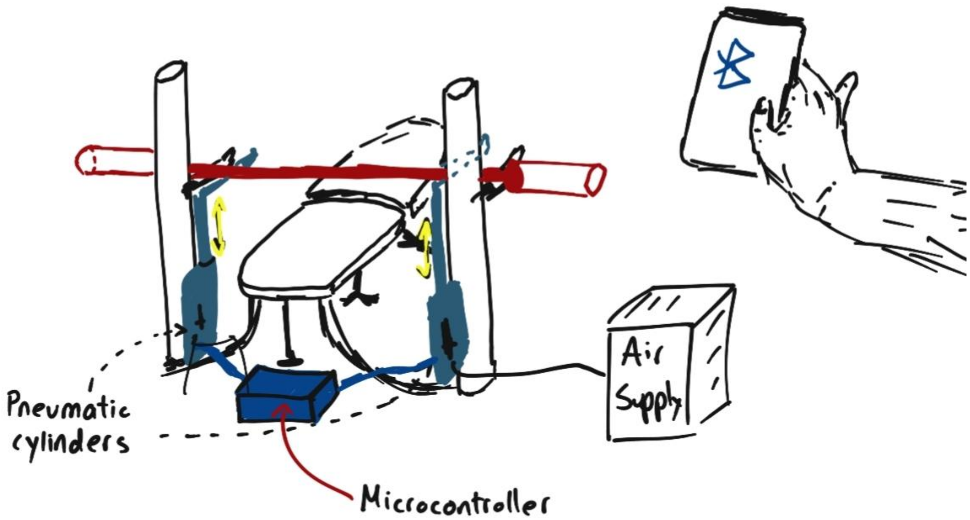
We aim to create a smart machine that solves all of these problems at once. Our solution will simulate the role of the ‘spotter’ in a more sophisticated and complete way. The spotter is the person at the gym who helps another perform an exercise; their task is to actively follow the motion of the lifter, correct any mid-exercise misforms, and ultimately, provide an extra hand for the person to lift the weights. However, unlike a real spotter, our system will be able to accurately control the amount of help it delivers, when it delivers it, and for how long.

Our idea is that the lifter, prior to performing the bench press, inputs the amount of weight he or she will move, the repetitions to be performed, and how much help is desired during which repetitions. Say, the person wants to lift forty-five pounds, and is generally able to perform eight repetitions with that weight without help; if he or she wants to perform two more repetitions (ten in total) with ten percent less of the weight, he or she should specify that to the system; the machine will track the movement, and on the ninth repetition, a canceling force will be applied to lay off the specified amount of weight. This will help the lifter maximize muscle use and go to failure in a safe manner. Our other idea is that the machine is able to detect imminent failure: if the lifter has not been able to move the weight for a certain amount of time, a signal will be sent to the force-exerting mechanism, and the entire weight will be lifted.

The first goal of our project is to help the lifter minimize the possibility of getting injured; The second goal of our project is to help the lifter maximize muscle use by providing a controlled, specified amount of help.

The weight-canceling force will be exerted by two pneumatic cylinders, each placed below opposite ends of the barbell, and the amount of force they apply on the barbel will be regulated by a microcontroller.

1.3. Visual Aid



1.4. High-Level Requirements List

1.4.1. Repetition Tracking

Our system must be able to follow the motion of the barbell and successfully track repetitions performed by the lifter.

1.4.2. Weight Reduction

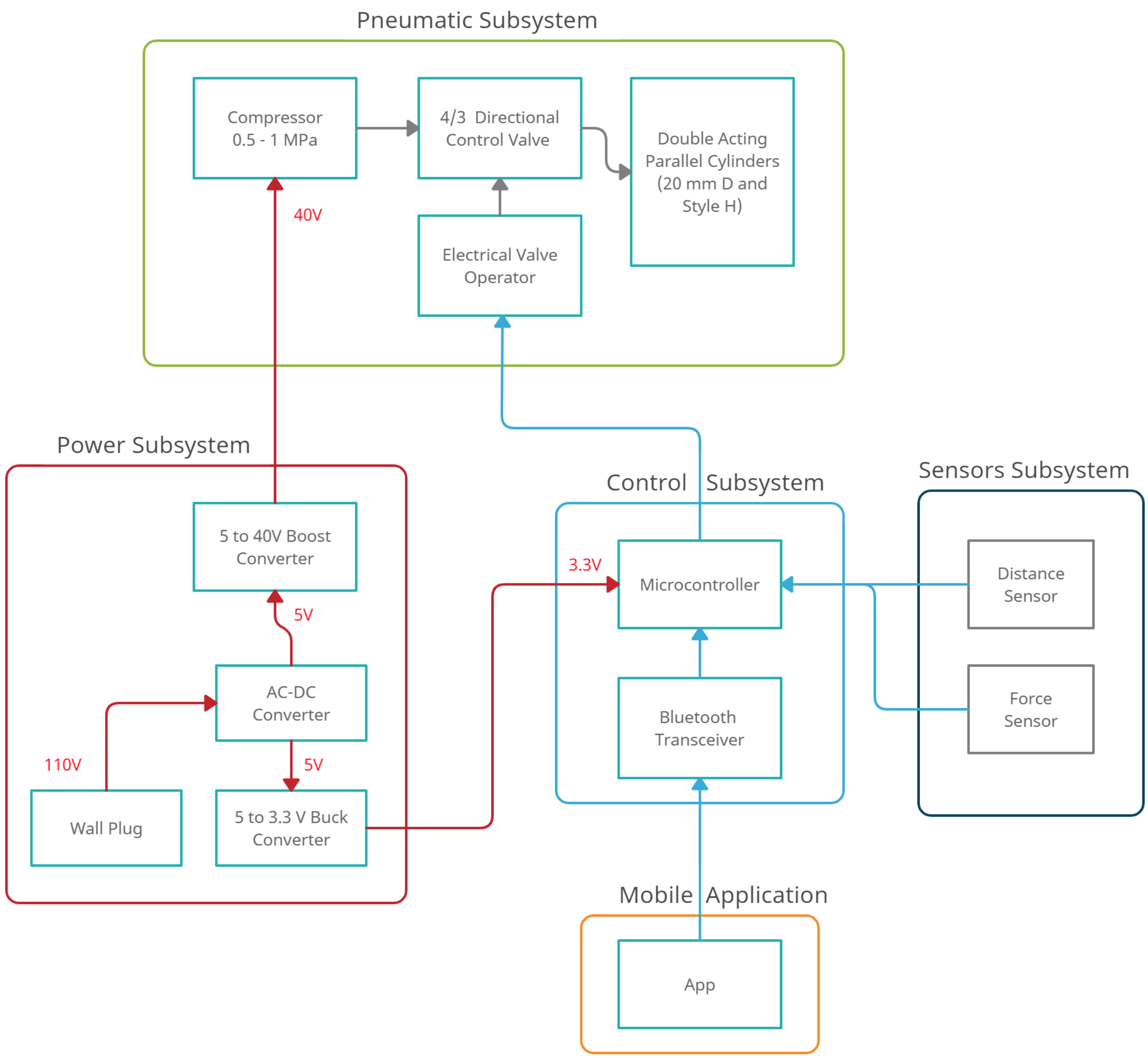
Our design must be able to help the lifter by laying off the specified amount of weight from the barbell. The amount will be given in the form of a percentage. There will be two pneumatic cylinders that apply a constant force upwards to each side of the barbell. The amount of force it applies will be specified by the lifter previously.

1.4.3. User Control

Our system will be externally controlled. The lifter will input the amount of repetitions he or she wants to perform, and then specify on which of those repetitions he or she wants help, and how much.

2. Design

2.1. Block Diagram



2.2. Subsystem Overview & Requirements

2.2.1. Power Subsystem

This subsystem will be in charge of regulating the power that goes into each component of our design. It consists of:

- Wall Outlet: starting point of our power supply; will provide around 1800 W of power at 120 V from the grid.

- AC-DC Converters: will convert the voltage supplied by the wall outlet from AC to DC through a IRM-10-5 converter which supplies adequate voltage and is reasonably efficient.

- DC-DC Converters: given the different needs of the systems and control unit, they will be powered using LT3467/LT3467A (boost) and LM2576-5.0WU (buck) converters to prevent component damage due to voltage fluctuation.

2.2.2. Pneumatic Subsystem

The force upon the barbell will be exerted by two pneumatic cylinders, one on each end. This subsystem will be in charge of exerting the physical force on the barbell and be able to move it upwards. The decision of using this mechanism is based on a study of the Milwaukee School of Engineering **[2]** Its requirements are:

- Pneumatic Cylinders: most commercially available pneumatic cylinders are equipped with a 20 mm bore diameter, which is more than enough for our purposes. The one that would fit our needs the most would be Double Acting Style H Cylinders.

- Compressed Air Supply: powers the pneumatic cylinders; ideally found in university laboratories. To achieve the desired force of 45 Pound-Force (which is the weight of an olympic barbell), the pneumatic piston needs to operate under a pressure of 0.637 MPa. Most cylinders available can operate under up to 1 MPa.

- 4/3 Directional Control Valve: in order to be able to expand, retract and keep our cylinders at a stationary position, a 4/3 Electrical Controlled DCV would meet our requirements.

2.2.3. Sensors Subsystem

The sensors subsystem will be in charge of sending the electrical signals that generate the data to be processed by the microcontroller. Its component and requirements are:

- Distance Sensors: sharp, long range infrared sensors that actively measure distance and output an analog voltage proportional to a specific target's range. An affordable and suitable option for our design is the Sharp GP2Y0A710YK0F Long Range IR Distance Sensor **[3]**, which has a working range of 100 cm to 550 cm. Ideally we would prefer to use sensors like the SP1-25 Wire Position Transducer; however, that option seems far-fetched since it is way beyond our given budget.

- Force Sensor: provides constant feedback of how much weight the machine is lifting when it is operating (a way of comparing how much weight is falling over the pneumatic sensors vs how much the person is actually lifting). A proper sensor is the FlexiForce™ A301 Sensor **[4]**. The dynamic range of this force sensor can be modified by changing the drive voltage and adjusting the resistance of the feedback resistor. The sensors are available in three force ranges: Low 4.4 N (0 - 1 lb), Medium 111 N (0 - 25 lb) and High 445 N (0 - 100 lb).

2.2.4. Control Subsystem

This subsystem will be in charge of retrieving and analyzing the data from the sensors subsystem, and sending back information to the pneumatic subsystem. It consists of

- Microcontroller: 16-bit dsPIC microcontroller; receives the data sent from all sensors and inputs, and tells the pneumatic subsystem at what pressure it should operate to exert the required amount of force over the barbell.

- Bluetooth Transceiver: establishes communication between the user's phone and the microcontroller of our system. It will receive the desired number of repetitions to be performed without support and also enable/disable the emergency activation system.

2.2.5. Mobile Application

A mobile application with a simple design and very manageable. It will be used as a controller device where the user will select the mode he wants the smart helper to perform. Moreover, if the pre-election mode is chosen, the application will ask the user the number of repetitions and the intensity of the help prior to the exercise. This application will be connected via Bluetooth to the bench press helper.

2.3. Tolerance Analysis

One of the most challenging tasks of our project is integrating the two position sensors in the most accurate way possible. The sensors we are planning to use have a working range of 100 to 550 centimeters. An imprecise placement of them will lead to incorrect readings of the microprocessor about the distance between the barbell and the user. If this happens, the microprocessor might send a signal to the machine to start acting when it is not supposed to. Or in a worse scenario, it will send a signal to one cylinder sooner than it does to the other one. This will probably end up in an incorrect execution of the exercise, or even worse, in injuries.

3. Ethics and Safety

As stated in the IEEE Code of Ethics I.1: "to hold paramount, the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to promptly disclose factors that might endanger the public or the environment" **[5]**. One of our main objectives is to reduce the risk of injury during the exercise. Therefore, the development of a secure and safe design will be a priority in our project.

According to the ACM Code of Ethics and Professional Conduct 1.3: "Honesty is an essential component of trustworthiness. A computing professional should be transparent and provide full disclosure of all pertinent system capabilities, limitations, and potential problems to the appropriate parties."**[6]** Since our project involves the user's physical integrity, we are aware of the need to warn and report about the limitations of our product. We will not consent to false statements about the capabilities of our system. More specifically, we will inform users about the maximum weight our machine can lift safely, including and considering a safety coefficient.

Finally, regarding group members and other students' safety, we will strictly follow the rules of the laboratory while working there. We will always wear the required protective gear. We will work dutifully and responsibly. We will never question lab policies, and condone activities such as working alone or taking food or drinks into the lab space.

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