LiftSense - Olympic Weightlifting Technique Analyzer

Team 2 - Ethan Filzone, Chase Johnston & Rohin Kumar
ECE 445 - Project Proposal - Fall 2019
TA: Jonathan Hoff

1. Introduction

1.1 Objective

Olympic weightlifting is a sport that comprises of two lifts - the clean & jerk and the snatch. The clean & Jerk is the movement of a barbell from the ground to the shoulders, then from the shoulders to overhead. The snatch is the movement of a barbell from the ground to overhead in one movement. Both of these lifts require a very high level of technique and years to master. The optimal technique for both of these lifts is for the barbell to travel at a 180-degree angle from the ground to overhead with little deviation. Also, it is imperative to accelerate the barbell as fast as possible between the first pull (ground to above the knee) and the second pull (above the knee to either shoulders or overhead). All this must be done while maintaining a high velocity on the barbell throughout both pulls of the lift.

The main challenge with Olympic weightlifting is developing the precise technique required for a successful lift. Many recreational Olympic weightlifters do not have access to a coach who watches and critiques their every lift. Furthermore, a phone camera is not a viable solution to improving technique since it is unable to determine acceleration and velocity at the respective positions of the barbell. Also, a phone camera is often unable to determine the barbell path with a high level of precision necessary for these lifts.

Our solution is to create two lightweight attachments that will be placed on either end of the barbell. These attachments will be equipped with a high-performance inertial measurement unit (IMU) to determine position, velocity, acceleration of the barbell as a function of time. This data gathered from the IMU will be processed and displayed on a phone application that will allow Olympic weightlifters to receive near-instantaneous feedback of each lift.

1.2 Background

The need to understand the position, velocity and acceleration of the barbell throughout an Olympic lift cannot be understated. Chinese Olympic lifters routinely use an “Instant Lift Assessment System Presentation”, which is a Microsoft Kinect camera system that provides real-time measurement and instant feedback of barbell path, barbell height, barbell velocity, barbell acceleration, horizontal barbell displacement [1]. This system is used for every professional Chinese weightlifter during every training session thus demonstrating the importance of such metrics. Unfortunately, these systems are very expensive and are unrealistic

for the recreational Olympic weightlifter. On the other hand, a few app developers have created phone applications to track the barbell path. However, these applications do not track velocity and acceleration as a function of barbell position which is a very important metric for Olympic weightlifting. Although phone applications are a more viable solution for the recreational Olympic weightlifter, numerous reviews of these applications have reported inaccuracies in these applications concerning the barbell path tracking [2].

LiftSense barbell attachments will accurately capture the important metrics necessary for improving Olympic lifting technique while being at an affordable price for the recreational Olympic lifter or small gym owners.

1.3 High-Level Requirements List

- Both of the LiftSense barbell attachments must be relatively low cost, ideally under $200.
- The Olympic weightlifter must be able to see the position, velocity, and acceleration of the barbell as a function of time on the phone application within at most 5 minutes after completing the lift.
- Both of the barbell attachments must not exceed 5 pounds each, and the difference between the weight of each attachment must not exceed 1 pound.

2. Design

2.1 Block Diagram

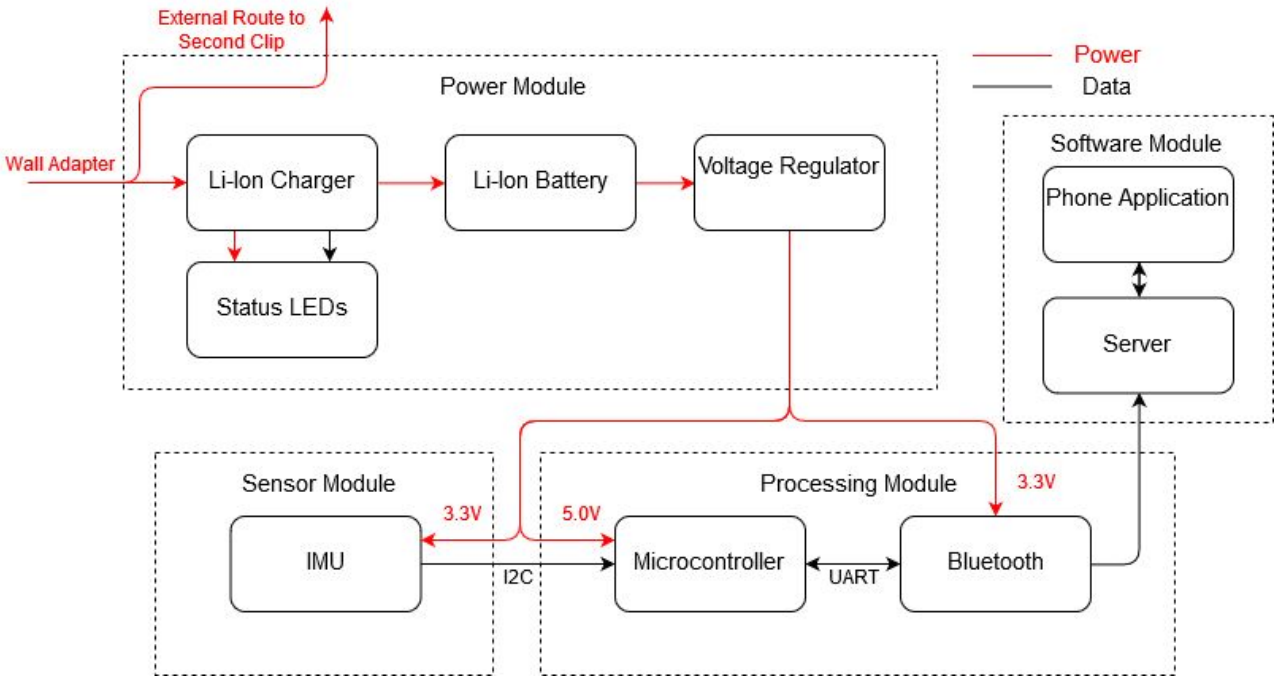

Figure 1. Block Diagram

LiftSense barbell attachments require four modules for successful operation: a power module, a sensor module, a processing module, and a software module. The power module is intended to provide power to the LiftSense barbell attachments for a minimum of two hours. The sensor module contains the IMU that will gather the various data needed to display position, velocity, and acceleration of the barbell as a function of time. The processing module serves as the interface between the sensor module and the software module. The software module will perform post-processing on the data gathered from the IMU and display the metrics from the data in a user-friendly format through a phone application.

2.2 Physical Design

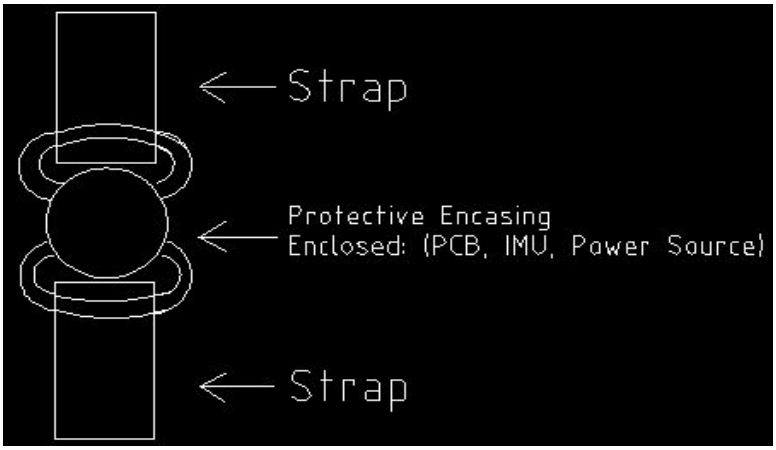

Figure 2. Physical Design

The figure above is a rough sketch of a LiftSense barbell attachment. There will be two of these attachments, each of which will be strapped on the outer ends of the barbell. The material used for the straps and the protective encasing have not been decided upon yet. Also, the specific dimensions for the strap and protective encasing has not been decided upon yet since it is dependent on the size of the printed circuit board, inertial measurement unit, and power source. The only measurement specification that is currently known is that the length of the entire attachment must be at least ~157mm, which is the circumference of the outer ends of an Olympic lifting barbell.

2.3 Functional Overview & Block Requirements

2.3.1 Li-Ion Charger

LiftSense barbell attachments will use rechargeable Lithium-Ion batteries so that the device will be portable and able to attach to the barbell without needing to be plugged into a wall outlet. Therefore, a charger is necessary to convert 120 V AC from the wall into the 3.7 V DC necessary to charge the battery.

Requirement 1: The Li-Ion battery must not exceed its operating limit of 45°C during charging.

2.3.2 Li-Ion Battery

Each of the attachments will need a rechargeable Lithium-Ion 3.7 V battery to power the IMU, Bluetooth, and microcontroller. The battery will need to be compact to fit within the encasing containing the other components.

Requirement 1: The voltage on the Li-Ion battery must be between 3.7V - 4.2V.
Requirement 2: The Li-Ion battery must never exceed an operating temperature greater than 60°C during use.

2.3.3 Voltage Regulator

Since some components are rated at a lower voltage than others, various voltage regulators are necessary to meet the voltage needs of each component. This component will take the DC voltage from the Li-Ion batteries and lower the voltage so the other components can be powered safely.

Requirement 1: The voltage regulator must regulate the voltage of the Li-Ion battery to 2.4V - 3.6V for the IMU.
Requirement 2: The voltage regulator must regulate the voltage of the Li-Ion battery to 1.8V - 5.5V for the microcontroller.
Requirement 3: The voltage regulator must regulate the voltage of the Li-Ion battery to 1.8V - 3.6V for the Bluetooth component.

2.3.4 Status LEDs

Status LEDs will be used to show whether the Lithium-Ion batteries are charging (Indicated by a red LED) or fully charged (Indicated by a green LED).

Requirement 1: When the Li-Ion batteries are charging, the status LED must be a red LED.
Requirement 2: When the Li-Ion batteries have been fully charged, the status LED must be a green LED.

2.3.5 IMU

The IMU (Inertial Measurement Unit) is the component that will be used to determine position, velocity, acceleration of the barbell as a function of time. This raw data will be sent to the microcontroller.

Requirement 1: The IMU must operate between 2.4V - 3.6V.
Requirement 2: The IMU must not exceed an operating temperature of 85°C.

2.3.6 Microcontroller

The microcontroller will take data from the IMU and send it to the Bluetooth module. It will act as the data line masters for both the IMU and Bluetooth. The microcontroller's memory will be used to hold the programs for data collection, processing, and transfer from IMU to Bluetooth.

Requirement 1: The microcontroller must operate between 1.8V - 5.5V.
Requirement 2: The microcontroller must not exceed an operating temperature of 85°C.

2.3.7 Bluetooth

Bluetooth will package and send data received from microcontroller to a data server. This will allow wireless data collection and the ability to interface with a mobile phone application.

Requirement 1: The Bluetooth to Serial Port Module must operate between 1.8V - 3.6V.

2.3.8 Server

The server will collect data and provide an easy interface for the phone application to collect from. This is important because there will be large amounts of data collected per lift and this data needs to be collected and organized in an easily accessible way.

Requirement 1: The server must be able to store the appropriate amount of data for each performed Olympic lift.

2.3.9 Phone Application

The phone application will take the data from the server and present it in a meaningful way by providing feedback to the user on their Olympic lift. This is the component that enables our users to interact with the device and is critical to the end goal of this project.

Requirement 1: The phone application must take the data from the server and present The metrics in a user-friendly interface via an android application.

2.4 Risk Analysis

The most challenging block that poses the greatest risk to the successful completion of this project is the software module. The software module is where the raw data from the IMU is post-processed and displayed to the Olympic weightlifter in a user-friendly format via a phone application. The difficulty lies in determining the position, velocity, and acceleration of the barbell as a function of time. This can be attributed to the fact that the barbell rotates while simultaneously moving in the x-y-z directions. This essentially throws off the reference frame of the IMU, since the IMU will have rotated positions from where it had essentially started. Understanding the mathematics for how the raw data from the IMU can be converted into position, velocity, and acceleration of the barbell as a function of time will be instrumental in how successful this project is.

3. Ethics and Safety

One of the largest concerns associated with this project is the potential dangers of Lithium-Ion batteries, which have been known to malfunction and explode. Although Lithium-Ion batteries typically have built-in protection against overcharging, this malfunction could lead to serious injuries or even death, which is why these risks be addressed. While the chances of explosions occurring are very small and usually only happen in poorly made Lithium-Ion batteries, it is still important to design LiftSense barbell attachments with the risks of overheating in mind in accordance with IEEE Code of Ethics #1 - “To hold the public safety first and to disclose factors of our project that might endanger the public” [3]. To mitigate these issues, Li-Ion batteries will need to be charged while the device is not in use. Additionally, the components within the encasing (PCB, IMU, and Li-Ion batteries) will be properly compartmented to avoid overheating as much as possible.

Also, it will be important to adhere to the IEEE Code of Ethics #3 - “To be honest and realistic in stating claims or estimates based on the available data.” [3]. To comply with this statement, mathematical formulas and derivations will be utilized throughout the process of converting the raw data from the IMU to displaying position, velocity, and acceleration as a function of time. This will ensure that the user can be confident that the data visualized on the phone application is accurate and will be advantageous to improving their Olympic lifting technique.

Finally, it is imperative to adhere to the IEEE Code of Ethics #9 - “To avoid injuring others, their property, reputation, or employment by false or malicious action.” [3]. Specifically, it is crucial that the LiftSense barbell attachments are secured on the barbell and cannot injure the user during a lift. As a result, appropriate measures will be taken to minimize the chance of these attachments flying off the barbell and potentially injuring the weightlifter or any bystanders. Also, LiftSense barbell attachments should not damage/scratch the barbell that they are strapped on.

References

[1] G. Winter, “Chinese Weightlifting Instant Lift Assessment System Presentation,” All Things Gym, 29-Jan-2017. [Online]. Available: https://www.allthingsgym.com/chinese-weightlifting-instant-lift-assessment-system-presentation/ .

[2] “BarSense Weight Lifting Log - Apps on Google Play,” *Google*. [Online]. Available: https://play.google.com/store/apps/details?id=com.barsense.main&hl=en_US.

[3] IEEE, “IEEE Code of Ethics,” 2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html.

[4] Adafruit Industries, “Adafruit Micro-Lipo Charger for LiPo/LiIon Batt w/MicroUSB Jack,” *adafruit industries blog RSS*. [Online]. Available: https://www.adafruit.com/product/1904?gclid=EAIaIQobChMIoYDNtu7T5AIVCsNkCh2wOwjpEAQYASABEgLEsvD_BwE. [Accessed: 16-Sep-2019].

[5] “ATmega328P,” *ATmega328P - 8-bit AVR Microcontrollers*. [Online]. Available: https://www.microchip.com/wwwproducts/en/ATmega328p. [Accessed: 16-Sep-2019].
[6] “HC-05 - Bluetooth to Serial Port Module,” *Electronica Estudio*. [Online]. Available: http://www.electronicaestudio.com/docs/istd016A.pdf. [Accessed: 16-Sep-2019].
[7] “MPU-9250 Hookup Guide,” *MPU-9250 Hookup Guide*. [Online]. Available: https://learn.sparkfun.com/tutorials/mpu-9250-hookup-guide. [Accessed: 16-Sep-2019].