Deadlift Assistant Plus

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1 Introduction

1.1 Objective

The deadlift is one of the top three popular weight training exercises along with the squat and the bench press. Yet, it is considered the most difficult amongst the three of them due to the weight involved in it. Many people tend to do the deadlift in a poor form to successfully complete the attempt, but end up hurting their backs or spines. They do not realize that they are doing the deadlift in the wrong way because they tend to avoid having an expensive lesson from a personal trainer.

Our solution will focus on preventing injuries while doing the deadlift by alerting the users whenever they are doing the deadlift in a poor form. We aim to make this cheaper than having the lesson from the personal trainer. A video camera with computer-vision will record the deadlift performance from the user and provide instant feedback on their forms by making a sound alert if the deadlift form is poor. The user will wear a color wristband which can be recognized by the computer-vision that the deadlift has been started. The wristband will also measure the heart rate of the user, and warns the user if the heart rate goes too high with a sound alert. In addition to the alert, the user will also be able to get the overall feedback on how their form got better or worse over time, as well as their heartbeat data. This will help users track their deadlift training and motivate them to improve their form.

1.2 Background

Deadlift is infamous for its risk when it is done in a poor form [1]. The reason for this happening is because of the weight that is involved in it. Normally people will start with 1.5 times of bodyweight for the deadlift barbell, which is approximately 315 pounds [2]. Considering that you are carrying a person similar to your weight with the power of your back only, the deadlift is definitely a challenging exercise.

The study shows that the professional weight trainers get back injuries from the deadlift 31% of the time [3]. Compared to the other popular weight exercise, the percentage is twice as high. This is what happens for the professional weight trainers, and it is obvious that those who are not professional in weight training will get more injuries due to the poor form.

Compared to the original project done by the team #32 in Fall 2019, the one major difference will be the targeted customers. Our product is more for the personal use than the public use. The original project uses barbell subsystem, which can be used by anyone in the public space like a gym. The original project can be bought by the gym and the product can be shared for anyone doing the deadlift. Our product is opposite of that; the product is more for the personal use. The

wristband is highly recommended to be used by one person at the time. Since we are in adifficult situation of where we need to avoid social contact, a personal device is more favorable than a shared device.

Instead of attaching the device on the barbell, wearing a wristband can prevent the balance issue when doing the deadlift. In the original project, the barbell subsystem is attached to the barbell itself, and this can possibly affect the balance of the barbell - causing poor deadlift form. A light-weight wristband can solve this issue and it reduces the amount of stuff to carry when going to the gym.

Since the product is for the personal use, we added the heart rate sensor on the wristband. Having too high heart rate can cause an issue when exercising. It is recommended to stop exercising when the heart rate is too high, and the wristband will emit a warning sound to enforce this. This sound alert will be different than the sound alert from the bad form.

The sound alert system is also a huge difference compared to the original project. The original project uses an LED indicator to inform the user. Yet, it is very difficult to see the LED indicator while doing the deadlift. The sound alert is much easier to notice even when the user cannot see the LED indicator.

We have mentioned two feedback systems in the above: the deadlift form feedback sound alert and the heart rate feedback sound alert. We have one more feedback system, which is a log of how well the user did for the entire workout. This will help the user track their improvements and motivate them to fix their forms. A percentage-based system on top of a binary good or bad alert system helps not only beginners but also slightly more experienced users to perfect their form over time.

The ease of set up is what distinguishes our project from the original project. The original project needs to attach a barbell subsystem on the barbell and the user needs to make sure the barbell is properly balanced. Instead of using a barbell subsystem, we are using the wristband subsystem which is very easy to set up. You just need to wear the wristband on the wrist. Also, the camera subsystem will be literally a camera with a tripod. This will be very small so that you can carry it inside a bag when going to the gym.

1.3 High-Level Requirements

- The system must recognize form that poses potential harm to the user and emit an alert sound in less than 0.5 second.
- The camera subsystem must be able to make the alert sound when the heart rate of the user reaches 180 beat per minute.
- Both wristband and camera must be able to run for at least 1 hour continuously to satisfy the regular workout time.

2 Design

Our entire design is simply compromised of two subsystems: wristband subsystem and camera subsystem. The wristband subsystem will be worn by the user and it will measure the heart rate of the user while doing the deadlift. The heart rate data will be sent to the camera subsystem through Bluetooth.

The camera subsystem is a camera with the tripod. This will be set next to where the user will be doing the deadlift and capture the motion of deadlift attempt. The camera lens will capture the motion in video, and the single-board computer inside the camera will process through computer-vision. If the deadlift form is good, then there will be no feedback, but if the deadlift form is bad, then there will be instant feedback from the camera with the unique alert sound through the speaker. The unique color of the wristband will act as the indicator for the computer-vision to understand that the deadlift attempt has started.

The heart rate data sent from the wristband is processed by the single-board computer and if the heart rate is too high, it will alert the user. For our product, we are going to set it at 180 beats per minute, which is the average maximum heart rate at 100 percent exertion [4]. Once the heart rate is above 180 bpm, the unique alert sound will be made through the speaker. This is different from the sound for the deadlift form feedback.

The overall summary of successful deadlift attempts will be shown through the LED display at the end of entire deadlift exercise.

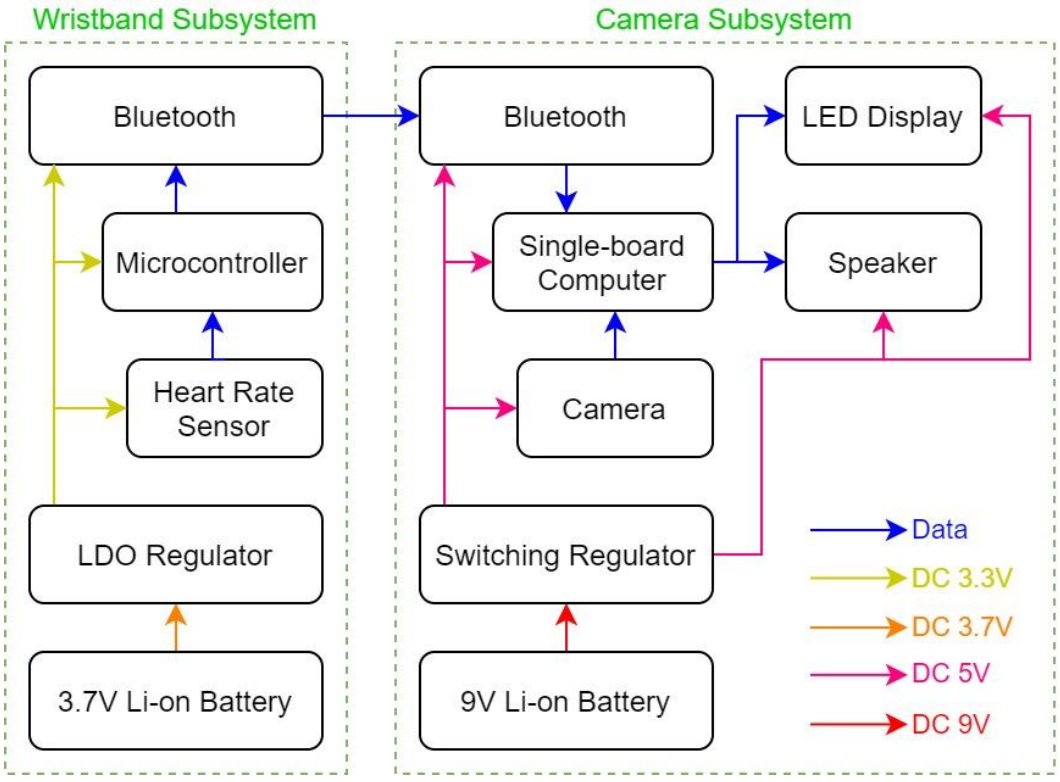

Figure 1. Block Diagram Wristband Subsystem and Camera Subsystem.

2.1 Wristband Subsystem

This is just a wristband that the user can wear it. It contains the heart rate sensor, the microcontroller, Bluetooth module, the LDO regulator, and 3.7V Li-on battery. The heart rate sensor will measure the heart rate of the user, and the microcontroller is used to process that and send the heart rate data to the camera subsystem via Bluetooth. All of these components will be powered by low-dropout voltage regulator that converts 3.7V to 3.3V.

2.1.1 Heart rate Sensor

The heart rate sensor monitors the heart rate of the user and warn the user if the heart rate is too high. The heart rate data will be sent through the microcontroller via Bluetooth to the camera subsystem. This will be powered by 3.3V.

Requirement: The heart rate sensor must be able to constantly measure the heart rate of the user in beat per minute.

2.1.2 Microcontroller

The microcontroller processes the heart rate data sent from the heart rate sensor and sends it to the camera subsystem via Bluetooth. The heart rate sensor itself cannot really measure the heart rate data, so the microcontroller needs to assist in order to convert it into digital data. This heart rate data will be sent to the camera subsystem through Bluetooth. ATmega328 will be used.

Requirement 1: The microcontroller must be able to digitize the heart rate signal from the sensor to the digital data.

Requirement 2: The microcontroller must be able to communicate with the Bluetooth module and send the heart rate data to the camera subsystem.

2.1.3 Bluetooth

The Bluetooth module communicates between the wristband and the camera subsystem to send the heart rate data. This will act as the wireless communication between the wristband and the camera subsystem.

Requirement: Bluetooth module from the wristband must be able to send the heart rate data to the camera subsystem.

2.1.4 LDO Voltage Regulator

An LDO voltage regulator converts 3.7V to 3.3V. An LDO voltage regulator is used because the dropout voltage needs to be small and the device on the wristband need to be small. The circuit size will be small as the number of components attached to LDO voltage regulator is smaller than that of switching regulator.

Requirement: LDO voltage regulator must provide 3.3V$\pm$5% from a 3.7-4.2V source.

2.1.5 DC 3.7V Li-on Battery

3.7V Li-on battery will be used to power the wristband subsystem. 3.7V DC will be converted to 3.3V DC so the entire wristband subsystem can be powered. The battery will be small so that the user cannot feel much weight from it while doing the deadlift.

Requirement: The battery must be able to store enough charge to operate at least 1 hour once fully charged.

2.2 Camera Subsystem

The camera subsystem contains a camera lens, the single-board computer, Bluetooth module, the speaker, the LED display, the switching voltage regulator, and 9V Li-on battery. The video recorded through the camera lens will be analyzed by the single-board computer through the computer-vision. The computer-vision algorithm will use OpenCV to detect the motion of the body movement [5]. The alert sound will be made if the deadlift form is poor after the analysis. The analysis will be done in real-time.

The Bluetooth module will be used to communicate between the wristband and the camera so the heart rate data can be received to the single-board computer. If the heart rate is above 180bpm, the alert sound will be made. This alert sound will be different from that of the deadlift form analysis alert sound.

The final summary result of proper deadlift attempt is shown through the LED display. Each attempt will be stacked accordingly in the single-board computer memory. The result is calculated in percentage and displayed on the LED display.

All the components in the camera subsystem are powered by the switching regulator with a 5V conversion from the 9V battery.

2.2.1 Camera

The camera lens captures the video of the deadlift attempt of the user. The video will be recorded and analyzed on the single-board computer.

Requirement 1: The camera lens must be able to communicate through MJPEG with the single-board computer.

Requirement 2: The camera lens must be able to record in 480p resolution at 15fps.

2.2.2 Single-board Computer

The single-board computer processes the computer-vision so the deadlift form can be analyzed after receiving the video through the camera lens. The user's heart rate will be also monitored. The overall summary report of successful deadlift attempt will be calculated. For this project, Raspberry Pi 4 will be used.

Requirement 1: The SBC must be able to communicate with MJPEG to receive the deadlift video.

Requirement 2: The SBC must be able to communicate over Bluetooth to receive the heart rate data.

Requirement 3: The SBC must be able to calculate and stack in memory the data to display the summary report on the LED display.

2.2.3 Bluetooth

Bluetooth module communicates between the wristband and the camera subsystem to send the heart rate data. This will act as the wireless communication between the wristband and the camera subsystem.

Requirement: Bluetooth module from the camera subsystem must be able to receive the heart rate data from the wristband.

2.2.3 Speaker

The speaker outputs the alert sound when the bad deadlift form is detected or when the heart rate is too high. These two unique alert sounds are different so the user can distinguish them.

Requirement: The speaker must be able to make the alert sound based from the signal received from the SBC.

2.2.4 LED Display

The LED display displays the entire workout summary report. The result shows the total number of deadlifts attempts since the device started and the total number of successful deadlift attempts. The percentage of successful attempts over the total attempts is also shown.

Requirement: The LED display must be able to display the result calculated from the SBC.

2.2.5 Switching Voltage Regulator

A switching voltage regulator will convert DC 9V to DC 5V. Instead of using LDO voltage regulator, the switching voltage regulator is used to save the battery life. The single-board computer and the camera will consume lots of battery power and the switching voltage regulator will definitely help. The audio output might get a slight bit of noise due to the switching property of the regulator, but the quality of the audio is not a big deal for this product.

Requirement: The switching voltage regulator must provide 5V±5% from a 9V source.

2.2.6 DC 9V Li-on Battery

9V Li-on battery is used to power the camera subsystem. DC 9V will be converted to DC 5V so the entire camera subsystem can be powered.

Requirement: The battery must be able to store enough charge to operate at least 1 hour once fully charged.

2.3 Risk Analysis

The hardest part of this project is without doubt the computer vision algorithm that detects the gloves and determines their position. The software will also detect how bent the person's back gets while lifting. A noisy detection that results in false positives or false negatives can be very dangerous so we will need to figure out everything needed to get accurate detection. Different lighting conditions and different positions of the person related to the camera will make it difficult to make confident decisions.

Additionally, it might be difficult to design a wristband that is big and unique enough for the algorithm to detect; while also making sure it is comfortable. An ergonomic design is important because if it is uncomfortable people would not use it. It could also distract people while lifting and worsen their form which instead of improving it.

3 Ethics and Safety

The IEEE Code of Ethics #9 states that "avoid injuring others, their property, reputation, or employment by false or malicious action" [6]. In order to satisfy this Code of Ethics, this product aims to reduce the risk of injury and it is very important that it does not do the opposite by causing an injury. No matter how perfect a computer vision algorithm is it is prone to errors. If the user trusts the product completely, the user might injure themselves. We should make it clear to the user that they must pay attention to their form and proceed with care regardless of what the product says.

The other concern is the Lithium-ion batteries. We are using total of two Lithium-ion batteries: one on the wristband and one on the camera. The Li-on battery on camera is not a huge issue, but the Li-on battery on the wristband needs careful attention. Li-on battery is known for its potential risk of explosion, and we will prevent this by making sure there is no shorting of the circuit and the circuit has the protection to prevent over charging [7].

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