Muscle Activation Sensor System (MASS)

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1. Introduction

1.1 Background

There are numerous protocols suggested for lifters to improve their strength and muscle size, but it can take months to learn how to perform them with proper form, or what set and rep schemes are ideal for the person at that time. Skills like the mind-muscle connection and form have to be learned by trial and error, but could be learned much faster using EMG data. Advanced lifters could determine if reducing the weight and slowing down the reps on their exercises produce equivalent or improved muscle activation, and could then confidently perform those slower reps, which provide less of an injury risk.

Additionally, people who are developing degenerative muscle diseases may not know about it for months or years after the onset of a disease. Earlier detection with EMG sensors allows for improved prognoses and reduced medical bill and insurance costs.

1.2 Objective

Our project is an inexpensive, reusable EMG sensor that gives user's muscle activation data for optimizing their workouts themselves, on the go. It will also be able to refer user's to see a doctor if it detects frequent fibrillations that indicate a certain class of muscular degenerative disease.

It will consist of electrodes connected to an Atmel microprocessor that will send data to the user's phone for viewing in an app. The microprocessor will connect to a bluetooth modem, filters, a mixer, and the electrodes so the data received in the Atmel chip is filtered and amplified to be comprehensible for further processing. The device will be powered by a button cell battery.

EMG requires two electrodes to detect one muscle's activation, so the electrode that is not connected to the microcontroller (instead on a bone or joint; not on the muscle belly) will connect to the rest of the sensor using flat wires. The device would come with pre-cut gauze squares and 90% rubbing alcohol for cleaning the sites of electrode placement, as well as a manual with pictures of placement for each muscle. Data visualization and a user interface will reside in the Android app.

The microprocessor and hardware filters will be used to make the raw data readable for the Android phone app. The app will take readable data and separate it into differential muscle activations, as well as display it on a graph and detect fibrillations over time.

An additional idea would be to include an LED that lights up on the main electrode (housing the microprocessor and lying on the muscle belly) whenever the user can be said to be achieving a goal muscle activation amount. Also, I have reached out to a professor at the University of Pittsburgh about his patent on a dry electrode and if it is on sale. Such an electrode would simplify the search

for an appropriately reusable electrode. If those electrodes are not available,, we will include an electrolyte solution for the user to apply to their skin after the rubbing alcohol.

Another company has built a similar system (called Athos) consisting of clothes that incorporate EMG sensors and also track muscle activation, as well as calorie consumption, and heart rate. It does not consider fibrillation detection. The suit is $696 to track the whole body, and so our project aims to make a much more cost-effective solution, in addition to tackling the problem of diagnosing some degenerative muscle diseases [1]. We are not interested in tracking calories or heart rate, though calories are important for weight-training.

1.3 High-level requirements list:

Top 3 requirements from below

- The device must be easy to wear and take off while providing comfort for the users. This requirement also needs to address power delivery as it directly relates to the weight of the device.

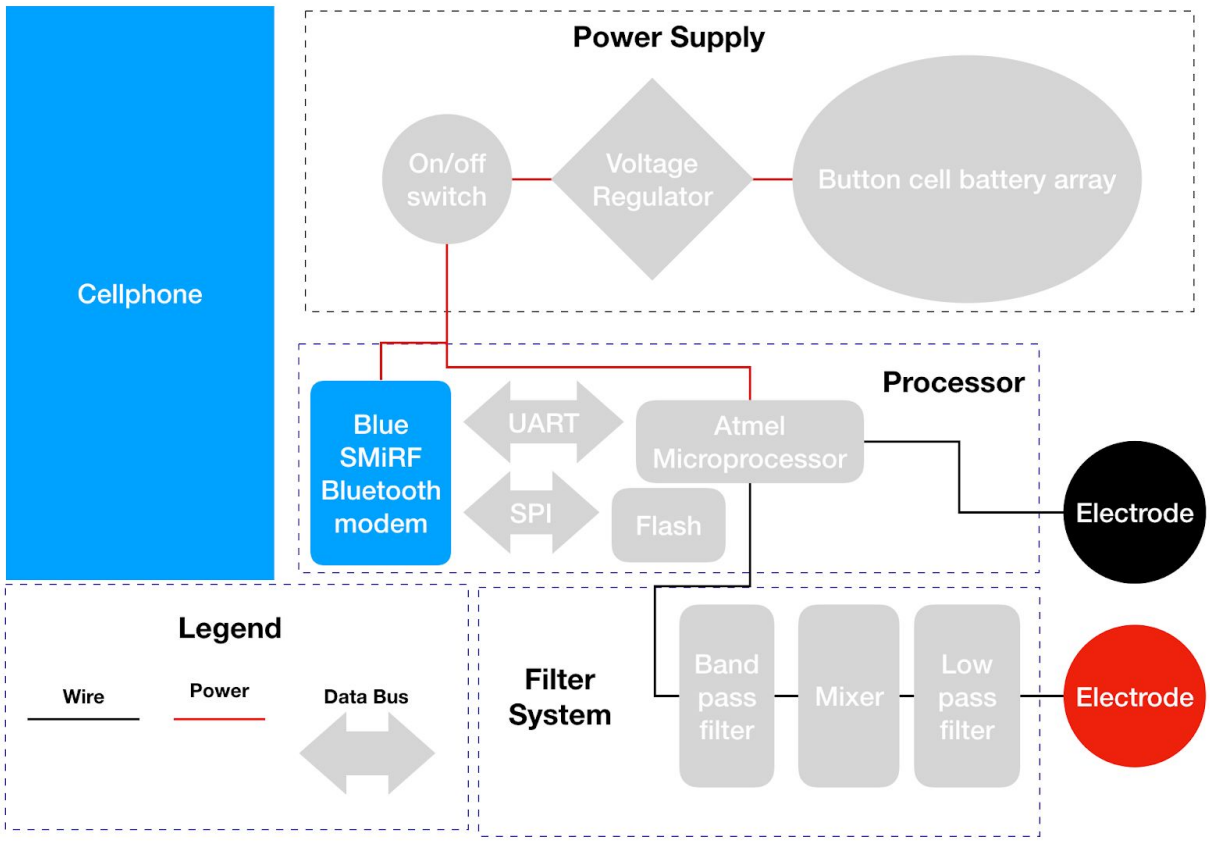
- The device should operate within a margin of error to differentiate between the different degrees of muscle activation.

- The device should be affordable to most users, possibly within the $99 range.

2. Design

MASS requires a power supply, Bluetooth modem, atmel processor and filter system to make electrode data distinct. The power supply provides 10W of power to the processor, Bluetooth modem and flash. The power should last 2 kWh. The electrodes contains the signal generated from the muscle and use a filter system to make the signal distinct. Then the filtered signal is sent into the atmel processor to format the information to be sent out to the cellphone through the bluetooth modem. The entire system should be small and portable and capable of process all information in real time.

Figure 1. Block Diagram



2.1 Sensor Subsystem

2.1.1 EMG Electrodes

The EMG circuits consist of various reusable electrodes and an electrolyte gel to measure muscle activities when the user walks in place and pass it through the filter to the microcontroller. This circuit should be designed with the idea of adjustability so it can be attached to any limb.

Requirements: The sensors should be able to be securely attached to various major muscles under and outside of clothes, including the biceps, triceps, quadriceps, hamstrings, calves, forearms, abs, pectorals, latissimus dorsi, erector spinae, and the deltoids.

2.2 Processing Subsystem

2.2.1 Filtering and Amplification Circuit

Will use linear components to handle signals through the low pass, band pass and mixer.

Requirements: The components have to handle signals with a voltage range of 50uV-30mV and frequency range of 7-20 Hz.

2.2.2 Atmel Microprocessor

We are considering the Atmel ATxmega series that process information at 32 bits and can act as a microcontroller. It is meant to process the information sent after filtration process to be formatted in some type of array or data type acceptable for the Bluetooth modem.

Requirements: Handle float data types that have over 100MB of memory.

2.2.3 Button Cell Battery

Main source of power for device.

Requirements: The system should last a few weeks on one battery, assuming 2 hours of use 5 days a week.

2.2.4 Control Buttons

There will be an on/off switch and a start/stop recording button to preserve battery and keep the final graphs readable to the user.

Requirements: The buttons should be easily accessible after the band is placed on each muscle group.

2.3 Data Transfer Subsystem

Output from the microprocessor will be sent to the user's phone app via a Bluetooth connection.

2.3.1 BlueSMiRF Bluetooth Modem

The Bluetooth modem will be connected to the microprocessor through a UART connection and will upload data at a rate of 2.4 GHz to the phone.

Requirements: The modem should send filtered readings at least 5 times a second.

2.3.2 Flash Memory

The measurements from the EMG sensors reside here post-process, then are sent via Bluetooth to the computer.

2.4 Phone App Subsystem

2.4.1 Graph Display

The graph will use floating point values and will be a time versus fibrillation scatter plot with a parabolic line of best fit.

2.5 Risk Analysis

The most important part of this project is the filtering and processing of the original signal. So there is high risk of failure if the signal can not be detected after filtration. Then if filtration is successful, the next hurdle is being able to process raw analog data to be displayed. If any part of these areas fail, the project could fail to function.

The next highest risk area in the project is displaying the data. The current method after processing is to have the data sent through the Bluetooth modem and have the phone display it as a graph. If the modem or phone app is insufficient then the back up plan of displaying the data on a screen attached to the processor will require more memory space along with a larger power supply to handle the hardware changes.

The smaller risk side of the project is the method of how to display the fibrillations on the device and power supply usage. These issues are small and can be fixed through program and wiring changes respectively.

Our solution should be able to detect electrical potentials roughly between 50uV and 30mV at a rate of 7-20Hz, sending it to the user's phone at 10 samples per second (subject to change). Fibrillations come in at amplitudes of 20uV to 300uV at rates of 2 to 20Hz, so not all fibrillations will be detected, but depending on the frequency with which we can poll the Network Subsystem, we hope to detect a significant percentage of fibrillations.

3. Safety and Ethics

We need to address a few safety issues in our product. The EMG sensors record electrical activity of the muscle, we need to make sure these don't become shocking hazards or create possibilities of movement restriction or constriction.

We will also need to make the the general electrical wiring and circuitry does not cause movement restriction or lead to electrical shocks cause of improper circuiting or protection.

We will strictly follow the IEEE Code of Ethics in bringing our engineering work to fruition. This product is a potential way to alleviate discomfort for many with muscle degenerative diseases and we will strive to do engineering work which is upto the standards, to make it a product. Information generated by the product such as health data would also be treated with utmost security. We will provide proper documentation and labels to make this product as safe and useful for the users.

References

[1] "MEN'S FULL BODY KIT - with two Cores," *Athos*. [Online]. Available: https://www.liveathos.com/products/mens-full-body-kit-dual-core-v3.