Wearable Muscle Sensing Exercise System

Team Members:
Ahmed Abdulkareem
Hai Dang Hoang
Todd Harlow
Than Tien Truong

Faculty Advisor:
Mark Faust

Background

Problem
- Overtraining and incorrect form are two major sources of personal injury
- A need exists for a system that prevents injury and maximizes results for any person performing exercises for general fitness or rehabilitation

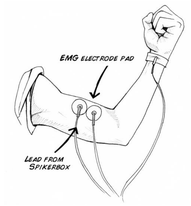
Objective
To design and prototype a wearable device that can effectively support a user's workout by allowing them to select their targeted muscle group and a corresponding exercise. Our device will provide users examples of the chosen exercise, count correct repetitions, and accurately alert them when they should stop the exercise.

Requirements
- The device must correctly detect reps and muscle fatigue
- The device should have low cost and be easy to use
- All parts in contact with user should be comfortable and washable

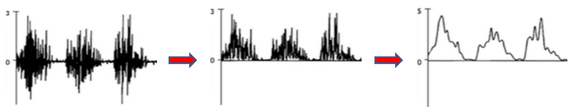
Surface Electromyography (sEMG)

Science
- Activated motor units in muscles produce voltage differentials
- Amplitude: < 10mV
- Frequency range: 20 – 500Hz

Surface Electrodes
- Sensors placed onto the skin measuring the voltage differential
- Less invasive and easier to use than needle-style electrodes



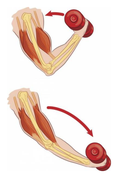
Muscle Measurement
- Signal must be conditioned before the digital processing stage
- 3 Steps: Amplify, Rectify, Integrate (Smooth)



Amplified *Rectified* *Integrated*

Testing

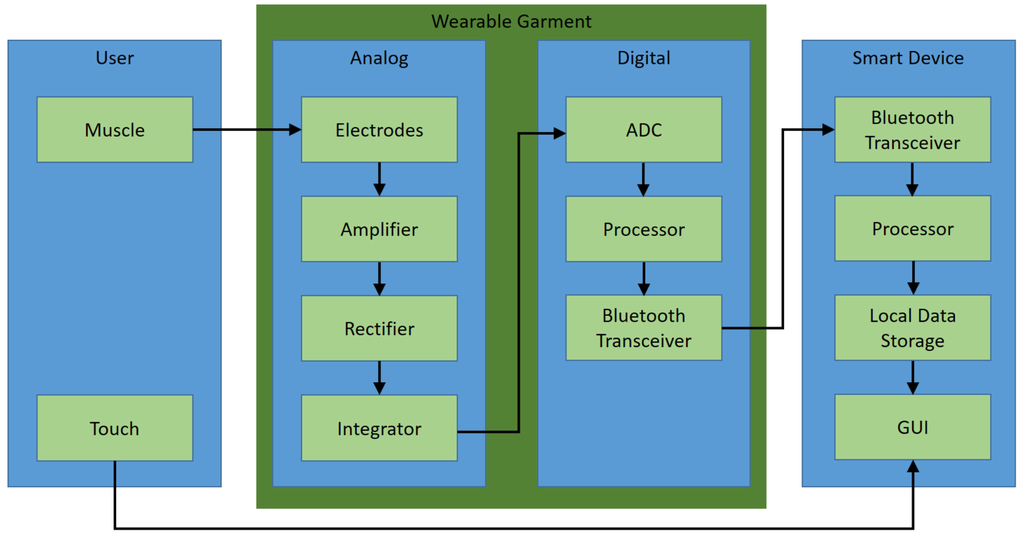
Data Collection
- Subjects performed sets of bicep curls while wearing the electrode sleeve and connected to prototype system
- Arduino analog-to-digital output stored to log file



MATLAB Analysis
- 24 subjects w/ 4 sets each = 96 sets of reps to be analyzed
- Developed batch processing system to run algorithm on entire dataset while using a range of tuning parameters
- Analyzed batch results to choose final values used in the rep and fatigue detection algorithms

Overview

We created a muscle sensing feedback system to help make exercises safer and more effective. Our system measures the electrical signal generated by muscle activity and processes that signal to detect correct exercise repetitions and muscle fatigue. Our prototype was developed targeting the bicep muscle and using the bicep curl exercise.



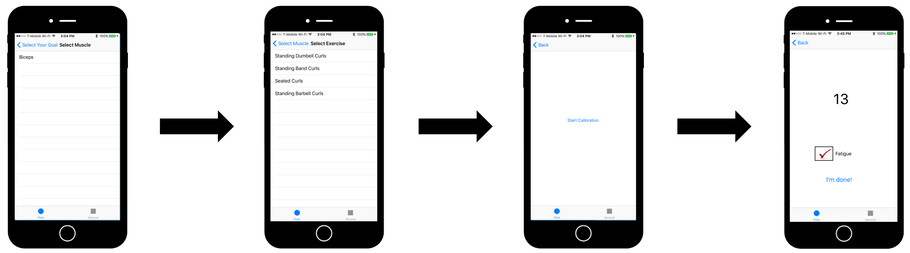
User
- Muscle provides voltage differential signal
- Touch controls system via GUI on smart device

Analog
- Custom electrodes on sleeve measure signal
- MuscleSensor v3 combines amplifier, rectifier, and integrator for signal conditioning

Digital
- Arduino used for prototype
- Rep & Fatigue detection algorithm
- Bluetooth communication with smartphone

Smart Device
- iPhone used for prototype
- Bluetooth communication with wearable
- Provides GUI and additional data analysis

iPhone Application



Select Muscle **Select Exercise** **Calibrate** **Feedback**

Market Opportunity

Consumer
- Transparency Market Research predicts that the wearable fitness device market will double in the next two years
- No device currently available on the market measures muscle activity

Medical
- Physical therapists need a way to effectively monitor rehabilitation exercises
- Patients need a cheap and convenient method for critiquing their exercises

Benefit

Improved Performance
- Muscle specific feedback enables users to perform their exercise correctly on every rep, making workouts more efficient

Cost Savings
- A less expensive alternative to a personal trainer
- Fewer injuries from incorrect exercise

Faster Recovery
- People can recover faster if they are performing their prescribed exercises correctly and re-building their muscles symmetrically

New Training Methods
- Exercises can be developed that use the voltage signal from our system as the metric of performance
- "Big Data" is a major trend in technology — our system can help provide a more complete view of a user's exercise regime

Summary

What worked
- Our custom electrode sleeve is lightweight, easy to use, and effectively measures muscle activity
- Our MuscleSensor/Arduino stack is able to process the sEMG signal from the sleeve and run our rep detection and fatigue detection algorithms
- Our iPhone app communicates with the Arduino via Bluetooth and provides the user with system control and feedback

What didn't work
- Our rep detection algorithm currently fails to meet our goal of at least 98% correctness
- Our fatigue detection algorithm detects fatigue earlier than anticipated and is currently not a reliable indicator of muscle fatigue by itself

What we learned
- **Research** – Thorough research on the project problem and existing solutions can prevent lost time working on untenable solutions.
- **Documentation** – Project documentation is critical to a successful capstone project and can help prevent miscommunication when dividing the work.
- **Specs** – When ordering parts, double-checking all relevant specs is time well spent. Wrong parts waste time and money.

What's next
- Further tune rep detection algorithm for greater accuracy
- Further develop fatigue detection algorithm for greater reliability
- Develop custom PCB to integrate circuitry onto the actual sleeve
- Port iPhone application to Android for greater market coverage

Department of Electrical and Computer Engineering

Portland State UNIVERSITY
Maseeh College of Engineering and Computer Science