Virtual Reality Muscle Activation Visualizer

Game Boonyawat, ‘22, Cameron Crowley ‘22, Brenna Hoar ‘22

Advised by Kevin Huang

Trinity College, Hartford, CT

Abstract

Virtual reality simulations are becoming an increasingly popular go-to for fitness, physical therapy and athletics. The Virtual Reality Muscle Activation Visualizer is designed to provide an alternative to in-person physical therapy appointments and public gyms. Through data acquisition and analysis of surface electromyography muscle activation data, integrated with body motion tracking and a unique virtual reality environment, this product offers visual validation to ensure an exercise or a specific movement is done correctly. The prototype exercise for the design of this system is a simple bicep curl, laying the foundation for a simple transition to essentially any movement requiring muscle activation validation desired by the user.

Motivation

The Virtuality Reality Muscle Activation Visualizer is a long-term cost-effective alternative to physical therapy or a gym membership. With COVID guidelines causing a widespread shift to telehealth appointments and presenting obstacles like social distancing and capacity limits, our design project has the potential to eliminate the trip to the physical therapy office or the gym altogether. However, the importance of visual validation from an expert is not being overlooked. With the Virtual Reality Muscle Activation Visualizer, you can perform an exercise and receive real-time muscle activation feedback right in front of your eyes, from the comfort of your own home.

Project Overview

The Virtual Reality Muscle Activation Visualizer integrates visual feedback of the user with numerical surface electromyography (sEMG) sensory data to confirm muscle activation and correct technique of a given movement or exercise. sEMG sensors use electrodes placed on the skin to measure the electric potential generated by muscle cells and, furthermore, whether or not that muscle is activated. The Xbox Kinect, used to collect the visual data, uses an infrared depth sensor and an RGB color VGA camera to track live motion. These combined data sets are then further integrated using Unity, a programming development platform for virtual and augmented reality environments. The final design allows the user to perform a specified movement in front of the Kinect, with sEMG sensors attached to the appropriate muscle group, while wearing the Oculus Rift VR headset, and receive real-time visual validation that they are performing the exercise properly and activating the correct muscle(s).

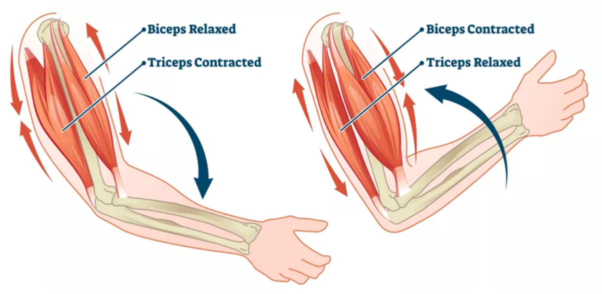
Approach

Data Acquisition

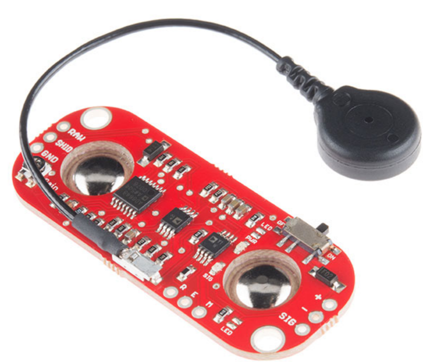
Muscle activation data is acquired using surface electromyography sensors placed on the desired muscle group. Surface electromyography signals are generated by muscle contractions. Muscle contraction begins with a signal from the nervous system. This signal arrives at the neuromuscular junction, where acetylcholine is released and binds to receptors on the neuromuscular junction. The movement of positive sodium ions and negative potassium ions through ion channels then creates a gradient change, resulting in depolarization. The action potential travels through the transverse tubules, calcium is released, and the contraction begins.

The prototype exercise used for data collection was a basic bicep curl. The sensors being used for data tracking are surface electromyography sensors. Surface EMG sensors are easy applied to the area of interest and can be reused making it a cost-effective alternative. These sensors provide an accurate signal and eliminate the intrusion of intramuscular EMG sensors. The placement of the sensors was chosen as the most anatomically relevant location as it would produce the strongest signal while also reducing excess noise. Bicep curls were performed with different weights, zero pounds, five pounds and 10 pounds to investigate the difference in muscle activity. While there are many diagnostic applications for EMG sensors, our focus remained on general muscle activity including the magnitude of the muscle output.

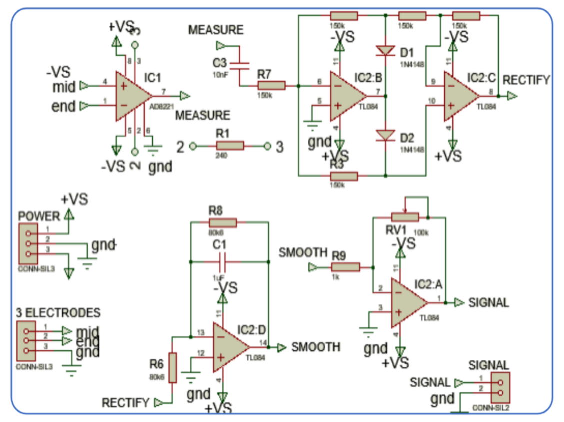
The first part of the circuit, shown in the upper left corner, is the instrumentation amplifier. The next part of the circuit features diodes that rectify the signal. Next is the active low pass filter, followed by the final inverting amplifier.



Prototype Exercise: Bicep Curl



Surface Electromyography Sensor



Sensor Circuit Details

Microsoft Xbox Kinect v2

Oculus Rift S VR Headset

Unity

Virtual Reality Development Software

The Xbox Kinect v2 is a motion tracking device that implements an infrared depth sensor, an RGB color VGA camera and a multi-array camera to collect data from a user. The Kinect tracks the user’s movements and records the position coordinates. The Unity program then extracts these coordinates and integrates the value of the sEMG sensors at the same time. This pairs the motion of the exercise with a confirmed activated muscle. The Kinect will track the user’s data to be collected by Microsoft SDK (Software Development Kit) and integrated into the Oculus headset.

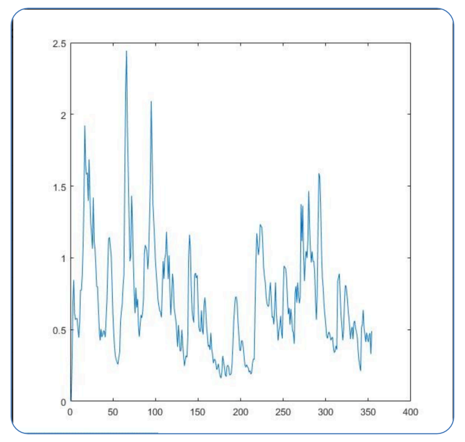
Data Integration

The visual validation portion of this design utilizes a virtual reality environment. The Oculus Rift S is a headset with virtual and augmented reality capabilities. The headset features 5 built-in cameras, an adjustable headband, and a built-in sound system.

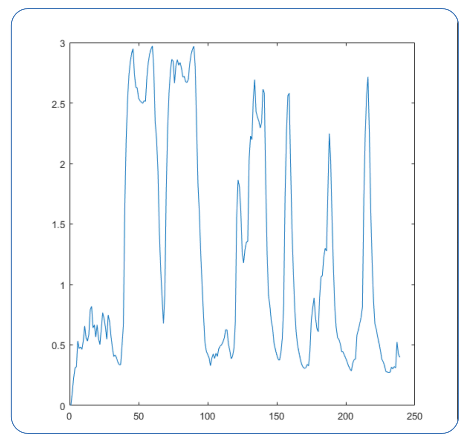
Within Unity, a Kinect Manager receives all the data collected by the Kinect including the RGB and infrared depth cameras. The Kinect Manager produces a skeleton model and joint base from initial readings by the Kinect. The skeleton map is then sent to a Kinect Gesture which aligns the skeleton map to a preset gesture that can be reproduced by the user. The data from the Kinect Gesture is then sent to an Avatar controller to add graphics.

The Avatar controller produces a 3D model base that reciprocates the users’ movements in real time as a mirror image within the Oculus headset. A separate script allows serial communication between Unity and the Arduino IDE collecting sEMG data from the user. Data from the Arduino is sent to Unity to be interpolated and then displayed as a color on the 3D model base. Based on the user’s movements and data collected by the Arduino, the 3D model will display a color of red or green.

Data Analysis



Muscle activation magnitude of a weightless bicep curl



Muscle activation magnitude of a 10-pound bicep curl

Future Steps

There are countless opportunities for virtual reality to be implemented into sports and healthcare. The virtual environment allows the user to perform exercises and activities in a realistic setting, while simultaneously collecting precise data. Virtual reality is slowly being implemented into many sports such as baseball, golf, skiing, boxing as technology continues to improve. Other uses include military training, physical therapy, fitness classes and rehabilitation. The future of virtual reality presents many opportunities for humans to improve efficiency in movement with improved muscle data collection, advanced graphics and realistic virtual settings.

Acknowledgements

Thank you to Professor Huang for your guidance and support throughout each step of our project. Thank you to Professor Blaise for offering expertise in biomedical engineering and sEMG signal generation. Thank you to Professor Palladino for providing presentation advice and progress feedback.

References

Portnoy, Jay, Morgan Waller, and Tania Elliott. "Telemedicine in the era of COVID-19." *The Journal of Allergy and Clinical Immunology: In Practice* 8.5 (2020): 1489-1491.

Jensen, Gail, et al. *Expertise in physical therapy practice*. Elsevier Inc., 2007.

Zheng, J. M., K. W. Chan, and Ian Gibson. "Virtual reality." *Ieee Potentials* 17.2 (1998): 20-23.

Wang, W., A. De Stefano, and R. Allen. "A simulation model of the surface EMG signal for analysis of muscle activity during the gait cycle." *Computers in biology and medicine* 36.6 (2006): 601-618.

Biagetti, Giorgio, et al. "Surface EMG fatigue analysis by means of homomorphic deconvolution." *Mobile networks for biometric data analysis*. Springer, Cham, 2016. 173-188.

Möller, Andreas, et al. "Gymskill: A personal trainer for physical exercises." *2012 IEEE International Conference on Pervasive Computing and Communications*. IEEE, 2012.