Determining Strength of Muscle Contraction Using Electromyogram

Kaitlin Abbate, Thomas Franklin, Morgan Rosenberger, Eugene Chabot, PhD and Ying Sun, PhD
Department of Electrical, Computer, and Biomedical Engineering,
University of Rhode Island, 4 East Alumni Avenue, Kingston, RI 02881-0805, USA

Abstract— **The purpose of this study is to detect forearm muscle contraction strength through use of electromyographic signals. Using a C coding software program, an algorithm is established to first detect an electromyographic signal and then to determine the strength of contraction of the muscle. A PIC microprocessor and printed circuit board (PCB) are also used to implement this task. Specifically, the amplitude of each contraction is studied to determine a weak, medium, or strong contraction type. This system can be used towards making objects (such as a wheelchair) move with different accelerations based on the strength of contraction of some muscle on the body.**

I. Introduction

Approximately 250,000 Americans have a spinal cord injury, with 11,000 new injuries occurring each year. Therefore, there is a growing need for assisting these patients, specifically those with paraplegia. Today, the most commonly used aiding device is the power wheelchair. However, this requires complete usage of arms/hands, and some injured patients are not capable of this. This project builds on the already existing idea of moving a wheelchair, or similar device, with muscle contractions. We will create an additional variable to relate the strength of a muscle contraction to some aiding factor. For example, the contraction will not simply make a wheelchair go or stop, but varying contraction strengths may cause a wheelchair to move with different accelerations.

II. Methods

A. Proposed Indicators

For years, researchers have used surface electromyographs to visualize and quantify a skeletal muscle contraction, allowing engineers to process these signals and gain insight into the physiology of a specific muscle. In order to investigate the strength of three forearm muscles, the same method was used, capturing the electrical activity from a series of contractions. Two signal electrodes were placed about one inch apart on the brachioradialis, and a third attached to a subject's elbow, serving as the voltage reference point.

Three signal characteristics served as proposed indicators that would gage the strength of such contractions: duration, frequency, and amplitude of the electrical signal recorded from a forearm contraction. Three short experimental studies were composed, based on each of the signal characteristics in order to determine the most effective method.

1) ***Duration:*** The duration of the signal was defined to be the time of the entirety of the signal to pass. The human subjects agreed that in producing more effort for the strong contractions, more time was a subsequent result. However, subjects could easily skew their signals by lengthening the time of their weaker contractions. Thus, the duration of the signal was deemed to be unrelated to contraction strength.

2) ***Frequency:*** The frequency of each contraction was found by studying the number of contractions an individual could produce in a given time. Each subject was given a ten second period, and asked to contract their muscle as many times as they could with weak, medium, and strong contractions. The calculated frequencies, even with a series of varying contraction strengths, were found to be nearly the same in all cases. Slight deviations were found, but did not give enough reason to prove useful and did not contain much relevance to the strength of a subject's muscle contraction.

3) ***Amplitude:*** The value of the amplitude was measured with an oscilloscope over a series of signals extracted from weak, medium, and strong muscle contractions. As expected, the amplitude was found to be significant, having a strong dependence on strength of contraction. Weaker contractions appeared as small, shorter signals whereas stronger contractions were shown to be much taller in appearance with a higher-valued amplitude. This is evidenced biologically, by the fact that a stronger contraction is made up of more muscle cells, requiring the stimulation of more motor neurons. Through multiple fiber summation, the electromyogram captures the sum of all electrical activity made up of the action potentials of each motor neuron that is activated. Hence, stronger contractions result in an increased sum of electrical activity, represented with higher amplitudes.

B. Human Study

A prior IRB approval for human study was obtained. As a result of our original contraction strength investigation, the amplitude of the signal proved to be most representative of

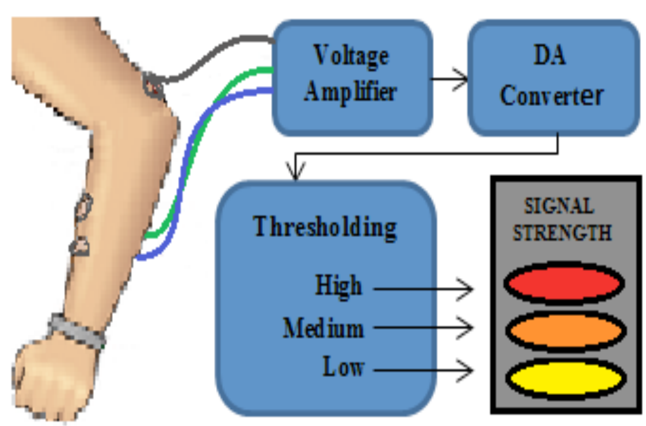

Figure 1. The above figure portrays the pathway of the experiment, starting from electrodes placed on an individual's arms, and concluding with the resulting signal strength indicator based on force of contraction.

the strength of a contraction. To further evaluate this relationship a human study was proposed, focusing solely on each signal's amplitude.

1) ***Instrumentation:*** The electromyograph, consisting of leads connecting to a patient's forearm muscles that are input into a voltage amplifier, is lead to a digital to analog converter. With the variety of voltages throughout the range of the signal's amplitude assigned to an 8-bit number, thresholds were able to be decided from 0-255. Each threshold was programmed to serve as a signal, outputting 5 V whenever the threshold was reached. The output voltage was connected to three LEDs, each illuminated as the thresholds are surpassed.

2) ***Hypothesis:*** Using three thresholds allowed a hypothesis to be made in the study. When the least of the thresholds was reached, the LED would light up representing a "Weak" muscle contraction. If a second LED lights up, the signal is increased through the next consecutive threshold and a "Medium" contraction is represented. If each of the three lights are on then a "Strong" contraction was thought to be occurring. Having no LEDs turned on represented a lack of muscle activity.

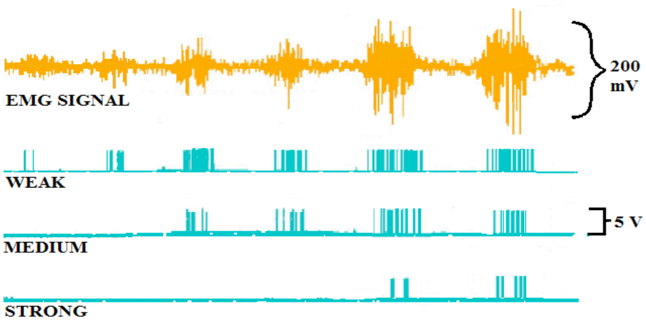

Figure 2. The above figure shows an example of a successful human study when contracting the forearm muscle with weak force to strong force (orange graph). The blue graphs show the detection of amplitude from a weak signal (small amplitude) to strong signal (high amplitude).

3) ***Human Subjects:*** Ten human subject volunteers participated in a study to test the validity of the system, and robustness of the thresholds determining contraction strength. Subjects were prepared for the study by being equipped with leads attached to specific and exact forearm locations, and having been trained through verbal and visual instruction of the efforts associated with the three discrete contraction strengths.

Each subject was asked to contract their muscles a total ten times. The amount of strength that a subject was instructed to use in their muscle contractions was determined at random. The LED response was recorded during each contraction, in order to compare the system's evaluation of signal strength with the contraction strength that was actually performed by the subject.

III. Results

The system's functionality was verified at least satisfactory by all ten human subjects. That is, each was able to illuminate the LEDs representing the signal amplitudes, proving the amplitude dependent of strength. Thresholding the amplitude of the signal allowed for capturing three discrete outputs to represent the contraction strength as well as the absence of an output, representing a lack of muscle contractions.

However, each subject was not able to illuminate the LED lights one hundred percent of the time. On average, the weak contraction proved to be the most difficult to access because the algorithm used to detect this picked up on even the slightest movement. Therefore, sometimes when the subject felt that he was not contracting the muscle at all, the LED would light up for a weak contraction. Also, the strong contraction was difficult for one subject because she could simply not contract her muscle with such force. The following table portrays the percentage of human study contractions that were detected correctly by the project:

TABLE 1

Percentage of Muscle Contractions Correctly Detected		
Strong	Medium	Weak
88%	92%	60%

IV. Discussion

This study contributes to the methodology for quantifying the strength of a muscle contraction based on the electromyogram. The strength information provides more controls for applications such as wheel chair, scooter, and adjustable bed control. Future work includes the completion of the IRB approved study and improvement of the detection algorithm using techniques of digital signal processing and information theory.

Acknowledgements

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