Introduction to sEMG Signals

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Introduction

As of 2018, there was an estimated 1.7 million of Americans living with limb loss. Out of the 1.7 million amputees, approximately 14% percent have undergone an upper extremity amputation below the elbow [1], meaning a loss of fingers, hand, or parts of the forearm. Although these individuals lose extremities, their brains can still send signals to the muscles that were used to control the now missing parts of their body. The signals are electrical charges (small positive and negative atoms) being driven by electricity, and they travel from the brain to the muscle and cause the muscle to contract. When the muscle contracts or relaxes, it creates its own electricity which can be measured. This measurement is referred to as Electromyography (EMG) and can be used to diagnose muscular diseases or to control a prosthetic limb. The rest of the paper is organized as follows: section 2 will give a more in-depth explanation of how the EMG signals are produced and will introduce Surface Electromyography (sEMG); section 3 will focus on sEMG characteristics; section 4 will provide conclusion and the next steps to understanding sEMG signals.

How is an EMG signal produced?

Different parts of our bodies communicate with each other by sending signals through neurons. For instance, sensor neurons tell your brain the stove is hot, and motor neurons tell your brain to lift your hand up. A neuron is made up of three parts: dendrites, soma, and an axon.

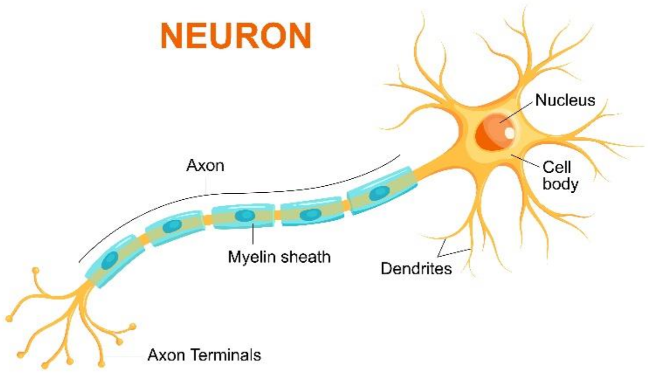

Figure 1: Neurons structure (licensed from Adobe Stock)

The dendrites are connections used to receive signals from other neurons. At the beginning of the dendrite, positive electrical charges received from another neuron begin to build up, which causes the neuron to produce electricity. This electricity is measured as voltage, which is like the voltage in a battery. Looking at figure 2, the red line shows the rise of voltage, created by the build-up of the positive charges. The first intersection between the dashed line and the red line is the point at which the voltage is high enough to cause the soma, or body of the neuron, to open. This opening allows more positive charges to flow into the soma, increasing the voltage further as seen in figure 2. When the voltage is at its peak, approximately 100 mV in figure 2, the soma stops taking in the positive charges and begins to send them out through the axon. In figure 2, this is shown by the red line decreasing. This process of the voltage increasing and decreasing by receiving and sending charges is how neurons communicate with each other, and how the brain sends signals to other parts of the body. The signal traveling through the neuron is called the "action potential". [3]

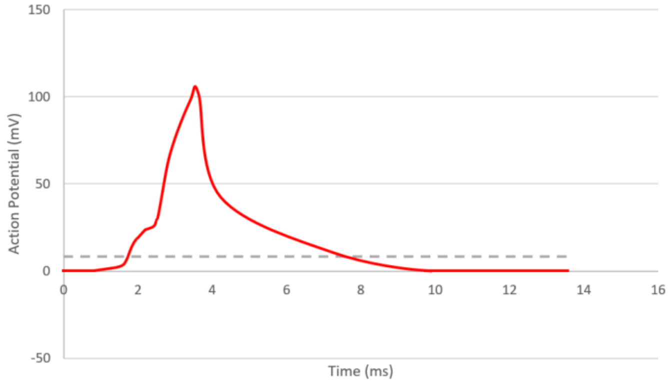

Figure 2: Action Potential

Skeletal muscles [2], muscles attached to our bones and responsible for putting our body in motion, are stimulated by the action potential traveling from our brain. To be more precise, muscles are composed of bundles of fibers (figure 3), so when an individual wants to complete a task, such as making a fist, it is the fibers within the muscle that are stimulated by the action potential. This stimulation causes the fibers to twitch [2]. The twitching in the fibers contracts the muscle, and the hand forms a fist. Even in the absence of a hand, our brain is still able to send action potentials to stimulate the muscle fibers. Since the action potentials are just electric signals, they can be measured. This measurement is referred to as Electromyography (EMG).

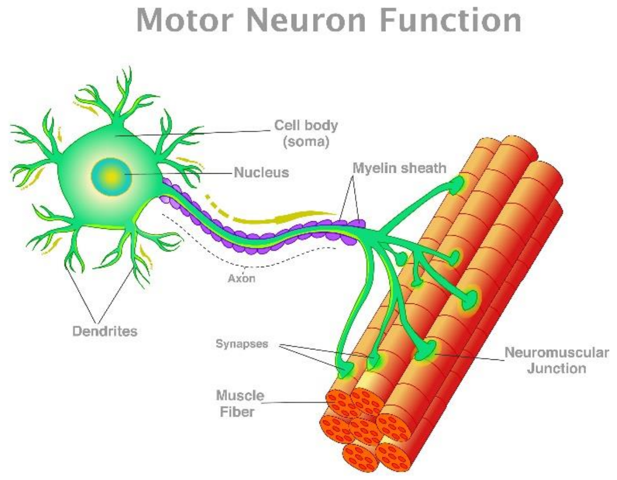

Figure 3: Motor neuron attached to muscke fibers (licensed from Adobe Stock)

Electromyography signals are measured using special devices called electrodes. You might have seen one type of these if you have seen doctors measure the electric activity of a heart (electrocardiogram). Electrodes can either be attached directly to the muscle by puncturing the skin (invasive electrodes), or by attaching to the skin on top of the muscle whose action potential we want to measure (surface electrodes). The process of recording action potentials using surface electrodes is called Surface Electromyography (sEMG).

sEMG Characteristics

sEMG signals can be explained in terms of a rainbow analogy. Most know that a rainbow appears when the sunlight hits the raindrops. The sunlight, also known as white light, is made up of several components. These components are other types of light, which are red, orange, yellow, green, blue, violet, and indigo. The combination of these seven lights produces sunlight. When the sunlight hits a raindrop, the raindrop reflects the components of sunlight differently, and that makes them visible to the human eye. We see the rainbow, the seven lights that make up the sunlight [8].

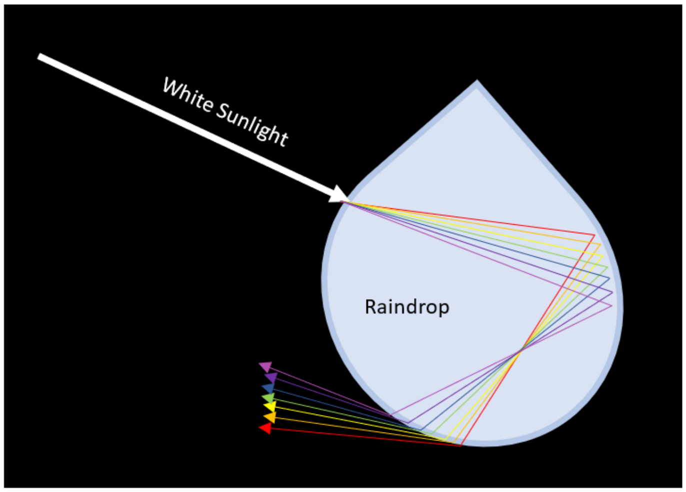

Figure 4: Sunlight hitting a raindrop

sEMG signals, like sunlight, consist of many components put together. These components are other electrical signals. The different sunlight components are identified by a measurement called wavelength. sEMG components are identified by frequency, which is measured in Hertz (Hz). Various academic studies have shown that the sEMG frequency of its combined components ranges from 20 to 450 Hz [4], 20 to 500 Hz [5], 30 to 400 Hz [6], or 40 to 450 Hz [7]. In most research, it is standard to assume the 20 to 500 Hz range.

Unfortunately, when electrodes measure sEMG, they might also pick up noise signals. For instance, if an electrode is not firmly attached on the arm, the electrode will move against the arm, creating another action potential. This type of noise is referred to as motion artefact, and it is made up of components with frequency below 20Hz [4], which can be separated from sEMG. Another common type of noise is called power line interference, an electrical signal generated by the interaction between nearby electrical devices and the electrodes. Unlike motion artefact, the components of this noise have frequencies that are approximately multiples of 60 Hz. Since these components and sEMG directly overlap, they are much harder to separate from each other. The industry has dedicated a lot of research to learn how to separate noise signals from sEMG signals.

The second most common characteristic of an sEMG signal is its strength. For example, the strength of sunlight is measured by its intensity. Since, sEMG is an electrical signal, we use voltage, the most common measurement, to determine sEMG strength. Just as intensity of sunlight can vary, so can the strength of an sEMG signal. Research shows that typical peak strength of sEMG is anywhere from a few tens of micro-Volts (µV) to 1 or 2 milli Volts (mV) [6], 0 to 6mV [5], and even as high as 10 mV [2]. To give you an idea of how small it is, the electricity strength needed to charge an iPhone is 5 Volts. Thus, for researchers to have the ability to analyze an sEMG signal, its strength needs to be increased by using a circuit device called an amplifier. This device has very specific hardware requirements such that it does not add noise to the electrode measurement.

Conclusion

Surface Electromyography (sEMG) signals have a huge importance in the medical industry. Without the presence of these signals, it would be very difficult to provide amputees with a more than basic, low functionality prosthetic. Hence, understanding the characteristics of sEMG signals and their origin is extremely valuable when attempting to do any work involving prosthetics. The goal of this report was to provide the reader with easy-to-understand overview of the basics needed to continue more advanced research into sEMG signals. I believe the information contained in [5] is a good next step to gain further understanding of sEMG and to learn more details on how to measure it. The research detailed in [4] provides a thorough overview of the noise signals and different techniques used to separate them from an sEMG signal. Although this paper is from 2002, most of the information is still quite relevant. The fundamental ideas in these papers provide the building blocks needed to help researchers develop prosthetics for the increasing number of Americans and people worldwide living with limb loss.

References

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