Electroencephalography and the Mechanical Operation of an Exoskeletal Arm

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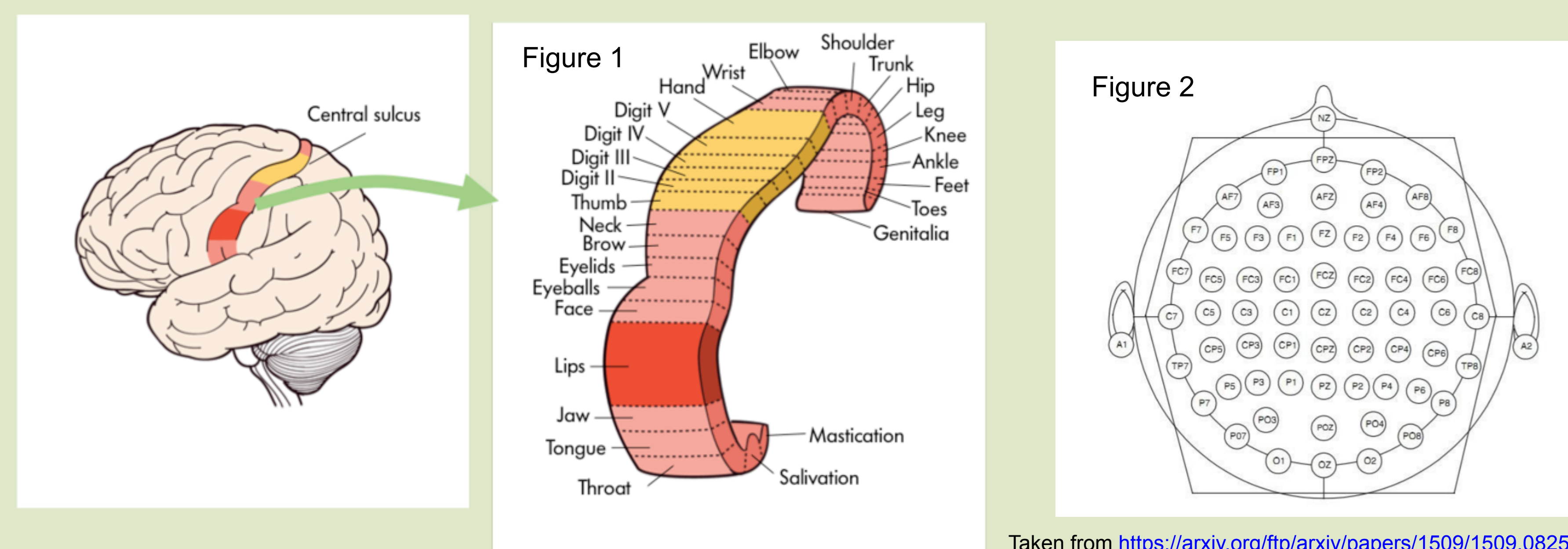Department of Physics and Astronomy, University of Northern Colorado, Greeley, CO 80639

Abstract

Advances in technology have opened the doors for research in the field of prosthetics, specifically prosthetics controlled by the mind. Every action we take within our daily lives requires our brains to produce electrical activity. This activity generates brain waves that can be observed and recorded using electroencephalography (EEG). By reading and processing these brain waves, it appears to be possible to control a pneumatic exoskeletal arm with nothing more than your thoughts. We attempt to find brain waves corresponding to the movement of raising and lowering the arm by using EEG hardware. We placed electrodes along the motor cortex which is a section of the frontal lobe that controls motor movements. Using hardware made by Bitalino and the software, Open Signals, we recorded data while test subjects were sitting still in a chair. With no movement, they had a steady wave pattern with well-defined amplitudes. We then had the subjects raise and lower their right arms to see what we could observe on a plot of the EEG data. There was a peak in amplitude followed by a window of oscillation and another peak when they lowered their arms. When they were back to their original position, the graph of the waves returned to its original pattern and amplitude. We hope this work could, someday, be applied in operating a prosthetic arm that amputees or physically challenged people could use.

Brain

EEG uses electrodes placed on the scalp. The electrical activity shows up in the form of waves. There are five types of waves: delta, theta, alpha, beta, and gamma. Our main focus was on the alpha, beta, and gamma waves, which are present most of the time in the conscious brain. The cerebrum is separated into four lobes that control senses, movements, and thinking. The four lobes include the frontal, temporal, occipital, and parietal. Our main focus is the frontal lobe which houses the motor and premotor cortex, also known as the motor strip. The motor strip controls voluntary muscle movement in the body. There are sub-divisions within the motor strip, each corresponding to the control of specific body parts. Figure 1 below shows these divisions in the motor strip and the corresponding regions they control. Figure 2 shows a diagram of standard electrode placement. The motor strip is in line with electrodes C1 through C8.

Figure 1

Figure 2

Taken from https://www.memrise.com/user/ziming-learning/?page=12

Taken from https://arxiv.org/ftp/arxiv/papers/1509/1509.08257.pdf

Experiment

We used the portable Bitalino Revolution board computer interface with three electrode attachments. These electrodes were placed on the scalp in line with the motor strip discussed earlier. We are still trying to determine their optimal placement pattern along this strip. At rest, the electrodes picked up a voltage of a few millivolts. When the subject performed the movement described in the abstract, the voltage increased to approximately 40 millivolts during the up or down motion of the arm, and then oscillated between motions about the resting voltage. This suggests that there is a reproducible voltage pattern associated with the up or down motion that can be used to control the exoskeletal arm.
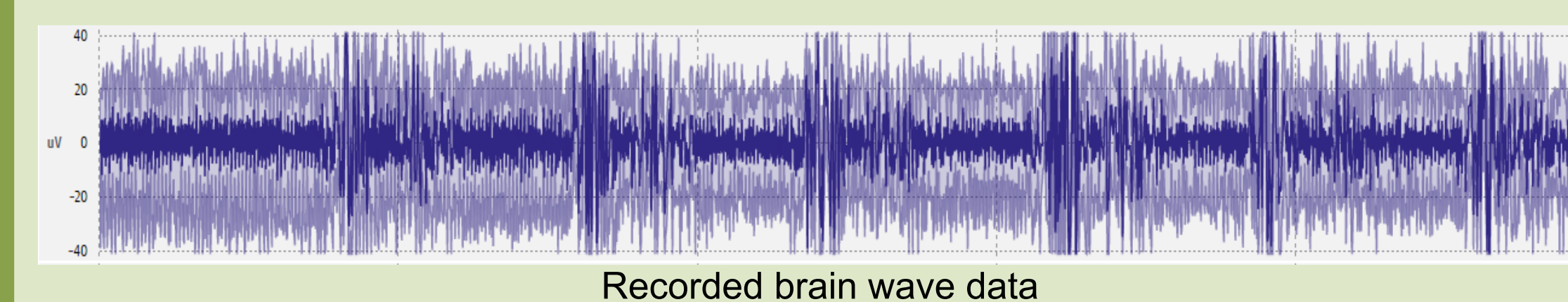
Recorded brain wave data
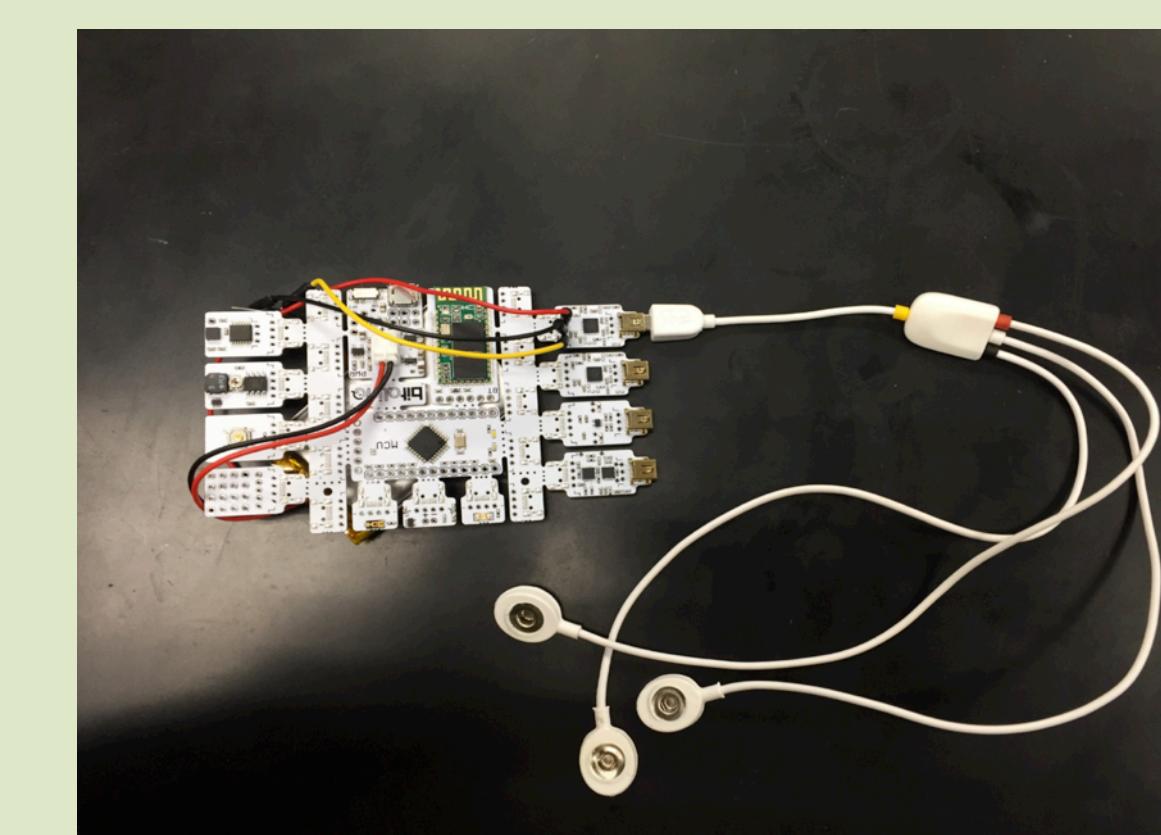
Bitalino Revolution Board

Electromyography

Motor neurons can transmit electrical signals that, in turn, cause muscles to contract. EMG (Electromyography) is the process in which the voltage of these signals can be observed and stored for later use. We implemented EMG to initially control an artificial exoskeletal arm. Using a Myoware muscle sensor in coordination with an Arduino microcontroller, we were able to translate muscle activity into voltage values that were then used in raising and lowering the arm via an actuator (to be explained later in this poster). The goal of this was to get a basic understanding for how the brain waves could be utilized to eventually control the arm.
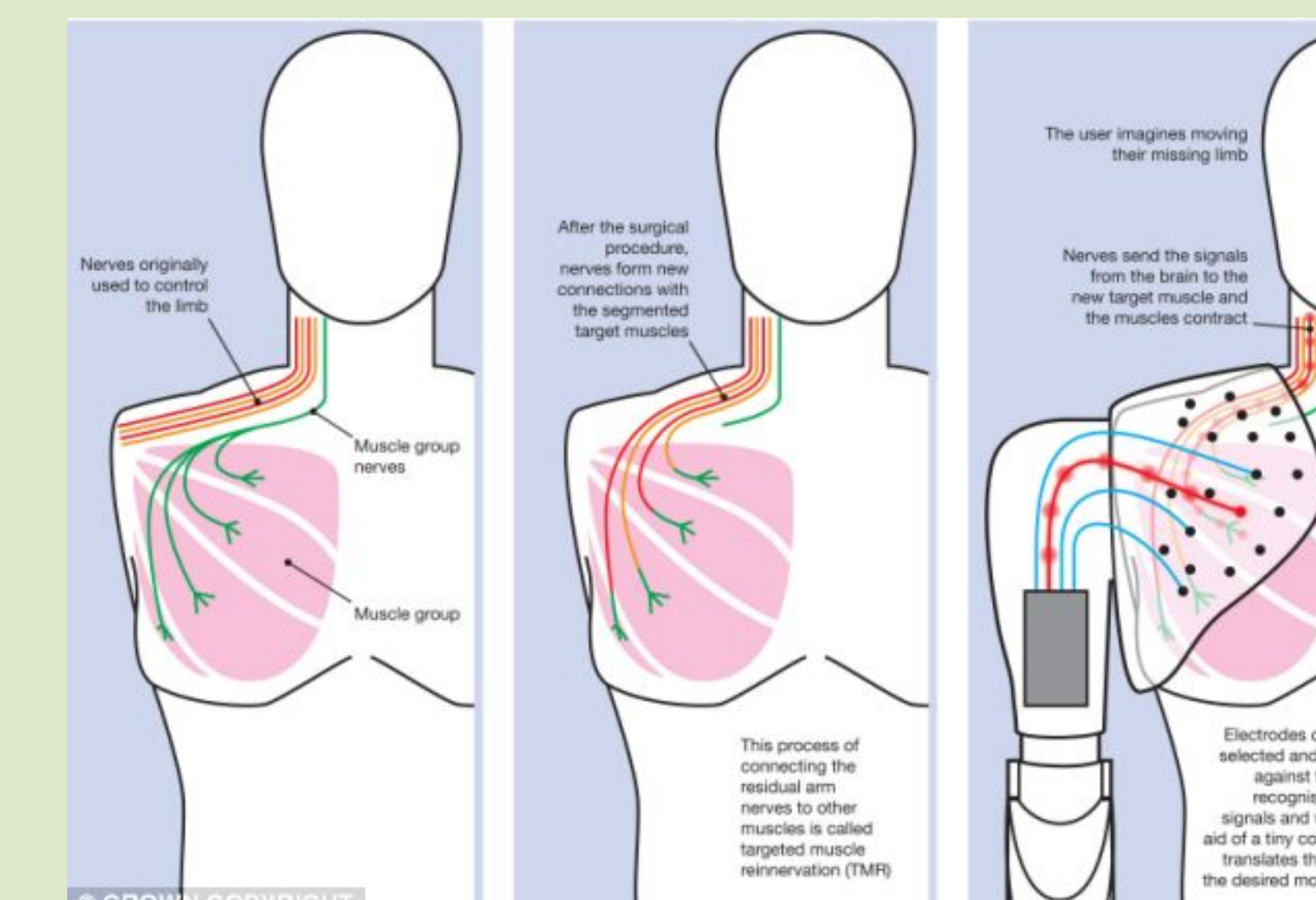
Myoware muscle sensor in use

Design

When designing things such as exoskeletons and prosthetic arms, there are many different forms of actuation that can be utilized. For our research we utilized pneumatics to achieve actuation in the arm. The piston could handle pressures up to 120PSI and, therefore, the arm exhibits good lifting capability. The piston was wired to a 5 port 4 way electronic valve that allowed us to have full control over the extension and flexion of the arm. The valve was then connected to an Arduino microcontroller so it could be programmed.
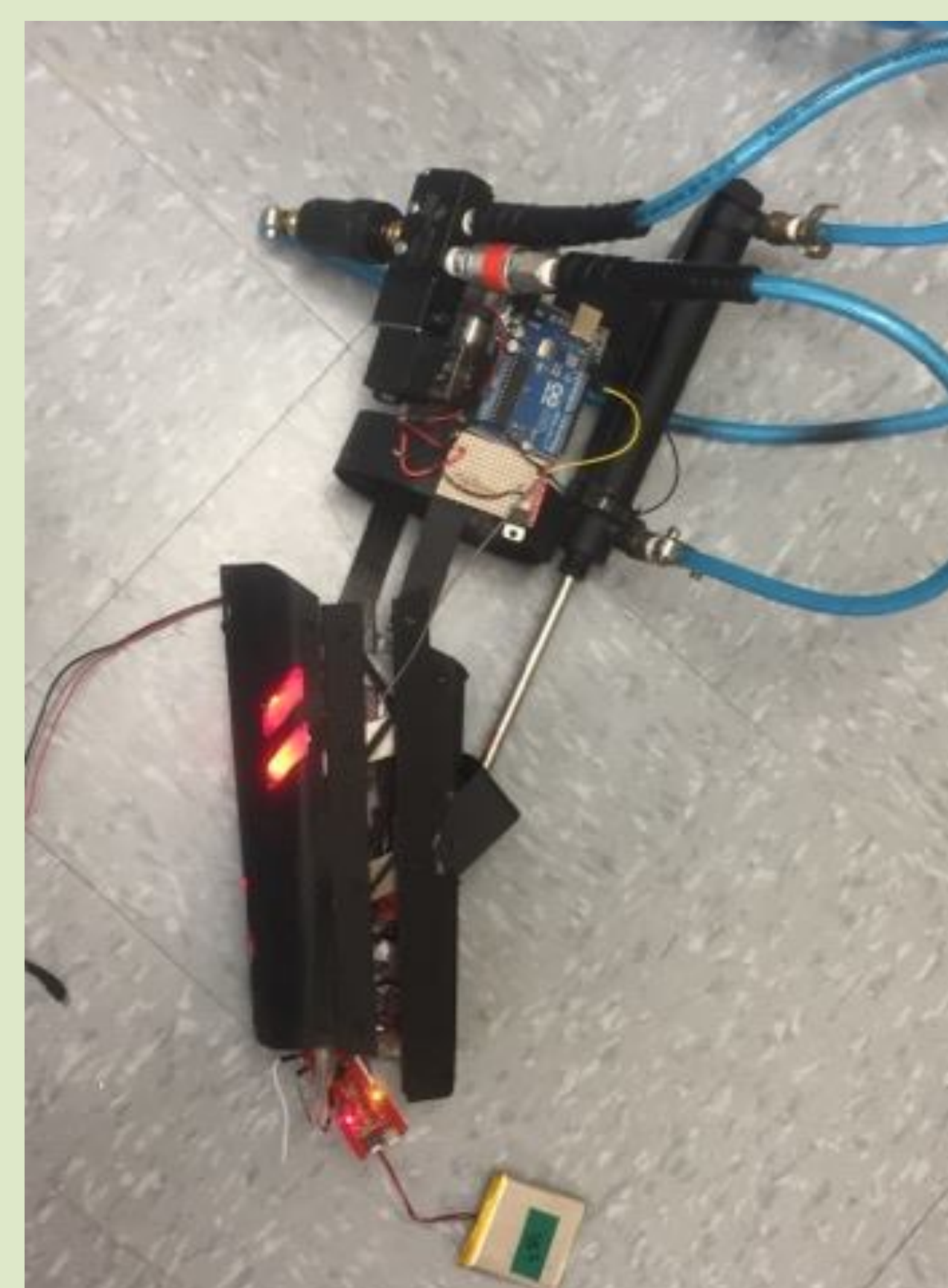
Future Research

Robotic prosthetic arms have been attached to nerves in the region where an amputation has occurred. This procedure requires the connection of numerous wires to the arm and the nervous system during a surgery (see below). Instead, we are focusing on a method that will send signals via thoughts to a robotic prosthetic arm using, for example, wireless technology. The brain wave data that we collect will be used to explore the possible range of capabilities of such a system. However, the user of such a system must train their brain to operate the arm in a purposeful fashion.

Acknowledgments