NYU | TANDON SCHOOL OF ENGINEERING

EG1003 Introduction to Engineering & Design

Biomedical Device (BMD)

Preliminary Design Investigation

The Spring Soldier

Team Members:

Tanvi Rahman

Louie Rivera

George Zhang

Introduction:

The project aim to develop a fully functional prosthetic arm for the rehabilitation of patients with loss of upper limb in hope of recapturing most of the essential functionalities of the human hand.it is hoped that user is capable of performing all dexterous motor task with the prosthetics developed in this project and achieve thorough rehabilitation of limb loss. Existing prosthetic technologies confront limitations such as high cost, low compliance, lack of neural control, and failure to mimic the biomechanics and musculoskeletal structure of biological limbs. In this project, attempts are made to solve this problem through rigorous biomechanical research as well as novel mechanical design.

Limb loss and implications

2 million individuals suffer from limb loss currently in the united states while 200,000 new amputations are performed annually. Worldwide, there are 2 million amputations performed annually, namely one amputation per 30 second. 50 percent of the amputation is caused by vascular diseases and diabetes; 45 percent is caused by trauma and 5 percent is caused by cancer. Because of the increasing prevalence of sedentary lifestyle as well as the uncontrolled situation of accidents, the number of amputees produced annually is steadily increasing.

Beside the inability to perform normal activities, amputees suffer from cascades of other physiological, psychological, and social problems. Because of the loss of limbs, amputees lack the motivation to engage in physical activities thereby causing a deteriorated health condition that arise from long term inactivity. Moreover, due to the dependence on other people, discrimination among peers, self criticism, and other consequential mental activities of amputation, amputees are susceptible to mental health problem such as anxiety, depression, insomnia, and even suicidal thought. Finally, because of their physical incompetencies, unique physicality, and, in some cases, mental deficiencies, amputees usually have lower socioeconomic status. Given both the prevalence and the impact of limb loss, a thorough and accessible solution is considered as a social imperative.

Review of existing technologies

Multifarious technologies have attempted to address amputation. However, they all confront limitations such as high cost, lack of neural control, and failure to recapture the biomechanics and structural features of human limbs.

One famous example of prosthetic limbs is the neurally controlled arm developed by John Hopkins university. It is by far the world's first mechatronic arm capable of generating movement based on human neural signals and transferring haptic feedback back to the human brain. However, the hand uses rigid motors whose position can only be influenced by the control input. When adapting to hard collision and abrupt environmental changes, it fails to deform angularly due to its lack of compliance.

Another advanced prosthetic technology is the prosthetic feet developed by hugh herr and his team at MIT media lab. This pair of leg uses agonist-antagonist myoneural interface (AMI) to generate proprioception that enables the patient to feel the angular position of prosthetic feet. Despite being a triumph in prosthetic technology, such bidirectional neural interface does not generalize to patients with little or no residual limb and muscle. Moreover, the entire system costs about 40,000 dollar and is not reimbursed by the current healthcare system. Only veterans with authentication could get access to such expensive prosthetic technology. A much cheaper, more functional, and accessible alternative is needed to resolve the problem of limb loss.

Goals and objectives

To address these problems, we aspire to design a fully functional biomimetic prosthetic hand that captures all degrees of freedom of the human hand while being constructed out of simple and easy to access materials to resolve the aforementioned limitations . We also attempt to achieve neural control of movement that enables the user to control the movement of prosthetics with the neurons within their residual muscle.

Project requirement:

The Biomechanical Device project requires teams to build a prosthetic arm that have an elbow that can move 90 degree and a wrist that can move 180 degree perpendicularly. A fully functioning hand that can wrap around a shopping bag handle and the implementation of motors and sensors are required to earn extra credit.

Project summary and value proposition.

Unlike traditional robotic hand design which is largely based on theories of machines and mechanical design, our robotic hand is deeply rooted in biomechanical research while aided by modern tools of engineering.

To build this prosthetic hand, a thorough research of the degrees of freedom of the human hand skeletal system, joint property, and ligament configuration is conducted. Then, a preliminary CAD design is constructed for further refinement. A detailed 3D model is created based on the preliminary CAD drawing. We use state of the art universal and revolute joint design to minimize space and maximize functionality. Also by modifying the 3D model, we could include hollow spaces for installation of onboard computers, sensors, and actuators that impart neuromechanics to our prosthetics. The choice of sensors, actuators are all based on research in robotics and biomechanics that optimizes their efficiency and functionality. For example, we use EMG muscle sensors to create convenient neural control. We also use string-motor actuation to closely mimic the compliance found in human nature.

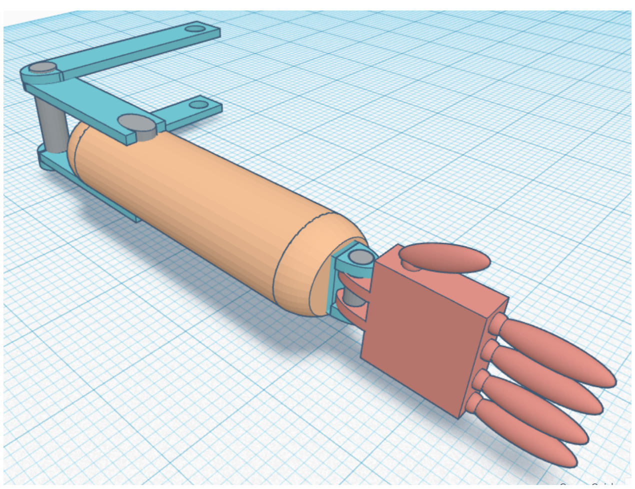
Limitations:

Because of the remote nature of our work, we confront multifarious challenges that hinders the performance of our team. For example, because of the lack of physical presence, we cannot 3D print, fabricate the machine and equip it with electronics. Also, we cannot test the device for the same reason. Also, because of the lack of muscle sensors in virtual design environments such as TinkerCAD, we have to use other analogous sensors as substitutes to illustrate our ideas.

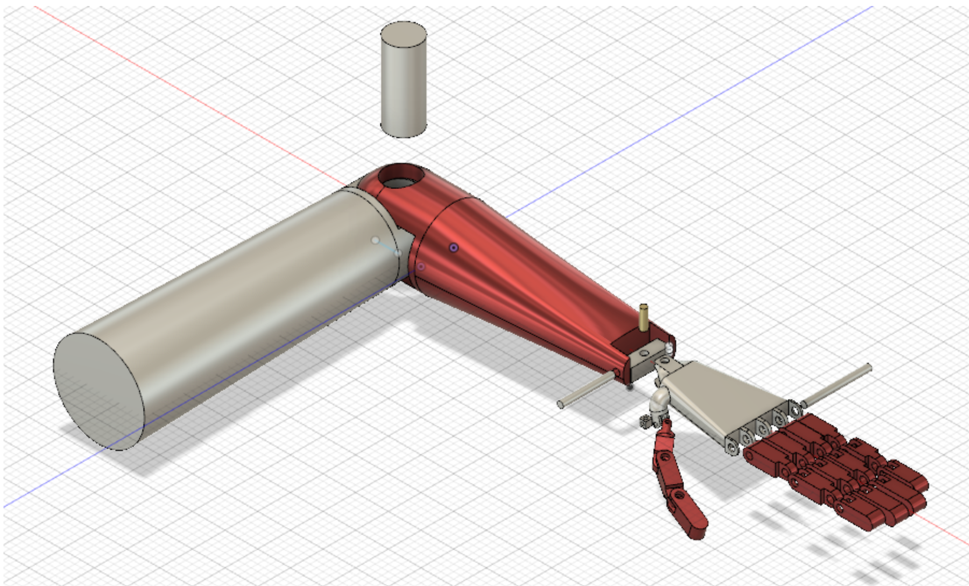
<u>Resources</u>

<u>Physical Components</u>

The Spring Soldier is a prosthetic arm that connects just above the elbow to a person with a missing arm. The arm will use a Myoware Muscle Sensor to retrieve inputs from the user's muscle and convert them into electrical signals. Different muscles in the remaining part of the arm of the user will be used to either extend or contract the elbow joint of the prosthetic arm. We have not yet decided which muscles will dictate which arm movements, but for the time being, let's say that the tricep will be flexed to make the elbow extend or contract, making the arm form a straight line or an L-shape. Flexing the bicep will be used to rotate the wrist 180-degrees left and right. The intensity of the flex will also factor into the degree of rotation. A full flex of the tricep/bicep will result in a full extension of the arm or rotation of the wrist, respectively. Slight flexes of the muscles will perform the same movements on a smaller scale.



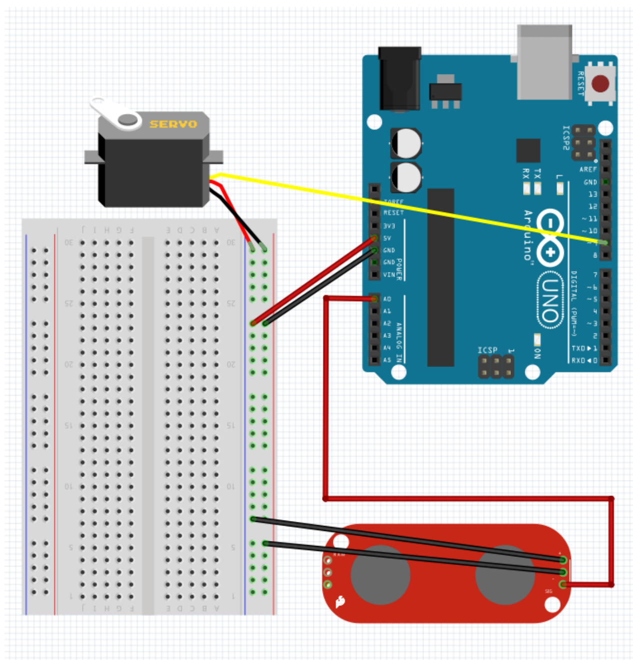
This design is more practical/effective than other designs, as it uses the relatively affordable Myoware Muscle Sensor. At a low cost of $37.99, each muscle sensor is much more affordable than the average sensors used in today's prosthetic arms. The average prosthetic limb costs upwards of $5,000 which is already almost double the price of ours including labor costs. Our design will also be easy to use, as it will be simply attached to the amputee's arm stump at the elbow which will be hollow and open for the arm to slip right in. It also requires the user to simply attach the muscle sensors to the bicep and tricep, allowing for optimal readings of the muscle signals. We plan to use a Servo motor which will be wired to the muscle sensors. The signals from the sensors will determine how quickly and how far the motor turns, rotating either the elbow or the wrist.

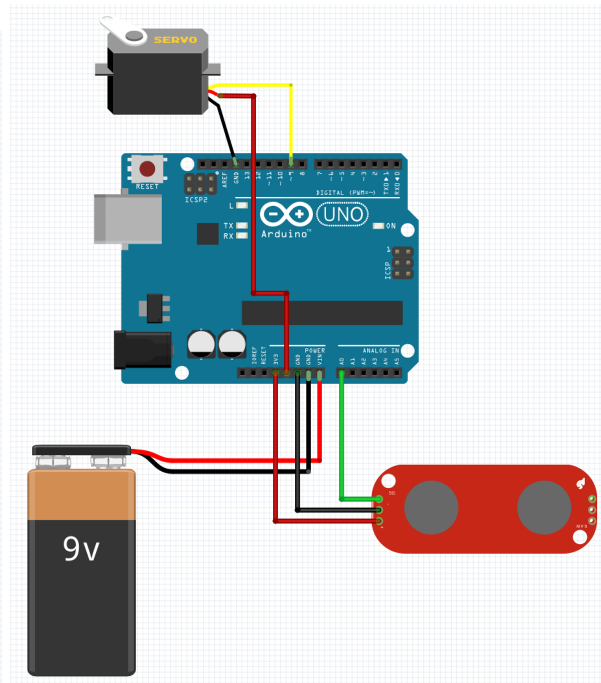


The motors, wires, and sensors will not be seen by the naked eye, as the actual prosthetic arm is hollow, and will store all the electrical components inside, since there is no real human arm in that spot. This gives us free range to decorate the arm's exterior to the fullest. In the preliminary CAD drawing above, the upper arm is not hollow, but we are thinking about making it so that it can easily attach to the arm stump without requiring surgical insertion. Ideally, the arm will be easily removable and reappliable.

Software Requirements

So far, we have the completed wiring done for the first muscle sensor on Fritzing. We are using the Arduino microcontroller to connect the muscle sensor to the Servo motor. The motor will be able to spin, but we need to figure out how to apply resistance to the spinning of the motor, and how to make it so that we can control the degree of rotation with our muscle movements.





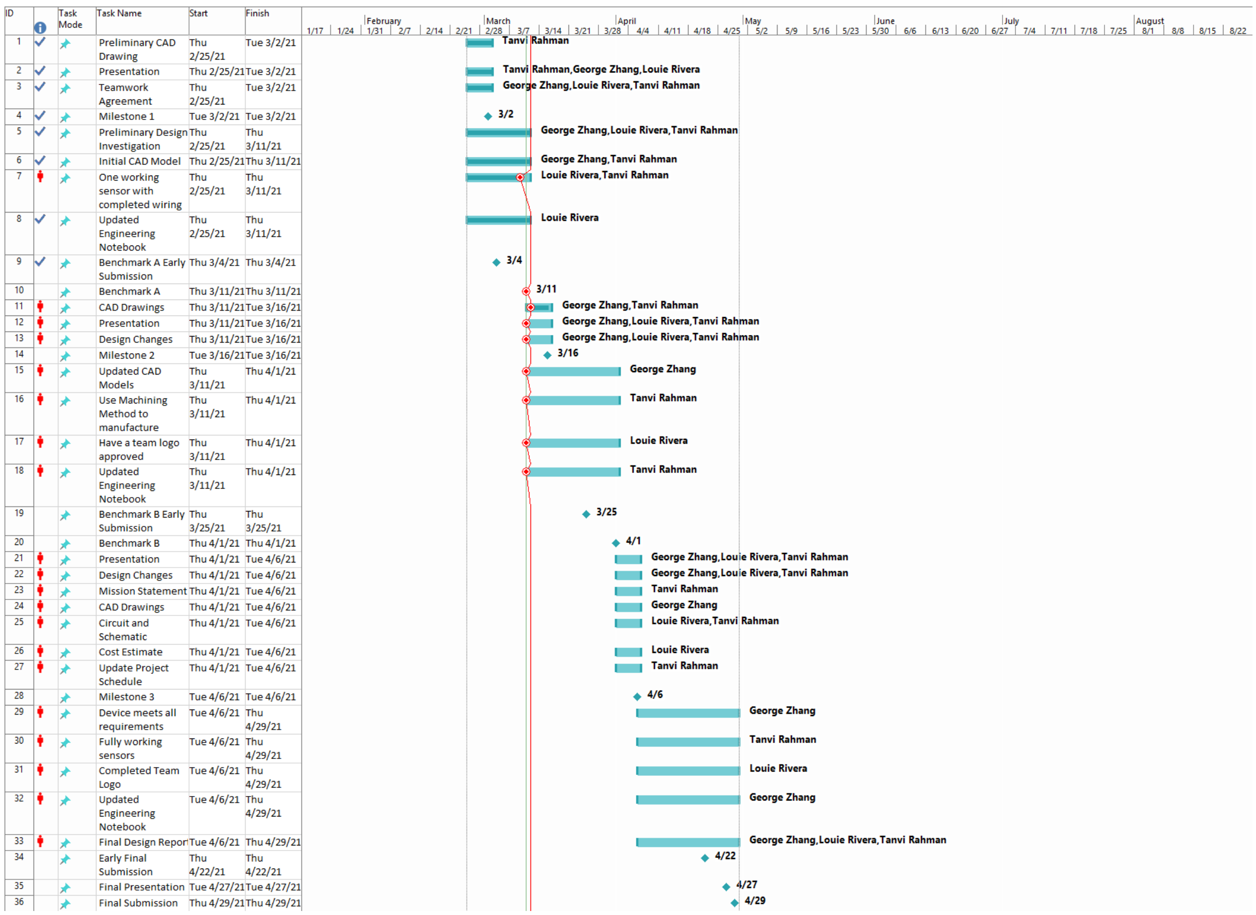
The two figures above show the two possible wiring systems that we have decided to use so far. We are not sure yet which one is the best possible circuit for a prosthetic arm, and we need to conduct more research to find out what the most optimal design will be. Aside from programming the sensors, we need to figure out how to control the degree of rotation of the elbow joint and the wrist joint so that we can have our users bend at those joints exactly how they want to. Ideally, if we get ahead of schedule, we will be able to apply the same research to learning how to bend the finger joints as well. This will allow us to complete the third task in the project, achieving extra credit for the final project. However, it will be very difficult to figure out a way to bend the fingers with the limited range of muscles that an amputee has in the remainder of his arm. This would be where the neural sensors from Backyard Brains will come in handy, as it will allow us to use signals from the brain to control the prosthetic arm, and not just muscle movements. This will widen the range of possibilities for inputs from a user because he will not be constrained to the two muscles left in his lost arm.

Cost Estimate

Resource	Cost Per Unit	Quantity	Cost
Plastic Printing Material	$22.99	1	$22.99
Arduino Cable	$5.89	20	$117.80
Arduino Uno Microcontroller (SparkFun Redboard)	$18.79	1	$18.79
Battery (9v)	$6.99	2	$13.98
Breadboard	$10.99	1	$10.99
DC motor	$6.89	1	$6.89
Muscle Sensor	$37.99	2	$75.98
Servo (Waterproof, boat/car)	$35.99	1	$35.99
String	$7.99	10	$79.90
Touch Sensor	$11.99	1	$11.99
Projected Labor	$50.00	75	$3,750

	Total		$4145.30

Project Schedule



ID	Task Mode	Task Name	Start	Finish
1		Preliminary CAD Drawing	Thu 2/25/21	Tue 3/2/21
2		Presentation	Thu 2/25/21	Tue 3/2/21
3		Teamwork Agreement	Thu 2/25/21	Tue 3/2/21
4		Milestone 1	Tue 3/2/21	Tue 3/2/21
5		Preliminary Design Investigation	Thu 2/25/21	Thu 3/11/21
6		Initial CAD Model	Thu 2/25/21	Thu 3/11/21
7		One working sensor with completed wiring	Thu 2/25/21	Thu 3/11/21
8		Updated Engineering Notebook	Thu 2/25/21	Thu 3/11/21
9		Benchmark A Early Submission	Thu 3/4/21	Thu 3/4/21
10		Benchmark A	Thu 3/11/21	Thu 3/11/21
11		CAD Drawings	Thu 3/11/21	Tue 3/16/21
12		Presentation	Thu 3/11/21	Tue 3/16/21
13		Design Changes	Thu 3/11/21	Tue 3/16/21
14		Milestone 2	Tue 3/16/21	Tue 3/16/21
15		Updated CAD Models	Thu 3/11/21	Thu 4/1/21
16		Use Machining Method to manufacture	Thu 3/11/21	Thu 4/1/21
17		Have a team logo approved	Thu 3/11/21	Thu 4/1/21
18		Updated Engineering Notebook	Thu 3/11/21	Thu 4/1/21
19		Benchmark B Early Submission	Thu 3/25/21	Thu 3/25/21
20		Benchmark B	Thu 4/1/21	Thu 4/1/21
21		Presentation	Thu 4/1/21	Tue 4/6/21
22		Design Changes	Thu 4/1/21	Tue 4/6/21
23		Mission Statement	Thu 4/1/21	Tue 4/6/21
24		CAD Drawings	Thu 4/1/21	Tue 4/6/21
25		Circuit and Schematic	Thu 4/1/21	Tue 4/6/21
26		Cost Estimate	Thu 4/1/21	Tue 4/6/21
27		Update Project Schedule	Thu 4/1/21	Tue 4/6/21
28		Milestone 3	Tue 4/6/21	Tue 4/6/21
29		Device meets all requirements	Tue 4/6/21	Thu 4/29/21
30		Fully working sensors	Tue 4/6/21	Thu 4/29/21
31		Completed Team Logo	Tue 4/6/21	Thu 4/29/21
32		Updated Engineering Notebook	Tue 4/6/21	Thu 4/29/21
33		Final Design Report	Tue 4/6/21	Thu 4/29/21
34		Early Final Submission	Thu 4/22/21	Thu 4/22/21
35		Final Presentation	Tue 4/27/21	Tue 4/27/21
36		Final Submission	Thu 4/29/21	Thu 4/29/21

- How will you split the project workload?

(If your project is heavy in certain aspects like mechanical design or programming, do not split up based on specialty. This will result in an uneven distribution of work.)

Conclusion

The biggest problem we plan to face on this project is making up the work for being completely remote. If we were in person we would have the opportunity to physically build the machine with sensors but now we will have to find a way to visualize the final design, including sensors, in a simulated environment. The problem with this is that we may not be able to properly display the exact motors and sensors we want on the arm in a simulated environment since tinkerCAD does not support importing 3D models. Since we fully remote and do not have to build anything physically, there will be no issues with cost.