Upper Limb Tensegrity Exoskeletons

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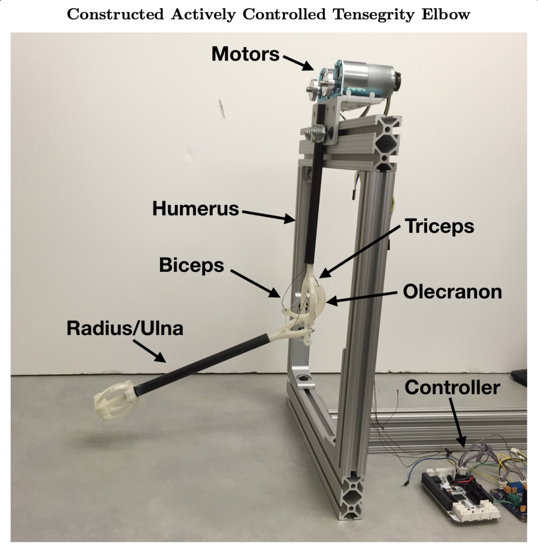
Preliminary Research

Initial research from Lessard revealed projects and prototypes most similar to our problem statement. Issues with their design include the active controlling of the elbow as opposed to fully developed tensegrity system. As seen in the first figure the elbow structure is controlled by motors pulling fishing lines as a sort of puppeteering motion.

Constructed Actively Controlled Tensegrity Elbow



The overall structure of their tensegrity system, however, was still valuable in improving our understanding of tensegrity and possible ways of actuating such structures.

Tensegrity Manipulator Prototypes

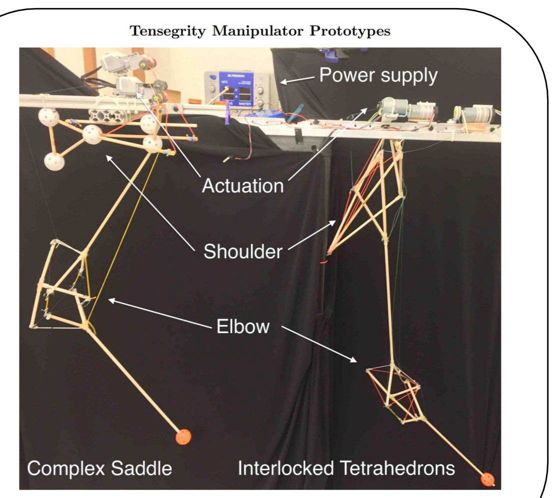
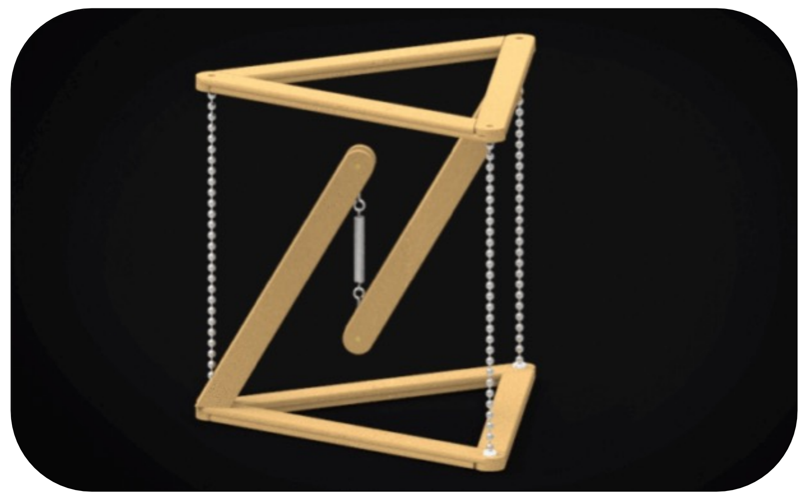
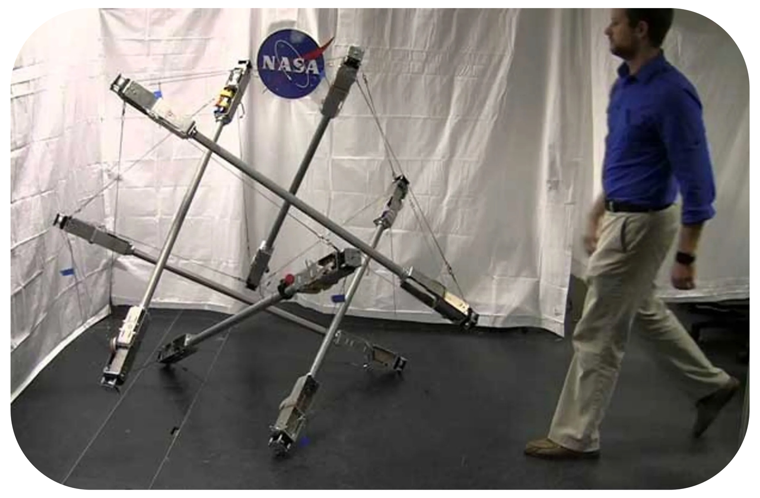


Figure 4.17: The complex saddle tensegrity manipulator (left) and the nested tetrahedrons manipulator (right) [39].

Introduction

Tensegrity, or a tensional integrity, is a geometric structure which obtains its rigidity solely from tension forces. When deformed, tensegrities distributes force across all tensile members reducing localized stress in the structure. Initially created as an artform, tensegrity has recently become a topic of interest among engineers due to its characterized lightweight, easy deformation, and elasticity that handles extreme loads more efficiently, granting it potential in many engineering applications.





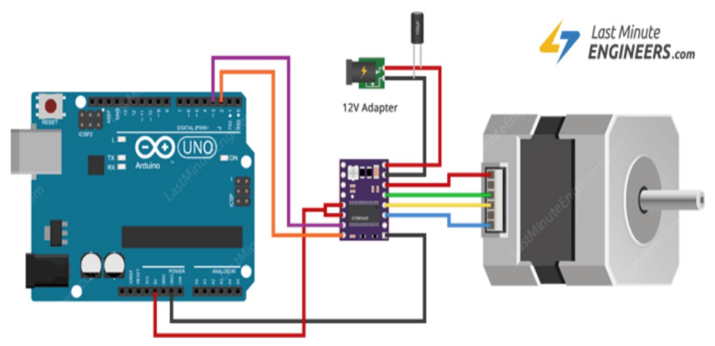
Project Statement

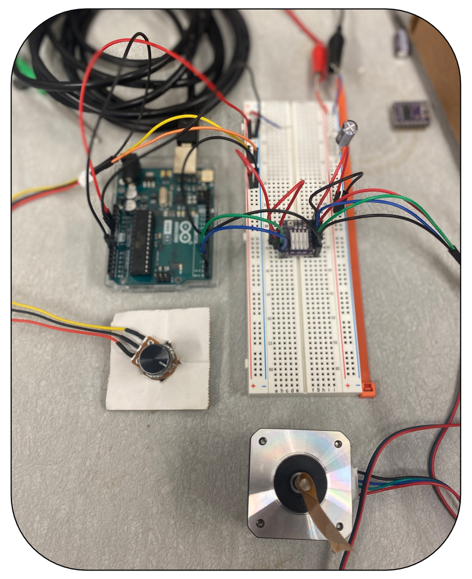
- This project explores the design space of assistive tensegrity devices to promote and augment human dexterity in the upper limb.
- Tasked with researching and studying the potential of tensegrity structures as an upper limb exoskeleton for long-term design
- Possible tool for stroke patients in rehab by assisting the elbow's ability to sustain load in either direction of rotation within a single plane
- Their inherent properties have several key advantages when used in assistive medical devices such as supportive braces or rehabilitation exoskeletons.

Electronics System

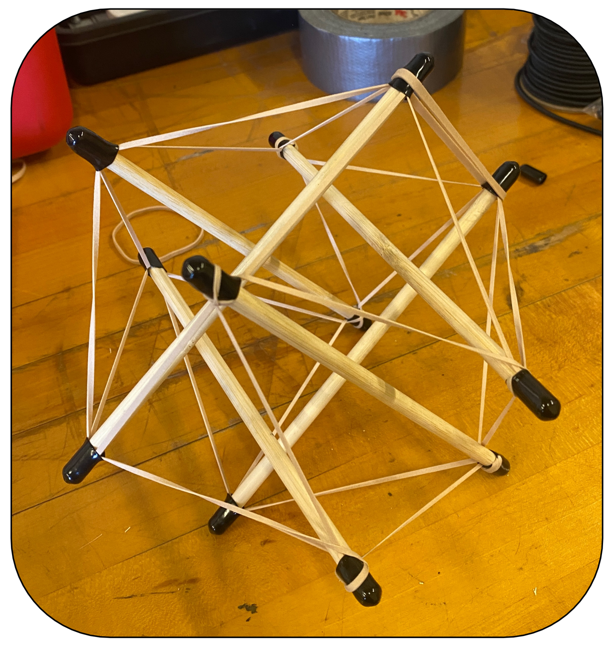
Purpose: To be paired with a spool or pulley mechanism to lengthen or shorten the cables to create tension in the tensegrity exoskeleton when the arm is moving in a specific direction.

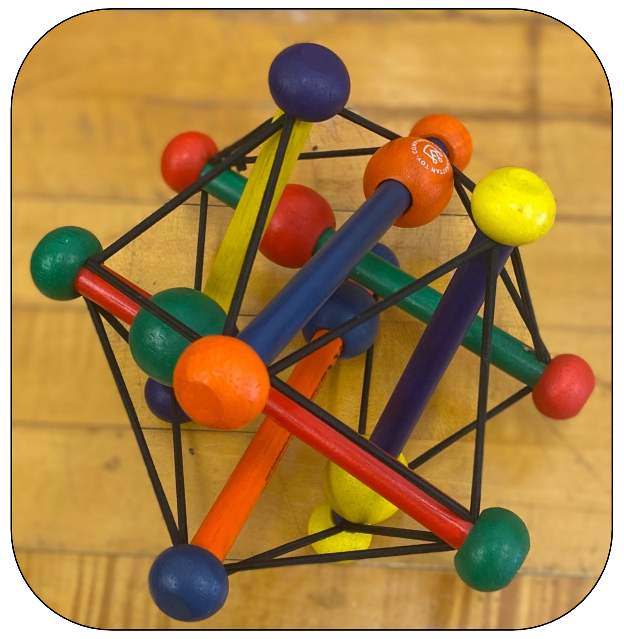
System Overview: Components include an Arduino UNO, NEMA 17 bipolar stepper motor, DRV8825 motor driver, a potentiometer, and necessary cable and wire components to connect respective pins and input output sources. Respective code allows the direction and speed of the motor to be controlled with the potentiometer.





Familiarization Modeling

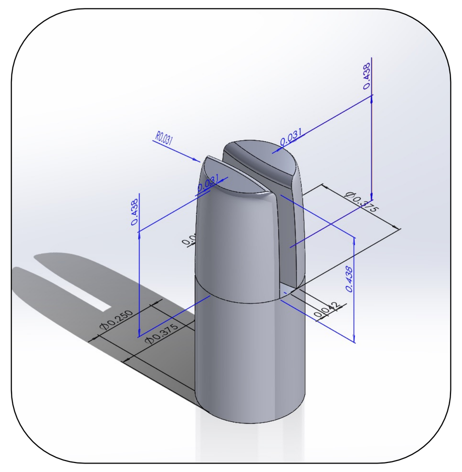


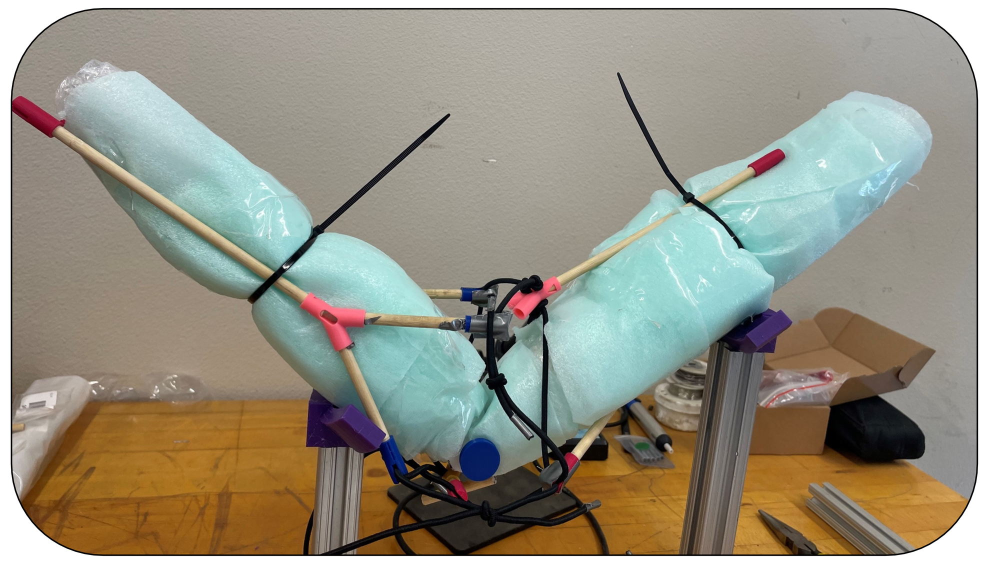


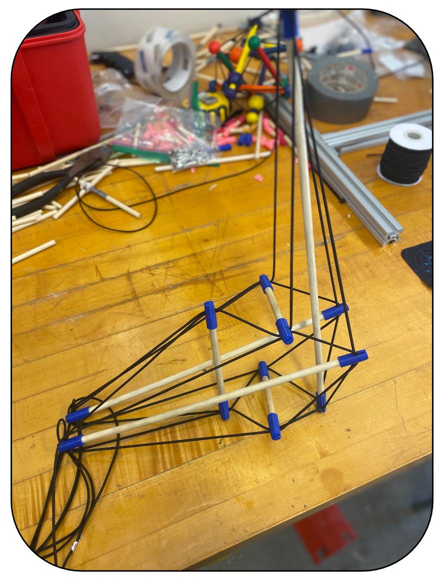
We constructed various tensegrity archetypes to gain intuition about manufacturing tensegrity and understanding tensegrity structural behavior. We discovered certain opposing directional forces that would cause tension and slack on opposing rods and impact the whole structure's integrity. Patterns of triangulation and having at most two tension lines per node appeared through this and were employed in an iterative design process.

Manufacturing and Prototyping

- Designed and 3D printed end caps to assist rapid prototyping.
- Experimented with icosahedron 6-bar elbow model.
- Manufactured arm stand with 8020 aluminum and 3D printed inclined arm supports.
    - Assist with visualization of possible tensegrity layout and structure.
- Upper arm and elbow joint model using PVC and 3D printed pin joint.







Conclusion

Our next steps for this project include manufacturing a wearable sleeve along with designing and manufacturing the spool or pulley mechanism that will be attached to our electronics system. Further in-depth research will be done to improve our understanding of tensegrity and allow us to rapid prototype more designs that can be used for more complete testing with individuals who may be interested or benefit from using this kind of medical device.

References

1. *Ackerman, Evan. "NASA's Super Ball Bot Could Be the Best Design for Planetary Exploration." IEEE Spectrum, IEEE Spectrum, 18 Aug. 2022*
2. *Lessard, Steven Robert. "The Design, Construction, and Evaluation of Crux: A Tensegrity-Inspired Compliant Robotic Upper-Extremity Exosuit." eScholarship, University of California, 29 Sept. 2018,*

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