Designing a Modular and Wireless Strut for a
Tensegrity Robot and Analysis of Motion Using a Closed Loop System

Project Proposal

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Abstract

The goal of the project is to design a modular wireless strut that can be used to create a n-bar tensegrity robot. This strut needs to meet many design requirements including size and power consumption. The strut will be used in a closed loop system that will be developed to be able to learn using a neural network. The learned motion can information can be collected using the struts and quantitatively analyzed.

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Introduction

A tensegrity robot is a soft robot made up of rigid struts and springs. These are connected in a disjoint manner such that the robot maintains it's shape. (Rieffel et al., 2007). The field of soft robotics is expanding due to their ability to transform in ways that humans and typical hard robots can not. These robots are unique because they are able to be

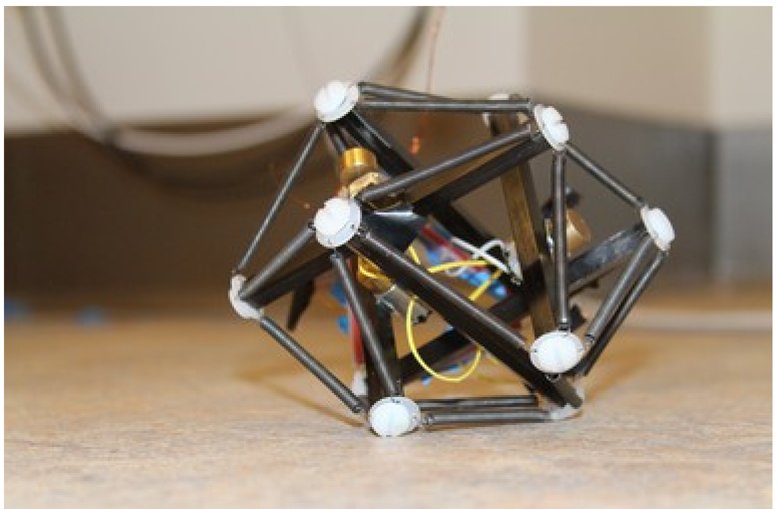

Image 1: A picture of a 6 bar tensegrity.

manipulated and return to it's original shape. Because of their structures, learning how to make soft robots move is an important research topic. Seen below in Image 1 is a 6 bar tensegrity robot. The robot is made up of 6 struts, 24 springs, and 3 pager motors. The shape of the robot is created by the forces of the springs onto the struts.

In order for a soft robot to be useful the robot has to be able to move. Paul et al. (2005 explains, there are three main ways that a tensegrity robot can be actuated: strut colocated actuation, cable colocated actuation, and non-colocated actuation. Strut colocated actuation is done by using actuators to vary the strut length, this changes the geometry of the structure. Cable colocated actuation is changing the length of the springs. Non-colocated actuation is using a force between two struts, springs or a strut and spring (Paul et al., 2005).

Tensegrity motion can be created with three motors being used to actuate the struts and springs. The motors vibrate at different frequencies which causes locomotion. Because of the dynamic coupling of the different struts by the springs the motors can generate frequencies that are transferred throughout the device. The entire tensegrity vibrating can cause motion (Paul et al., 2005). In the case of Paul et al. (2005), this motion was bad and research is done to limit it. In the case of this research we can exploit the motion of the tensegrity for locomotion.

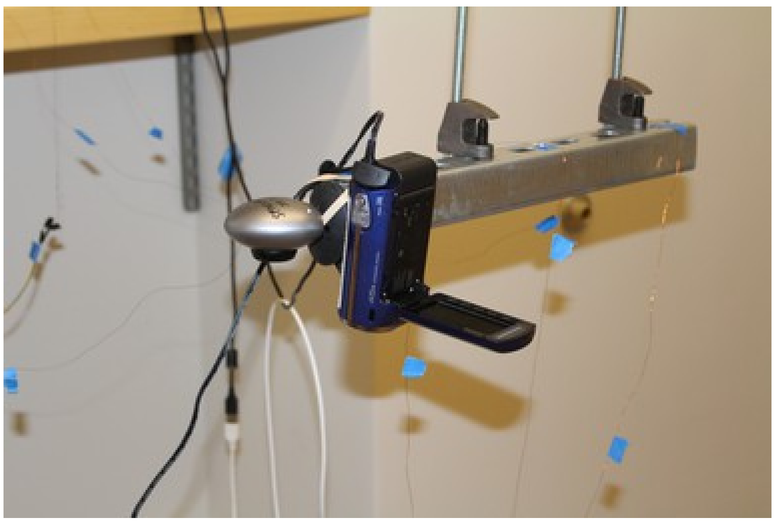

Image 2: The camera mounted above the tensegrity. The camera is used to capture the motion of the robot.

It is unknown what frequencies make the tensegrity robot move. In order to learn the frequencies one can use a machine learning algorithm. While the tensegrity is attempting to move a camera mounted above captures the motion of the robot (Image 2). This motion is quantified using image analysis. Once the motion is analyzed the data is processed using a hill climbing algorithm. This algorithm continuously changes the output of the motors and measures frequencies until it finds the optional frequency for motion.

One problem that the design creates is that when the tensegrity motors are being powered there needs to be a power source connected to them. The means that there is a tether that can possibly prevent motion from occurring. The advantage of the tensegrity robot design is that once a module is created that works well for the 6 strut version, it can easily be scaled to work with bigger versions (Rieffel et al., 2010). With the idea of modularity in mind, the struts can be designed so that they are able to be completely contained by themselves. Each strut can contain sensing, control, processing, and communication. The communication is not between struts, but to a central source for data collection. The communication between struts is created inherently by the struts being able to sense the motion of the other struts. This design allows for the robot to scale without increasing a complex web of connections.

The research of tensegrity is an early field and still has a lot to be done. A modular design will allow research in some larger tensegrity structures and also allow for more accurate measurement. Other research topics of tensegrities include the use of other algorithms, like genetic algorithms to learn the motion. This field is a very interesting one that has a lot of maturity that can be developed in the near future.

Design Requirements

This project has two different main components that can be developed independent of each other, but combine together in the end. The two components divide into electrical engineering and computer science. The electrical engineering goal is to design a modular, wireless, independent strut that can be implemented in a tensegrity robot. The computer science component is to work with instrumentation and quantitative analysis of an open loop system, and develop a learning algorithm with neural networks in a closed loop system.

Electrical Engineering

There are many requirements of the design of the modular wireless, independent strut. The primary design goal of this strut is to eliminate the need for a tether. The current design includes a magnet wire tether to provide the motors with control voltages. This tether is inhibiting the ability to conduct research with the device. To remove the tether each strut will need to be able to provide it's own power, sensing, processing, control, and locomotion.

The many enhancements that will be added to the tensegrity need to be done in a way that the overall size of the tensegrity is not effected. Seen below in Image 3 is the current strut. It is currently 9.6 cm long, the goal is to increase the length a minimal amount.

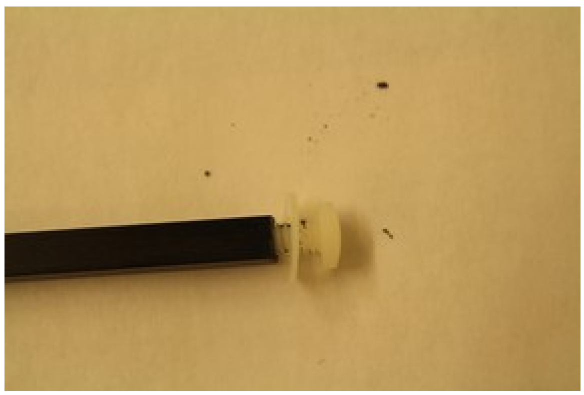

Image 3: A view of the end of a current strut of the tensegrity robot. The strut is about 9.5 cm long and .6 cm square.

To make the strut wireless, each strut needs to have it's own power source. This power source has to be able to power the device for at least an hour at a time. The battery needs to be able to be switched out with other batteries. This is so that there can be multiple sets of batteries can be used to extend the length of experiments.

The final requirement of the design is that the struts are to be designed in a way that is modular. This means that once one strut is created, additional struts can be added to a design without altering the original ones. This will allow us to complete research with any n-bar tensegrity robots.

Computer Science

There is a lot of computational analysis that can be done with the current tensegrity robot that has been created. There are currently two tensegrity robots, one with an inertial measurement unit (IMU) and the other with motors. These two robots can be used to experiment on.

The first analysis of the tensegrity can be done using the IMU version. The IMU has a gyroscope, accelerometer, and compass on it. Using this information we can collect data about how the robot moves in an open loop system. From this data we can do some computations and come up with quantitative analysis of the tensegrity robot. The goal is to figure out the natural frequencies that the robot oscillates at and what frequencies excite the robot.

The next major part of the tensegrity research will be conducting closed loop control of the robot using neural networks. The goals of this is to use a neural network to have the robot learn how to move. The system is a closed loop, meaning that the system is self adjusting. The robot will need to be able to use sensor data to adjust it's motion.

Putting it all together

The final stage of the project is to be able to come up with a complete tensegrity robot that consists of the modular design, and is able to run the neural network. This robot will allow for collection of data and will hopefuly produce quantitative results about the motion of tensegrity robots.

Design

The tensegrity robot will have to have a careful design such that all the goals and requirements are met. Currently there is research being done using the Pololu MinIMU v2 IMU. This IMU is ideal for use because of its size and sensor package. It will be idea to use this IMU in the final design since there is already research being conducted using it. An example output of this unit can be seen below in image 4. Here we see just the accelerometer's three axis.

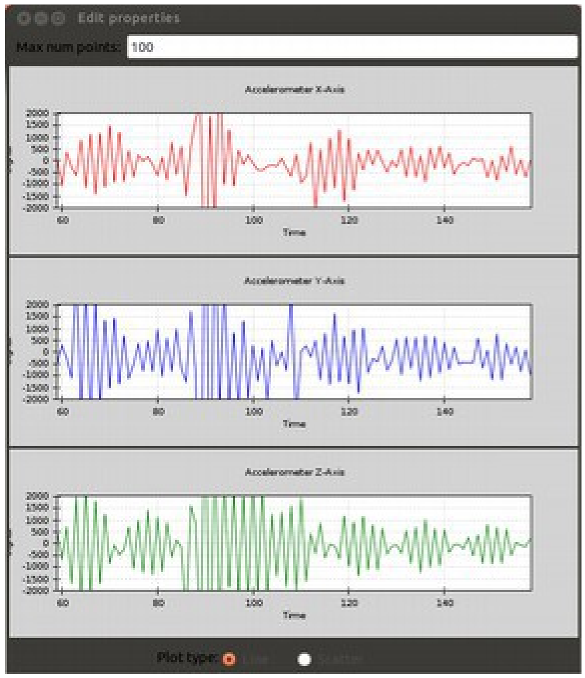

Image 4: Sample output from the MinIMU v2 accelerometer. This component will be used as part of the final tensegrity strut design.

In order to control the tensegrity there will have to be some sort of processing unit. This unit will have to be small and low powered. While designing on a final component for the project it is likely that a PIC Microchip or Arduino Mini will be used as the processor.

There must be a wireless communication device on the tensegrity to allow for information logging at a central source. This communication will be done over a short range. It has been suggested that a bluetooth module would be an ideal device to use. But this device requires a large amount of power for the communication distance. Part of the design will be to look into possible other communication methods that require less power, but are still small and reliable.

The design of the motor will be one of the biggest design decisions that will have to be made. The motor is the component that will draw the most current and be the limiting factor in the length of the battery life. The motor will also be required to have a shaft encoder on it so that the position of the motor can be accurately tracked.

The final design component of the tensegrity will be the battery. The requirements are very difficult to fulfill. The best option for powering the robot will be to use a Lithium Polymer battery. These units have a good current density that allows for the battery to be small and last a long time. Some research in other power sources such as super capacitors and inductive power will be conducted to make sure the best power source is selected.

Project Schedule

The two main areas of the project can have overlapping schedules, since they are not fully dependent on each other. The following is a preliminary schedule for this project.

Fall Term:

Weeks 1-3

Research on the best components to use to accomplish the goals of the project.
Complete the analysis of the open loop system using the IMU based tensegrity.

Week 4

Have the orders in for the components of the modular strut.

Weeks 5-8

Complete the build of the first prototype of the modular strut.
Begin work on the Neural Network to be used to work with the closed loop system.

Weeks 9-10

Testing of the modular strut for performance.

Winter Term

Weeks 1-3

Assess the performance of the prototype and fix any issues.
Build a total of 6 of the struts.
Continue work on the Neural Network.

Weeks 4-6

Combine the two components so the Neural Network can run on the modular tensegrity

Weeks 6-9

Using the tensegrity and the Neural Network gather results and do quantitative analysis.

Week 10

Complete the final report of the robot's performance.

Project Budget

This project has a lot of small components in it. These components are expensive and can cost a significant amount especially when building 6 of the modular struts. The following is a preliminary cost breakdown of components.

Item	Qty Unit Price Total
MinIMU	$40 * 12 = $480
MicroGearMotor	$15 * 12 = $180
Bluetooth	$40 * 4 = $240
Battery	$12 * 18 = $216
Total	$1,116

Conclusions

In conclusion the goal of the project is to come up with a tensegrity robot that is engineered to be modular and wireless that can perform the task of learning using a closed loop system and neural networks. There are many different design decisions that will need to be considered as the project commences. But ultimately the final goal is obtainable to have a complete working system that will further the tensegrity research at Union.

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