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LEMUR SCP Actuator Research Proposal

Introduction

The goal of my research is to allow casual users to be able to design and create desire SCP actuators out of conductive nylon sewing thread. The user should be able to design a SCP actuator that would fit their needs of application. With a few specified user inputs (Force the actuator can generate, length of the actuator), the user should be able to obtain the information on the best fabrication method (Motor speed, hanging weight, initial sewing threat length) for the actuator.

To achieve this, the first step is to come up with a way to characterize the SCP actuators. We need to have a setup that allows us to find the different characteristic of the SCP actuators (spring constant, damping constant, voltage constant, and force generated). With this setup, we will find the relationship between force, strain and voltage.

Once we have a reliable way to characterize any SCP actuator, we will need to know how different fabrication approach (different motor speed, hanging weight) affect the performance (Spring constant, damping constant, Voltage constant, force generated) of the SCP actuators.

To achieve this, we will first need to improve the SCP actuator fabrication setup we currently have. Currently, the motor we are using to manufacture the SCP actuator is hold on to the stand with a 3-Prong Dual Adjust clamp. However, one of the most essential step to making the actuator is to make sure that the motor is spinning the sewing thread without causing any wobble. We can't ensure that motor is completely aligned with the sewing thread with a 3-Prong Dual Adjust clamp. Another adjustment we will need to make to the setup is our method for preventing the weight from rotating. Currently, our approach to preventing the weight from rotating is by holding on the weight with our hand. This problem can be solved by adding some 3D printed attachment to the setup.

After we improved the setup we have currently, we will make SCP actuators by using different hanging weight and motor speed combination. Next, we will using the SCP actuator characterization setup we have to find out the performance of these SCP actuator and determine the best fabrication method.

By knowing the relationship between motor speed, sewing thread length, hanging weight mass, and performance of the SCP actuator, we will be able to write up a calculator that would determine the way to manufacture SCP actuator for different application.

Related Works

High-Performance Robotic Muscles from Conductive Nylon Sewing Thread

Most traditional robotic actuators are different from the natural muscles in that, natural muscle have a very high power-to-weight ratio while still have a fast actuation and high dynamic range. However, the recent discovery of super coil polymer actuator opens up another path to artificial muscle. These nylons fishing line or sewing thread constructed actuator are light weight and have the ability to produce great mechanical power.
This paper developed a thermomechanical and thermoelectric model for the SCP actuator and used these models to study the controllability of the SCP actuator. The thermomechanical model of the SCP actuator identifies the relationship between temperature, force and strain. The paper propose that this model of the SCP actuator will follow this thermomechanical model:

$$F = k\ (x - x_0) + bx' + c(\ T - T_0)$$

The Thermoelectrical model that was proposal in the paper is:

$$C_{th}\frac{dT(t)}{dt} = P(t) - \lambda(T(t) - T_{amb})$$

One can design a desire SCP actuator by using the two equations listed above.

Furthermore, in this paper, the researcher also implemented the SCP actuator into a 3D printed hand to show the various things we can do with the SCP actuator.

Artificial Muscles from Fishing Line and Sewing Thread

Modern artificial muscles have gain many ground. Many have large and powerful stroke, however, most of them still have limitation such as low cycle life, hysteresis and low efficiency. Furthermore, a lot of these artificial muscles have a huge limitation of the type of application it can be use in. Deployment of these artificial muscle seem to be restricted by their high cost and scalability into different applications. The discovery of artificial muscles from fishing line and sewing thread solve many of these problems.

This paper discusses in depth about the behavior of the SCP actuator base on different manufacturing method and how with different fabrication method would affect the performance of the actuator.

Fabrication Parameters and Performance Relationship of Twisted and Coiled Polymer Muscles

Twisted and coil polymer (TCP) aka SCP muscle is soft actuator. These actuators have a great potential for different engineering application because it experiences a "large linear deformation in response to applied power (Joule's Effect)"

These actuators are made by twisting a precursor fiber while attaching a dead weight at the end. This process is followed by heat treatment that annealed the fiber. The actual performance of the SCP actuator depends greatly on the fabrication parameters. This paper looks into the effect of different parameter have on the performance of the actuators. More specifically they look into input parameters such as load, current, voltage and output results such as displacement, force and temperature. Furthermore, they also look into have different plying of the coil would affect the performance of the SCP actuators.

Experimental characterization of a new class of polymeric-wire coiled transducers

The recent discovery of the polymeric-wire coils opens up a new path in the field of thermal actuator. These newly discover actuator are cheap to manufacture and have powerful and reliable actuation when exposed to heating.

This paper talks about the manufacturing method of nylon coils with explanation on their working principle (*Nylon coil working principle)*. Furthermore, the paper presents the test bench setup they have for characterization of the nylon coils.

Project Timeline

Weekly Goal

- Week 0
  - Doing background research on SCP actuators
    - Finish writing up the related works section of the Research Proposal
  - Finding the expected values for the SCP actuator characterization pre-lab
    - Using the spring constant k value from [1] to find the expected Force and Strain value.
    - Using the damping constant b from [1] to find the expected Force and velocity value
  - Finish writing up the procedure for the SCP actuator characterization Pre-lab
    - Step by step instruction on how to run the experiment
    - Force vs strain table for finding spring constant (zero voltage)
    - Force vs velocity table for finding damping constant (zero voltage)
    - Force vs strain tables from finding the voltage constant (1 table for different voltages)

- Week 1
    - Finish designing the experimental setup
        - Figure out how to use an encoder.
            - How to program it?
            - What software to use?
            - What other electronic we need for controlling it?
        - Figure out how to use a load cell
            - What software to use
            - How to calibrate it
            - What other electronic we need
        - Have a complete CAD model of the experimental setup
    - Finish making the list of material needed for running the experiment
        - Website links
        - Material dimension and spec
- Week 2
    - Purchase all the necessary material for running the characterization experiment
    - Start making the experimental setup (once the material arrives)
        - 3D print load cell attachment
        - 3D print SCP actuator attachment
- Week 3
    - Continue working on making the experimental setup
        - Test bed`
            - Make marking on the position of the hole
            - Drill, tape and counter-sink the hole
            - Done in the machine shop
        - Motor mount
            - Make in the machine shop
        - Vertical stage
        - (To be updated after finish designing the experimental setup)
    - Setup the load cell
        - Calibrate the load cell
        - Use calibration weight to make sure the load cell reading is correct
    - Setting up the encoder
        - Learn how to use the encoder and how to record values using it
- Week 4
    - Finish making/remaking all the parts for the experimental setup
    - Assemble the experimental setup and make sure everything works as indented
        - Make sure the position control of the vertical stage is accurate by using caliper to measure the position
    - Run the first part of the experiment to find the spring constant of the SCP actuator
        - Fill up the force vs strain table in the pre lab and figure out the spring constant

- Run the second part of the experiment to find the damping constant of the SCP actuator
  - Fill up the
- Week 5
  - Find the voltage constant of the SCP actuator
    - Record down force vs strain at different voltage in the pre-lab table
    - Graph them on the same plot
    - Find the voltage constant from the plot
  - Compare the result of the experimental value to the expected values calculated in the pre-lab
    - Explain any discrepancy if the experimental value is different from the expected value
  - Write up a summery for the characterization of the SCP actuator experiment
- Week 6
  - Redesign and the fabrication setup
    - Compile a list of material needed
    - Improve the motor mount setup
      - CAD Model + 3D printed part
    - improve the counter rotating attachment
      - CAD Model +3D printed part
    - Improve the stability whole setup
- Week 7
  - Writing up the pre-lab for finding the relationship between motor speed, hanging weight and performance (spring constant, damping constant, force generated)
    - Introduction
    - List of material needed
    - Equations that we will be using
    - Tables for recording data
- Week 8
  - Finish writing up the pre-lab
    - Expected value
      - Motor speed
      - Mass of hanging weight
      - Spring constant
      - Damping constant
      - Voltage constant
    - Procedures
  - Start running the experiment once the pre-lab is approved
- Week 9
  - Finish running the motor speed/ hanging weight vs performance experiment
    - Fabricated SCP actuator using different speed/hanging weight combination
    - Find the performance for each of these actuator
    - Record down all the data in the table
- Week 10
  - Write up a summary on the experiment
    - How does mass of the hanging weight affect the performance?
    - How does that speed of the motor affect the performance?
    - What motor speed and hanging weight mass combination create the SCP actuator with the best performance?

Reference

[1] High-Performance Robotic Muscles from Conductive Nylon Sewing Thread

[2] Artificial Muscles from Fishing Line and Sewing Thread

[3] Fabrication Parameters and Performance Relationship of Twisted and Coiled Polymer Muscles

[4] Experimental characterization of a new class of polymeric-wire coiled transducers