SDSU
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# Biomimetic System for Artificial Spider Silk Spinning

HOLLAND LAB

## MEET THE TEAM



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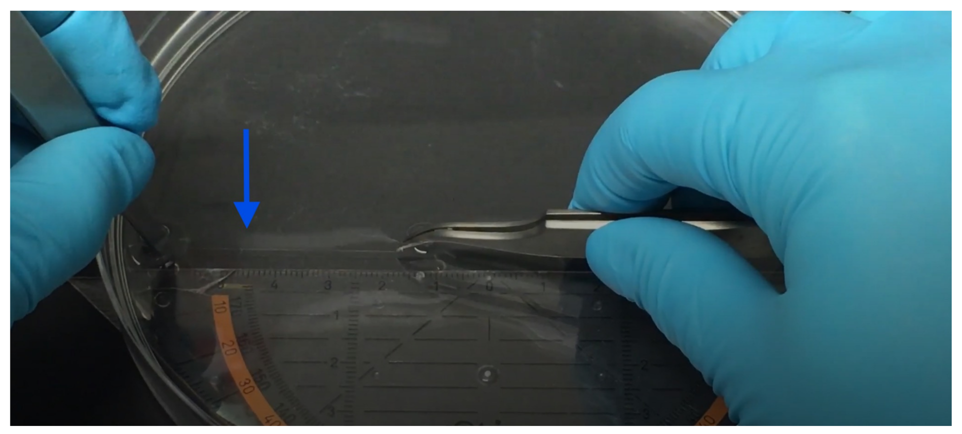
## INTRODUCTION

Current methodologies for biopolymer fiber production, particularly those imitating natural processes such as spider silk formation, are unable to integrate precisely controlled systems capable of transforming biopolymer solutions into continuous fibers through coagulation baths. Traditional methods rely on manual intervention or non-optimized systems that result in inconsistent fiber characteristics such as variable diameters, weak mechanical strength, and irregular morphology. This presents a significant challenge in the biomaterials field, where exact control over fiber extrusion and tension is critical. There is currently no well-documented system that seamlessly combines the extrusion of biopolymer solutions via a microfluidic chip with synchronized fiber collection and processing mechanisms. Specifically, the absence of an automated system capable of efficiently extracting and processing biopolymer solutions into fibers through a set of coagulation baths.

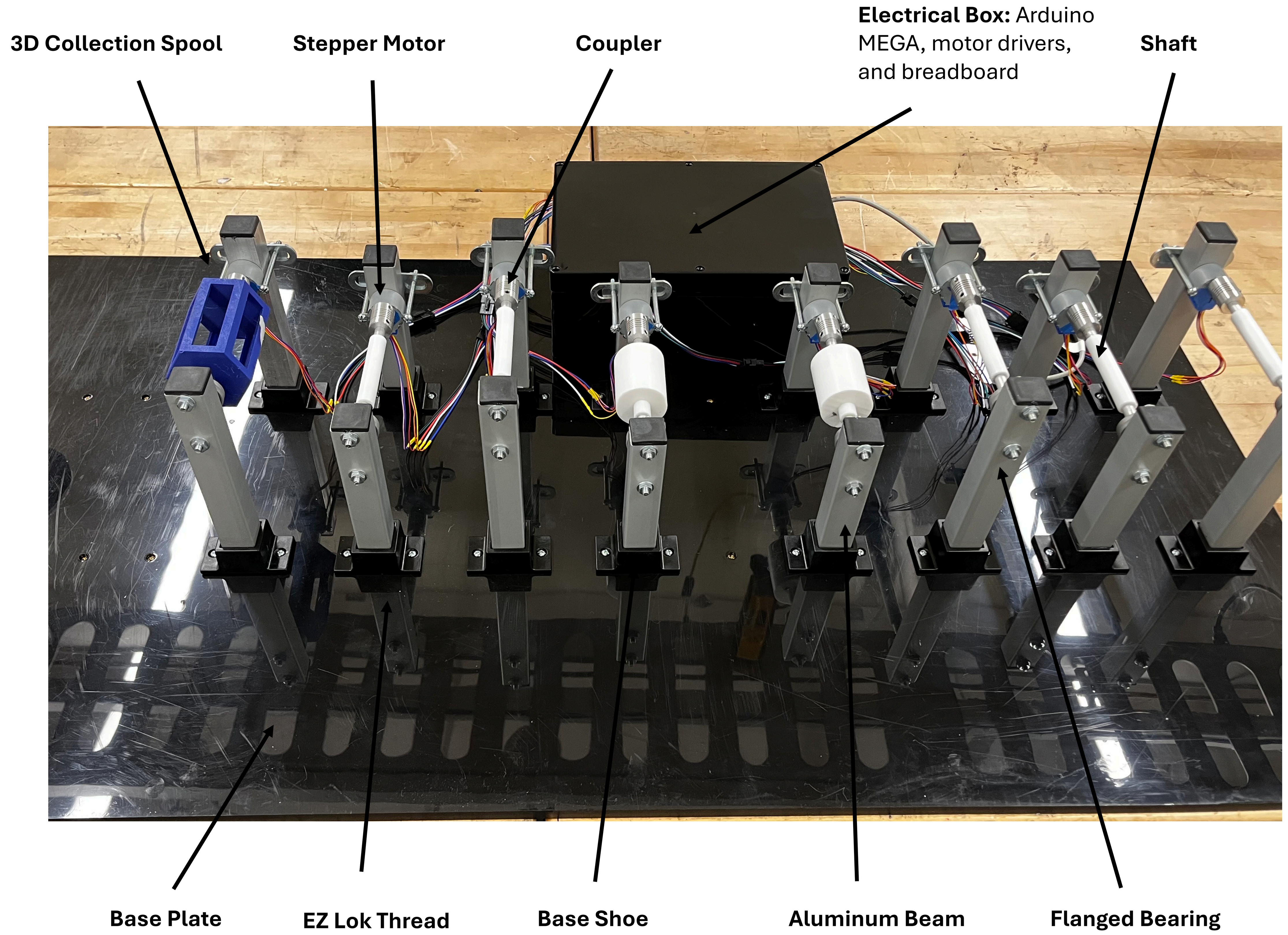


Developing this system would allow real-time control of key parameters such as flow rate, collection speed, and tension to closely replicate the refined fiber spinning mechanisms found in nature, particularly in spiders. Our ultimate goal is to develop a system capable of reproducibly producing fibers with uniform diameters, improved mechanical strength, and well-controlled morphology.

## OBJECTIVES

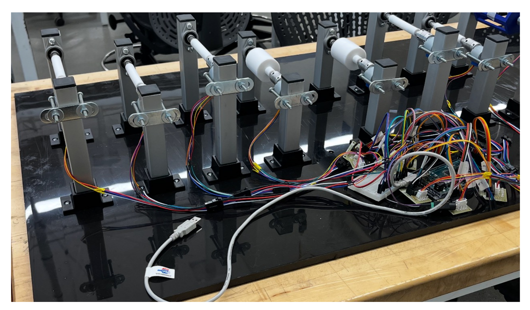
1. Replicate spider mechanical drawing
2. 3D printed collection spool
3. Provide a reliable, easy-to-operate control interface

## DESIGN

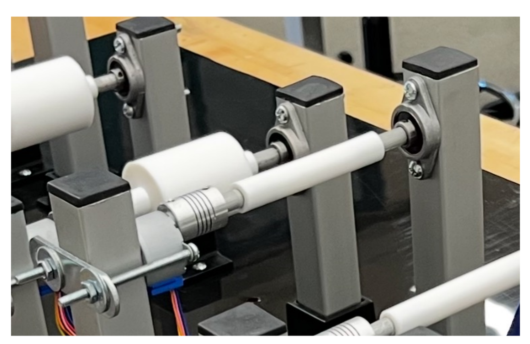



## MANUFACTURING SPECIFICATIONS

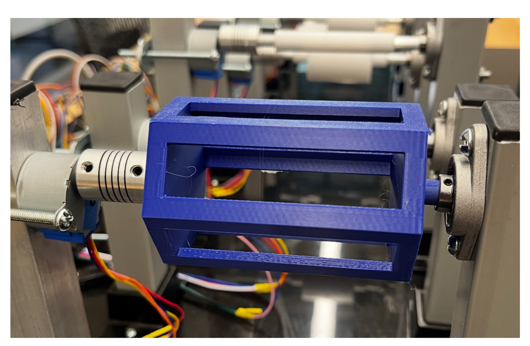
**Assembly:**
Base plate: HDPE



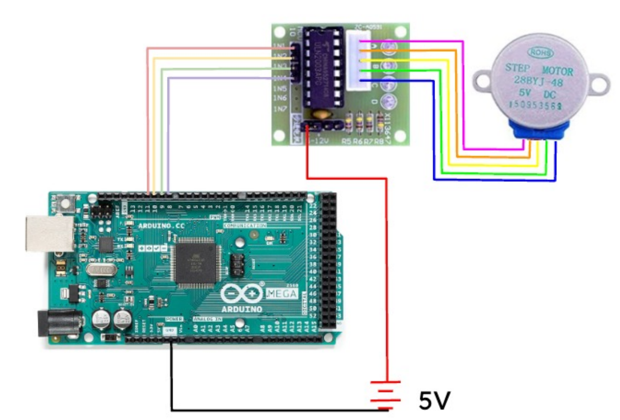
Shafts:
Flanged Bearing → Aluminum shaft → PTFE → Coupler →



3D print collection Spool: PETG

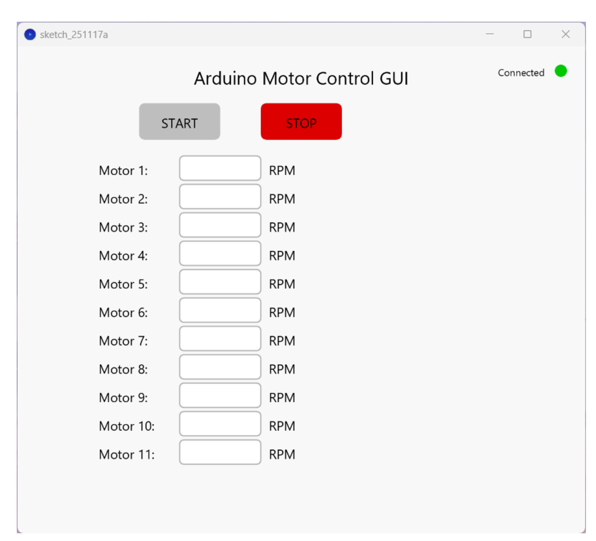


**Electronics and Hardware:**
Microcontroller: Arduino MEGA
Motor Driver: ULN2003




Stepper Motor: 28BYJ-48

GUI: Processing 4




## FUTURE TESTING

Synthetic fibers from the Holland Lab have yet to be formed. To test our pultrusion device's functionality, we have substituted synthetic fibers with a natural black widow. In order to prove that it will work with synthetic fibers as well, we have gathered data on natural and synthetic fibers for comparison.

Mechanical testing compared natural Black Widow silk to synthetic microfluidic spider silk to determine safe operating limits for our pultrusion system. Natural silk exhibits higher performance across all metrics, including approximately 30 percent greater tensile strength, 39 percent higher extensibility, and 52 percent higher toughness. Because synthetic fibers fail under lower stress, the tensile strength difference was quantified using:

**% Stronger** = $((\sigma_{natural} - \sigma_{synthetic}) / \sigma_{synthetic})$ x 100% = ((1.3 GPa - 1.0 GPa) / 1.0 GPa) x 100% = ((0.3 GPa) / 1.0 GPa) x 100% = **30%**

This 30 percent reduction in strength directly informed our operating parameters. Motor RPM controls tensile loading during pultrusion, so we lowered RPM by 30 percent to prevent overstressing synthetic fibers while still maintaining adequate stretching for alignment. Combined material comparisons, tension sensitivity analysis, and structural testing validated the system's tension control strategy and supported the final bio-inspired pultrusion design.

## RESULTS

Design Requirements:
- Final assembly meets the 7" benchtop requirement.
- Mechanical layout supports two coagulation baths (with an optional third) and uses staggered beam heights to enable controlled stretching and post-treatment.
- Maintained a desired modular design for future experimental changes to synthetic fiber production.

Electrical and Control Components
- Motor speeds can be synchronized with microfluidic extrusion rates to maintain uniform tension along the pultrusion path.
- Arduino-based control system independently drives 11 stepper motors.
- Generated UI for ease of use for the Chemistry department using Processing 4

Cost and Manufacturing:
- Maintains performance while using minimal expenses
- Stayed within our sponsor budget.

## ACKNOWLEDGEMENTS


We would like to give thanks and show our appreciation for Dr. Gregory Holland of the Holland Lab for sponsoring our project. We would also like to thank Dr. Alexander Lehman for his guidance and SDSU Engineering Department for providing us the necessary tools and facilities to complete our project!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