CAREER: Adaptive Actuation and Control in Embodied Biohybrid Robots

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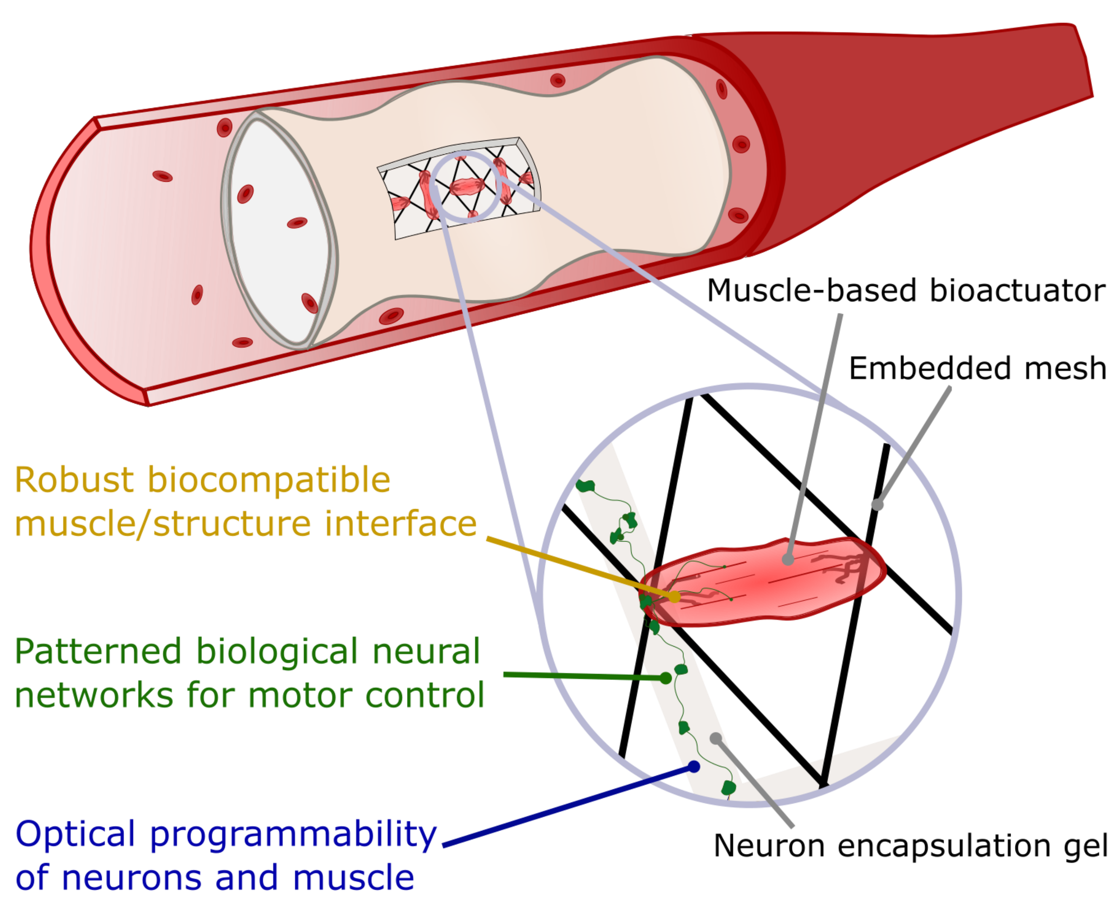
Challenge

(1) Current bioactuators are limited to interfacing with soft or small-scale substrates

(2) Bioactuator stimulation approaches often result in low actuation forces and muscle fatigue

Technical Approach

- Adaptive bioactuation with embedded fiber-based interfaces
- Bioinspired biological neural networks for motor control
- ‘Programed’ bioactuators and biological neural networks for robotic applications



Key Highlights

Long-fiber embedded FRESH (LFE-FRESH) printing for bioactuators

LFE-FRESH Printing Process

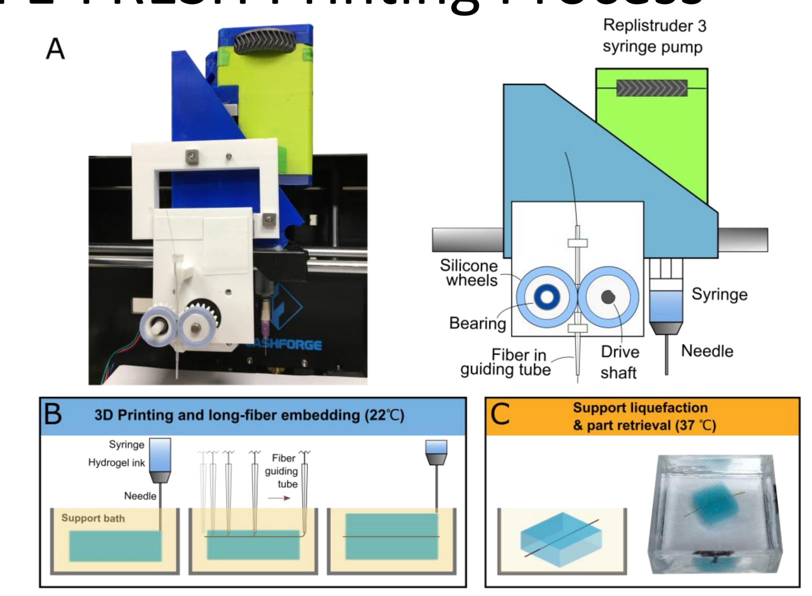


Figure 2. (A) A photo (left) of the multi-head printing platform (B) A schematic drawing of the LFE-FRESH process. (C) The support bath material liquefies upon raised temperature.

Printability analysis

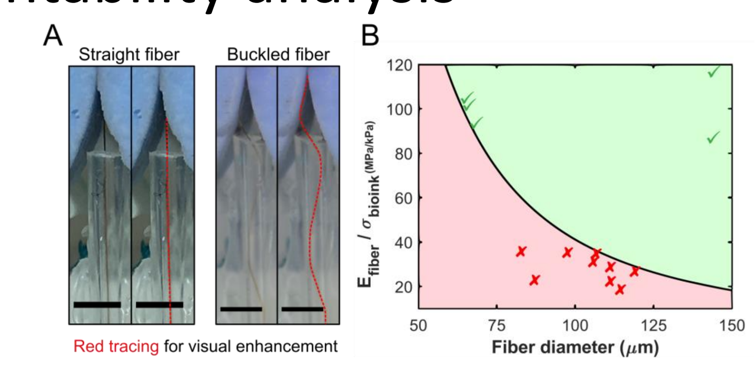


Figure 3. Fiber printability analysis (A) straight (left) and buckled fiber (right). (B) Design diagram for fiber printability as a function of fiber diameter and fiber tensile modulus v.s. bioink strength ratio.

Long fiber reinforcement improves hydrogel strength

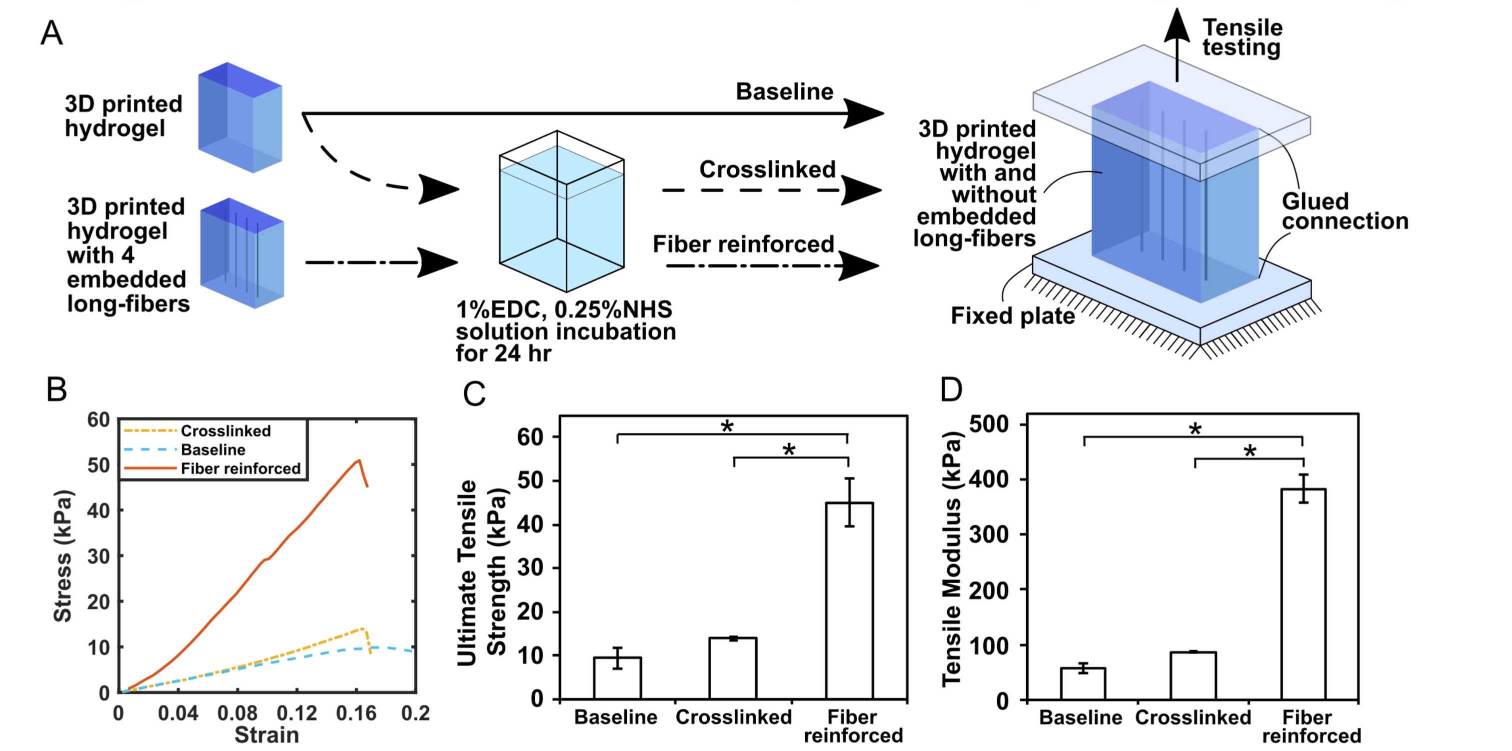
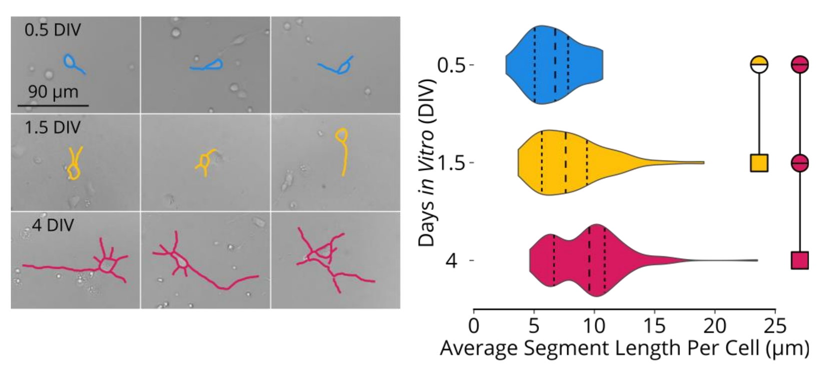


Figure 4. Long-fiber embedding provides structural reinforcement to 3D printed hydrogels. (A) Schematic drawing of tensile testing pipeline of 3D printed hydrogels with three treatments. (B) Representative stress v.s. strain curves during tensile testing for the three groups. Comparisons of (C) ultimate tensile strength and (D) tensile modulus of each treatment group.

Biological Neural Networks

Figure 5. Developed and compared quantitative morphometrics for assessing neuron maturation and growth directions in vitro for validation of biological neural network growth models and design tools.



Education and Outreach

Incorporate neuromuscular modeling in educational curriculum

- Added new lecture on biohybrid robotics to graduate course
- Creating new summer mini course titled “Introduction to Bioinspired and Biohybrid Research”

Improve recruitment of young women to robotics

- Scaling up undergraduate research opportunities
- New Canvas based onboarding and training tools
- Supported 5 female or URM undergraduate researchers this year

Build and assess community tools for women faculty in robotics

- Created web-based landing page and search feature for the CMU Women Faculty in Robotics list
- Tracking new additions to the list (9 to date)

Publications and dissemination

1. W. Sun, A. W. Feinberg, V. A. Webster-Wood, “Continuous Fiber Extruder for Desktop 3D Printers toward Long Fiber Embedded Hydrogel 3D Printing”, accepted at HardwareX.
2. W. Sun, et al., “Long-fiber Embedded Hydrogel 3D Printing for Structural Reinforcement”, ACS Biomaterials Science & Engineering. Dec. 2021.
3. W. Sun, V. Webster-Wood. “An Integrated Computer Vision System for Real-time Monitoring and Control of Long-fiber Embedded Hydrogel 3D Printing”. accepted at International Conference of Additive Manufacturing for a Better World, 2022.
4. A. S. Liao, et al., “Quantification of Neuron Morphological Development Using the Change Point Test”. Summer Biomechanics, Bioengineering and Biotransport Conference 2021. Virtual. June 14-18, 2021.
5. K. Qian, et al., “Modeling Multi-Neuron Biomimetic Growth Stages using Isogeometric Collocation and Phase Field Model”. 16th US National Congress on Computational Mechanics. Chicago, Illinois. Virtual. June 25-29, 2021.

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