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In Situ 3D Robotic Bioprinting of Therapeutic Hydrogels for Esophageal Surgeries

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Introduction

Background

- *In situ* bioprinting delivers biomaterials to a surgical site within the body
  - Excellent printing resolution [1, 2]
  - Personalized structures tailored to patient anatomy [1]
  - Achieved via minimally/non-invasive procedures [2]
- Functionalized with therapeutics to accelerate post-surgical recovery [1, 2]

Problem Statement

Surgical performance in cramped anatomical regions of the esophagus is constrained by inadequate bioprinting accuracy and dexterity.

Proposed Design

- Continuum bioprinting tool attached to a 6 DOF robotic manipulator

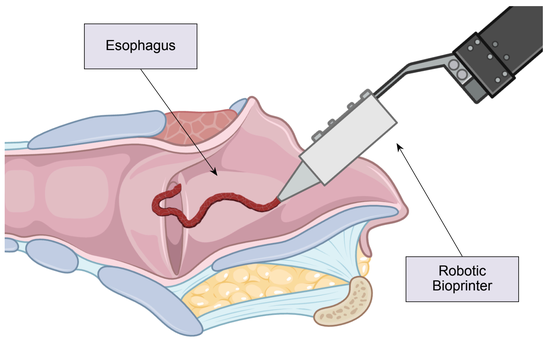


Diagram developed in BioRender

Design Requirements

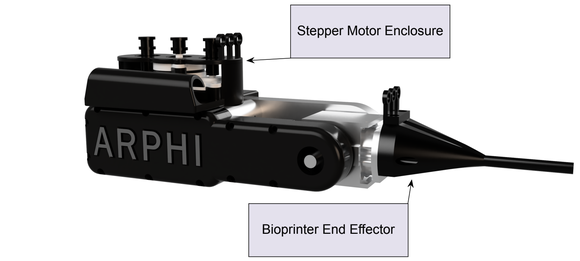
Continuum Bioprinting Tool

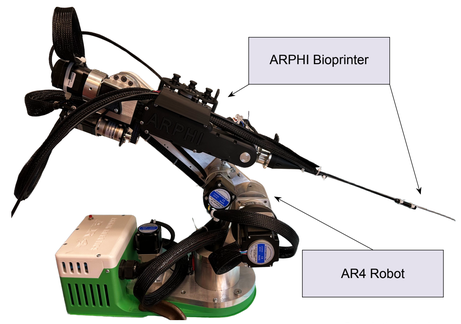
- Low weight (< 500 g)
- Low spatial profile (11 $\times$ 4 $\times$ 15 cm)
- High accuracy (< 1 mm)

Design

Hardware:

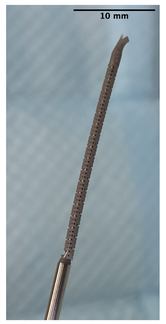
- Annin Robotics AR4 MK3 robotic manipulator modified with the ARPHI bioprinter





Full robotic manipulator

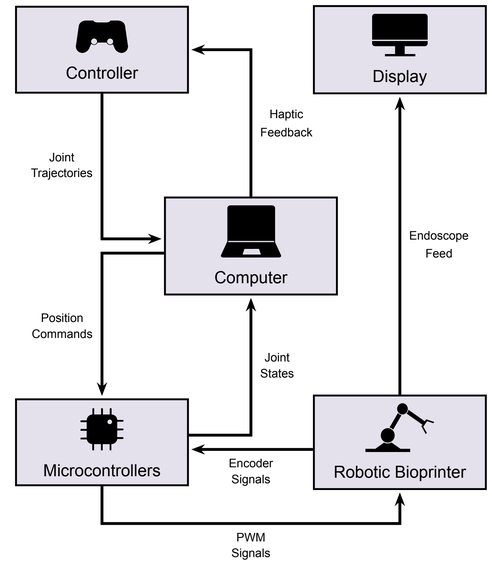
CAD rendering of the ARPHI bioprinter



Tendon-actuated continuum tool

Software:

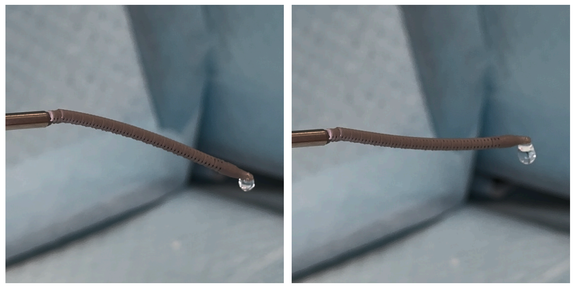
- Controlled via ROS 2: publisher-subscriber framework
- Live control using controller and endoscope video feed



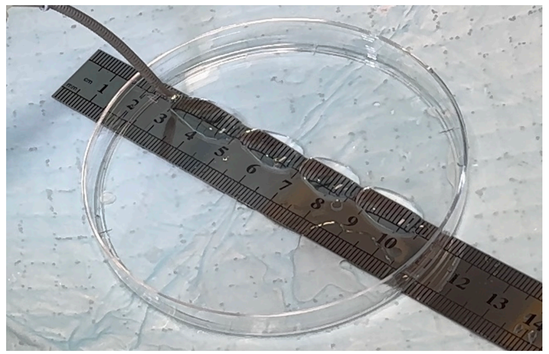
Results

Different Configurations of the Continuum Tool

- Moving the stepper motors applies tension to the tendons of the tool, bending its backbone

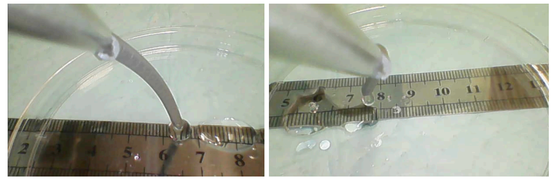


Bioprinting Results - External View



Results (Cont.)

Bioprinting Results - Endoscopic View



Conclusion

Accomplishments

- Designed low profile, lightweight robotic components
- Programmed a fully controllable robotic bioprinter
- Successfully printed therapeutic gels

Proposed Future Work

- Spatial mapping of the esophagus via LIDAR
- Autonomous bioprinting in the esophagus

Acknowledgments

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References

[1] A. MacAdam, E. Chaudry, C. D. McTiernan, D. Cortes, E. J. Suuronen, and E. I. Alarcon, "Development of in situ bioprinting: A mini review," Front Bioeng Biotechnol, vol. 10, p. 940896, 2022.

[2] Z. Mahmoudi, M. Sedighi, A. Jafari, S. Naghieh, E. Stefanek, M. Akbari, and H. Savoji, "In situ 3d bioprinting: A promising technique in advanced biofabrication strategies," Bioprinting, vol. 31, p. e00260, 2023.