Colon polyp detection through advanced scanning and nano-optical metasurface-enhanced visualization in vine robots

Morimoto Lab Meeting - Monday November 27th

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- Colorectal cancer is second leading global cause of cancer-related deaths. [1]
- Early detection through colonoscopy is crucial. [2]
- Detecting and distinguishing colonic polyps using an endoscope camera is a notable clinical challenge.
  - Varied morphological characteristics can resemble surrounding tissue. [3]
- A standard colonoscope is often painful for the patient. [4]

Vine Robot offers a platform for minimally invasive/disruptive procedure

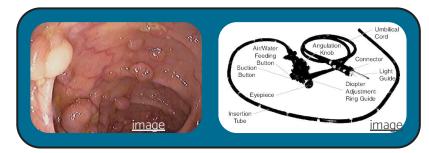**Nanophotonic Metasurfaces** can enhance detecting/distinguishing colonic polyps

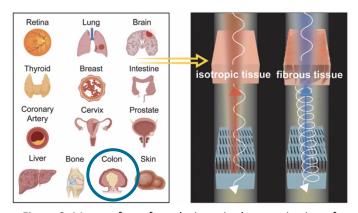
Figure 1: Colon Polyps   Figure 2: Colonoscope

Figure 3: Metasurfaces for colorimetric characterization of various fibrous tissue [5]

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Project Aims and Current Work

SPECIFIC AIMS

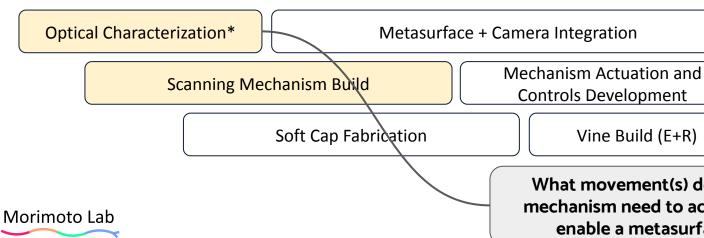|		
1: Build a vine-compatible mechanism that enables an endoscopic camera to scan its surroundings at the tip of the robot.*	2: Integrate a photonic metasurface onto an endoscopic camera.	3: Demonstrate fibrous tissue detection using this novel system.

PROJECT TIMELINE

Optical Characterization*

Metasurface + Camera Integration

Scanning Mechanism Build

Mechanism Actuation and Controls Development

PCL Fiber Detection Demonstration

Soft Cap Fabrication

Vine Build (E+R)

What movement(s) does the mechanism need to achieve to enable a metasurface?

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Outer Diameter = 26mm

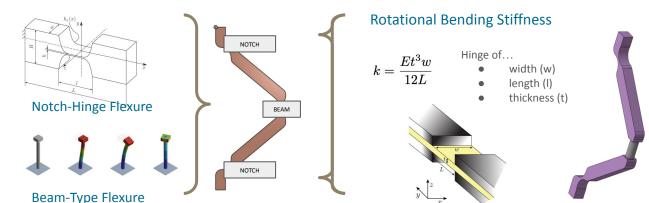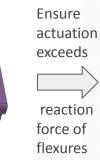- Yaw Angle (**Pan**): 0° - 360°
- Pitch Angle (**Tilt**): 0° - 90°

Actuation:
- Pneumatic
- Shape Memory Alloy
- **Flexure-Based**
- Magnetic
- IPMC's

Parallel Mechanism + Flexure + Push Rod + Soft Cap

Notch-Hinge Flexure

Beam-Type Flexure

Rotational Bending Stiffness

$$k = \frac{Et^3 w}{12L}$$

Hinge of…
- width (w)
- length (l)
- thickness (t)

Ensure actuation exceeds reaction force of flexures

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Qu, Haibo & Fang, Yuefa & Guo, Sheng. (2015). Theory of Degrees of Freedom for Parallel Mechanisms with Three Spherical Joints and Its Applications.

Suulker, C., Skach, S., Kaleel, D., Abrar, T., Murtaza, Z., Suulker, D., & Althoefer, K. (2023). Soft Cap for Eversion Robots. *ArXiv, abs/2301.12862*.

SPECIFIC AIMS

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Tune for Desired Response → **Transfer to Camera Lens** → **Characterize Effect** → **Integrate!**

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Replicating the Cynandra opis Butterfly's Structural Color for Bioinspired Bigrating Color Filters

AIM 3: Demonstration of Detection

SPECIFIC AIMS

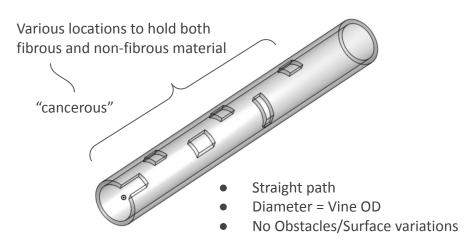|		
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system

Purpose:

- Demonstrate mechanism can properly orient camera/surface.
- Demonstrate visual superiority compared to typical colonoscope.
- Potential for user study.

Various locations to hold both fibrous and non-fibrous material

"cancerous"

- Straight path
- Diameter = Vine OD
- No Obstacles/Surface variations

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[1] Rex, D. K., et al. Missed Lesions Are the Most Common Cause of Right Colon Cancer in Colonoscopy Failures. Dis. Colon Rectum 2017, 60, 8, 791-797.

[2] Hassan, C., et al. Endoscopic management of subepithelial lesions: the role of endoscopic ultrasound and endoscopic full-thickness resection. Minerva Gastroenterol. Dietol. 2019, 65, 3, 226-236.

[3] Urban G, Tripathi P, Alkayali T, Mittal M, Jalali F, Karnes W, Baldi P. Deep Learning Localizes and Identifies Polyps in Real Time With 96% Accuracy in Screening Colonoscopy. Gastroenterology. 2018 Oct;155(4):1069-1078.e8. doi: 10.1053/j.gastro.2018.06.037.

[4] Quintero E, Hassan C, Senore C, Saito Y. Progress and challenges in colorectal cancer screening. Gastroenterol Res Pract. 2012;2012:846985. doi: 10.1155/2012/846985.

[5] Haddadin, Zaid et al, "Colorimetric metasurfaces shed light on fibrous biological tissue", J. Mater. Chem. C, 2021, Vol. 9, no. 23, pp 1619-11639, The Royal Society of Chemistry, doi 10.1039/D1TC02030G

References

Questions?