

DaVinci-Assisted Continuum Robot Navigation and Manipulation

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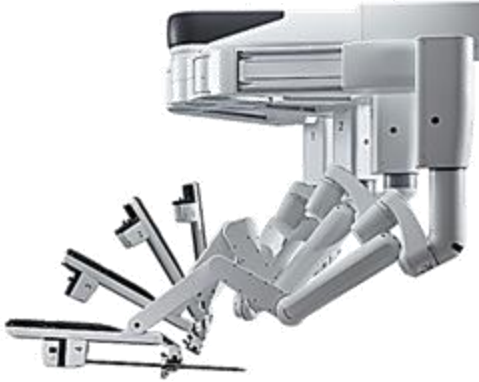


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Introduction



Da Vinci Robot: robohub.org/intuitive-surgical-da-vinci-surgical-system-gets-big-endorsement/



Acunav catheter: njmedtech.com/en-US/product/acunav-ultrasound-catheter

- **Objective:** a continuum robot navigation and manipulation system that combines the accuracy and reachability of the DaVinci robot arm with the unique capabilities of a tendon-driven continuum robot end.
- The intended approach involves designing DaVinci Research Kit (dVRK) with a flexible robot end, and then constructing corresponding remote actuation and navigation system through ROS and Python.
- Furthermore, the application will be expanded to various kinds of catheter[2] and teleoperation in surgical application domains.

Background

- Ion Inc.'s Endoluminal System[3] combines continuum robotics with Intuitive's expertise in surgical robotics to provide a high-accuracy, minimally invasive solution for lung biopsies.
- The dVRK Consortium, based at JHU, has been organized by members of the dVRK community to provide technical support.
- Previous work of dynamic modeling of the continuum robot end has been established.
- There are currently limited applications of flexible catheters integrated with the dVRK system, highlighting the potential for further development in our project.



Ion by Intuitive: <https://youtu.be/0ZaobUiJhCQ>

Significance

- The proposed DaVinci-assisted continuum robot navigation and manipulation system offers better reachability and dexterity in delicate surgical robotics and improves patient outcomes.

Workflow

Feb.11-(4 weeks)->Mar.10

Mar.11-(4 weeks)->Apr.07

Apr.08-(4 weeks)->May.07

Minimum

Hardware Design &
Basic Actuation

Endoscope

Acunav Catheter

+

dVRK baseplate

dVRK Navigation
and Manipulation



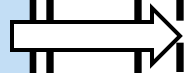
Expected

Collect experimental data
for catheter parameter
identification

Friction experiment

Weight release
experiment

Parameter
Identification



Code development
and Forward
Kinematics

PSM

Code
testing

Forward
Kinematics



Maximum

Find a fit
surgical
application

Inverse
Kinematics and
teleoperation
(optional)

Phantom Testing
(optional)

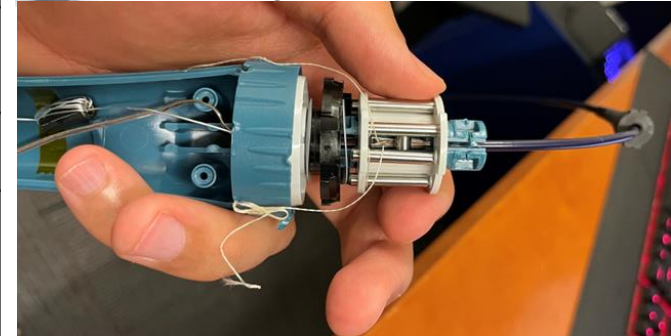
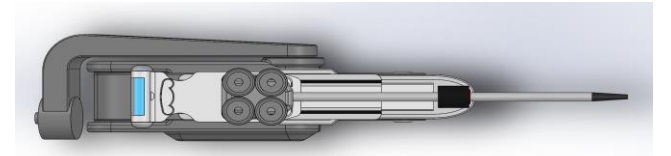
Ultrasound
catheter tracking
and imaging
(optional)

Proposed Technical Approach

Hardware

- Comparison of two end effectors:
- Endoscope catheter and Acunav catheter

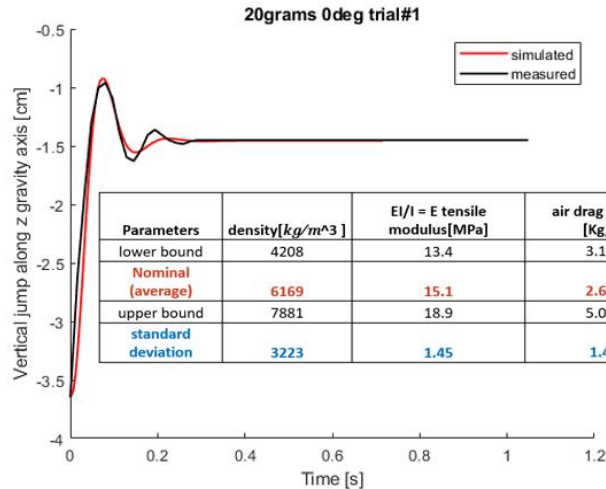
	(a) Endoscope	(b) Acunav Catheter
Driven method	Tendon	Tendon
Flexibility	Rigid rod + Flexible tip	Flexible catheter
Motion control principle	Bending in pitch, yaw, and rolling via rotary joints on the baseplate	Bending in Pitch and Yaw, rolling by DVR-K arm



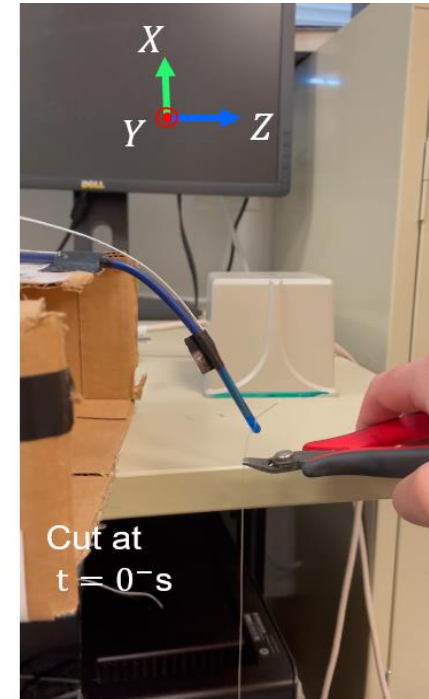
Acunav catheter (b)

Forward Kinematics: Experiment to Identify Catheter Parameter

Weight Release Experiment to Identify general Catheter's Characteristic Parameters

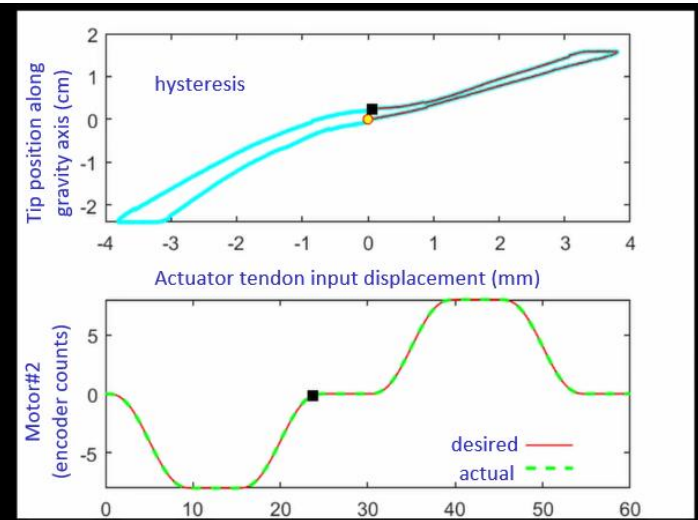
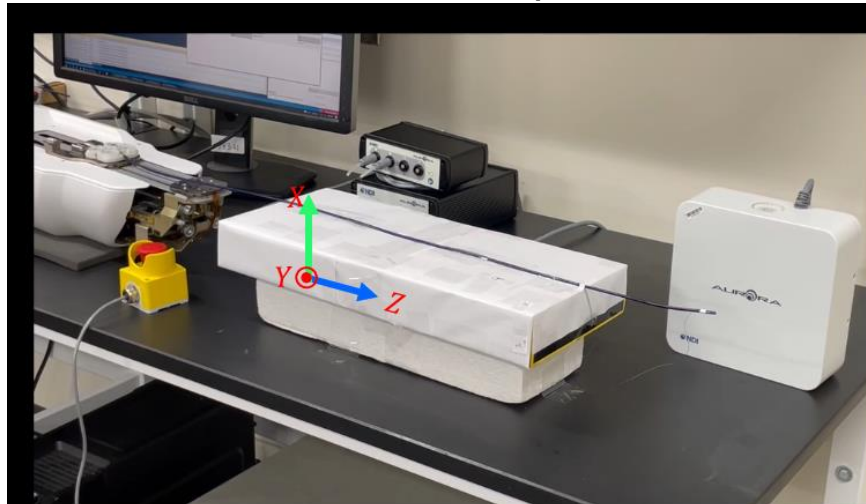


Catheter's tip dynamic response corresponding to the weight release experiment (20 grams test weight)



Collecting Experimental data for Identification of Catheter Friction Model

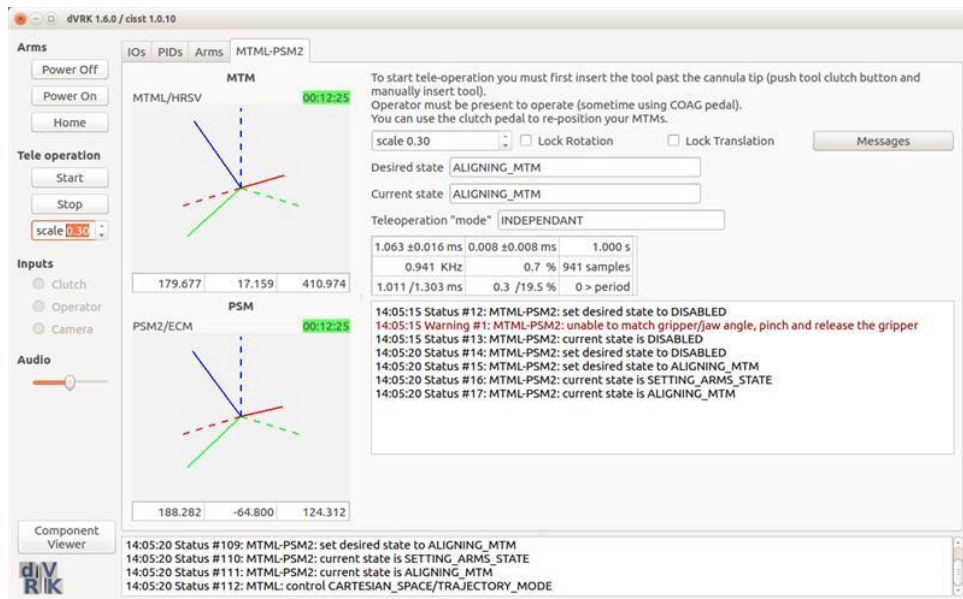
Tendon-Driven Actuation Experiment to Identify Friction Model Parameters



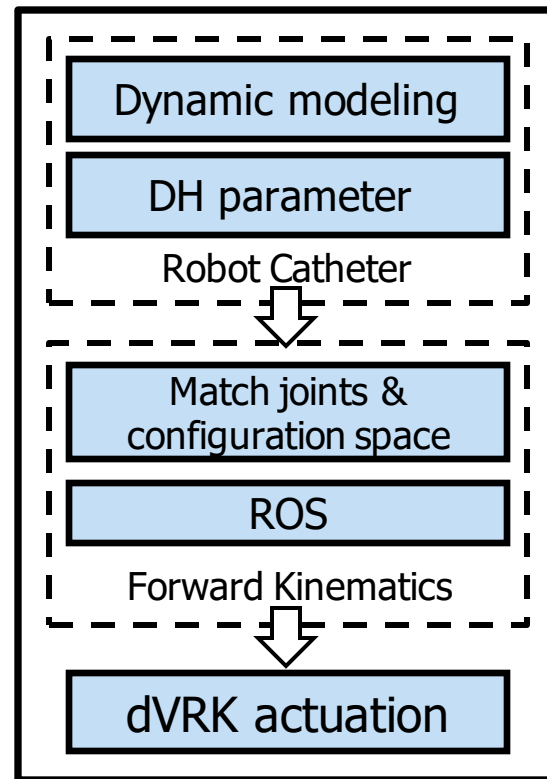
friction model
identified parameters

Parameters	β_{static}	$\beta_{sliding}$	ϵ	DC offset [N]
Nominal value	493892	266	4.75e-6	0.0027

Computer Integrated Functionality



GUI of dVRK[4]



Deliverables

Minimum (4 weeks):

1. Mechanical design enhancement and design innovation.
2. Verify the basic actuation function of dVRK with continuum end-effector through ROS and GUI.

Expected (4 weeks):

1. Obtain experimental results needed for identifying catheter parameters using DaVinci platform actuation.
2. Code development and forward kinematics actuation based on catheter parameters

Maximum (4 weeks):

1. Find a fit surgical application to our DaVinci-assisted continuum robot navigation and manipulation technology and (Optional) apply it in a phantom experiment.
2. (Optional) Teleoperation of the catheter using DaVinci dVRK
3. (Optional) Control tip of ultrasound catheter to do ultrasound imaging of a phantom

Key dates

	Milestones	Output (submit in the team's chat)	Deadline	Status
Minimum	Complete project proposal	5-8 pages summary	Feb.23	Done on Feb.22
	Prototyping & testing	An Acunav Catheter that can be controlled mechanically by DaVinci	Mar.10	In progress
	Actuating the dVRK with continuum end	Video about actuating the continuum end by dVRK	Mar.10	In progress
Expected	Obtain experimental results for parameter identification	PDF document and data visualizations	Mar.24	Waiting
	Integrate algorithms enable precise actuation of continuum ends	PDF document and code with comments	Apr.07	Waiting
Maximum	Find a fit surgical application	PDF document	May.07	Waiting

Dependencies

Dependency	Need	Contingency plan	Planned	Hard	Status
End-effectors for testing	DaVinci dVRK, endoscope and Acunav catheter	dVRK in Robotrium	Feb.27	Feb.29	Acquiring
Access to hardware Models	CAD Model of Acunav catheter and DaVinci baseplate	Manually measurement and modeling	Feb.27	Feb.29	Acquiring files
Software installation: ROS, Python, CISST library	License	Use Lab Computer with pre-installed software	Feb.24	Feb.27	Acquired
Access to dVRK	Access and training from Anton Deguet	N/A	Feb.25	Mar.02	Acquired
Identification experiments	Two EM tracker sensors Optical marker Test weights	from LCSR repository	Apr.07	Apr.17	Acquired
Phantom	Testing	Go without phantom testing	Apr.22	Apr.27	Waiting

Management

- Weekly meetings
 - Student team meeting: brainstorming, third times a week
 - Lab meeting: dVRK training
 - Mentor meeting: progress report, 3:30 PM-5:30 PM each Friday
- Platforms:
 - Zoom, Email: communication
 - Github: codes
 - Microsoft Teams: communication, documentation

Acknowledgement

- We would like to thank Professor Emad Boctor for generously providing us with the Acunav ultrasound catheter.

Reading list

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6. Cha H-J, Yi B-J, Won JY. An assembly-type master–slave catheter and guidewire driving system for vascular intervention. *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine.* 2017;231(1):69-79. doi:10.1177/0954411916679328

Reference

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- [2] “Acuson AcuNav™ Ultrasound Catheter.” Biosense Webster, <https://www.jnjmedtech.com/en-US/product/acunav-ultrasound-catheter>.
- [3] “Ion by Intuitive | Robotic Bronchoscopy Platform for Nodule Biopsy.” YouTube, YouTube, 4 May 2019, <https://www.youtube.com/watch?v=0ZaobUjHcCQ&feature=youtu.be>.
- [4] JHU-dVRK. DaVinci Research Kit. GitHub, <https://github.com/jhu-dvrk/sawIntuitiveResearchKit/wiki>.



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Thank You!



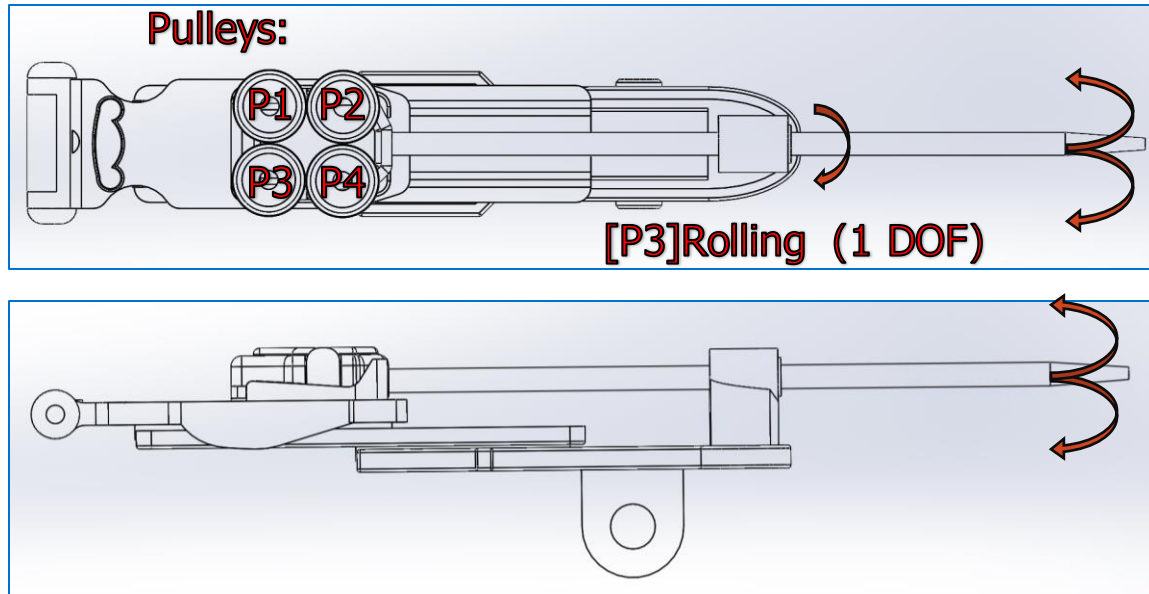
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Appendix I: Motion Control Principle for Semi-Flexible Endoscope



[P1]Pitch upwards (0.5 DOF)

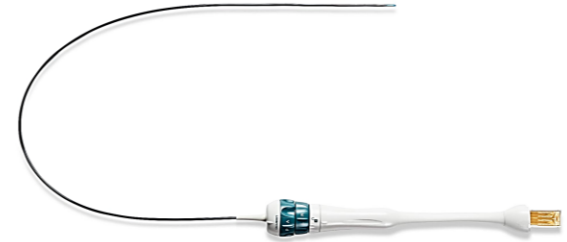
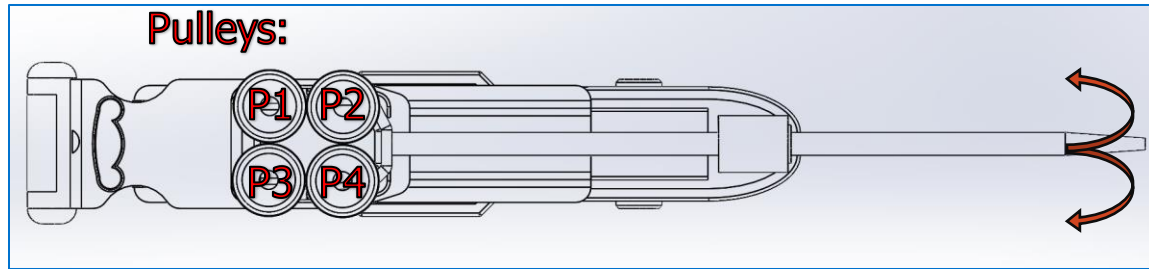
[P1]Pitch downwards (0.5 DOF)

[P2]Yaw upwards (0.5 DOF)

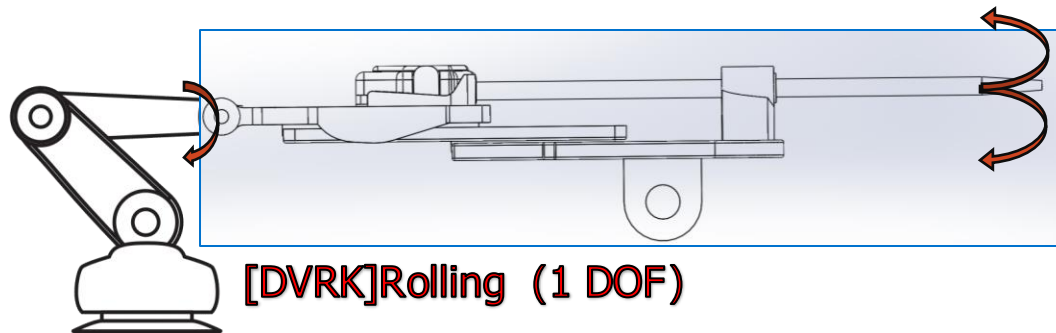
[P2]Yaw downwards (0.5 DOF)

Total: 3 DOF

Appendix II: Motion Control Principle for Flexible Acunav Catheter



[P1] Pitch upwards (0.5 DOF)
[P3] Pitch downwards (0.5 DOF)



[P2] Yaw upwards (0.5 DOF)
[P4] Yaw upwards (0.5 DOF)

Total: 3 DOF