

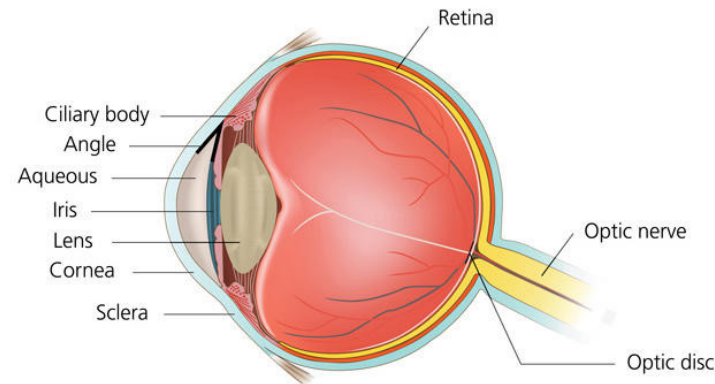
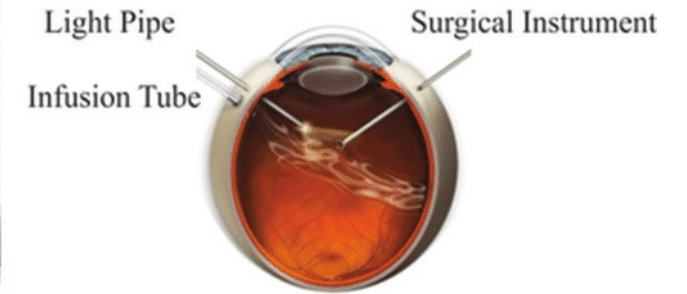
Tele-operation Control of a High Dexterity Robot for Vitreoretinal Surgery

Muhammad Hadi , Mojtaba Esfandiari

Mentors: Ali Ebrahimi, Prof. Iulian Iordachita, Adnan Munawar,
Alireza Alamdar

Clinical motivation

- Difficulty of retinal surgery
 - Epiretinal Membrane peeling
 - Retinal vein cannulation
- Issues with hand tremor
 - Retinal vein diameter: 80 - 120 μ m
 - Physiological hand tremor: 100 μ
- Risk of retinal tears
 - <7.5 mN
- Lack of fine force feedback
- Exceptional training



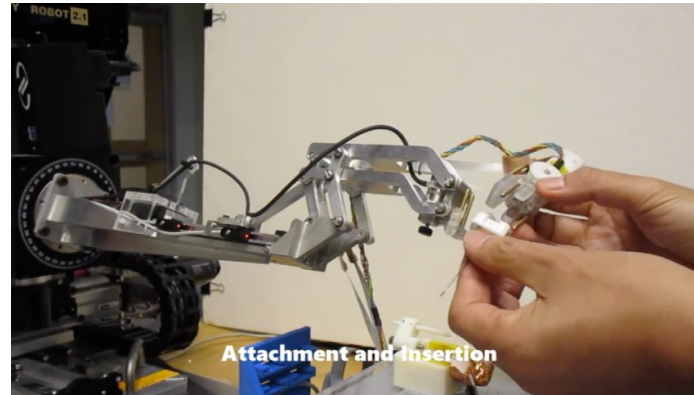
“The peripheral aspects of vitreoretinal surgery,” Centre for Sight, 07-Mar-2020. [Online]. Available: <https://www.centreforsight.net/blog/the-peripheral-aspects-of-vitreoretinal-surgery/>. [Accessed: 01-Mar-2022].

“Eye anatomy,” Glaucoma Research Foundation. [Online]. Available: <https://www.glaucoma.org/glaucoma/anatomy-of-the-eye.php>. [Accessed: 01-Mar-2022].

Specific aims

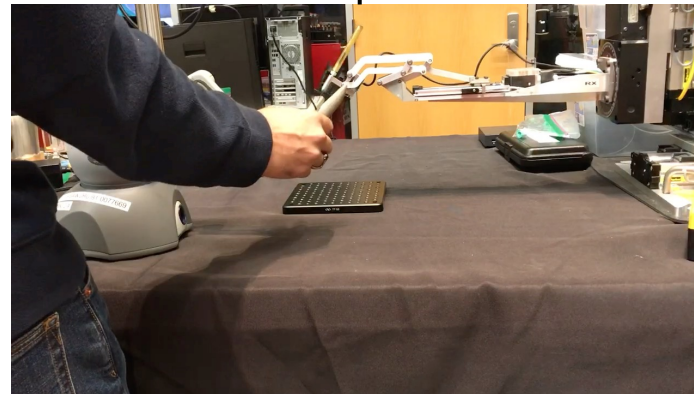
Implement satisfactory teleoperation control of hybrid robot with Phantom Omni for potential vitreoretinal surgery

- Reduce cognitive load on user
- Increased flexibility when tooltip inside eye
 - Relative to current stiffer models

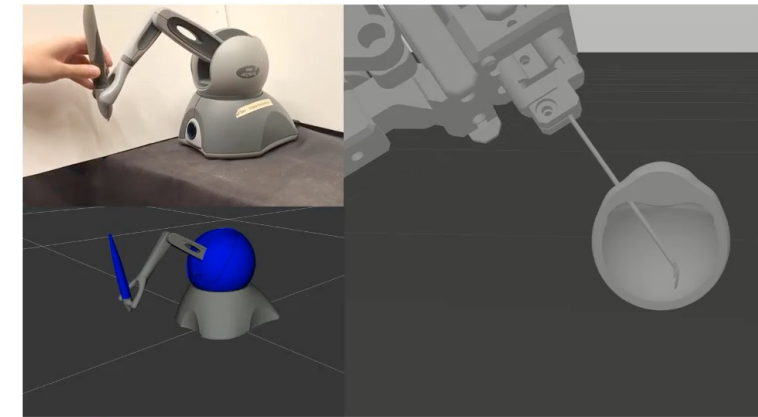


Combine snake and eye robot

Control both via teleoperation



Moving From Center To Surface



*simulated teleoperation control

Ebrahimi, Ali. (2018). *CIS II Project – Spring 2022* [PowerPoint presentation], CIS II.

Shi, Kaiyu; Zhou, Yishun; Ebrahimi, Ali; Li, Gang; Iordachita, Iulian (2022), Optimization-based Concurrent Control of a High Dexterity Robot for Vitreoretinal Surgery. Manuscript submitted for publication

Deliverables

- Minimum

- Successful integration of the Snake Robot software with the Eye Robot software
- A model of accurate mapping of snake robot movement/calibration mode of I2RIS

- Expected

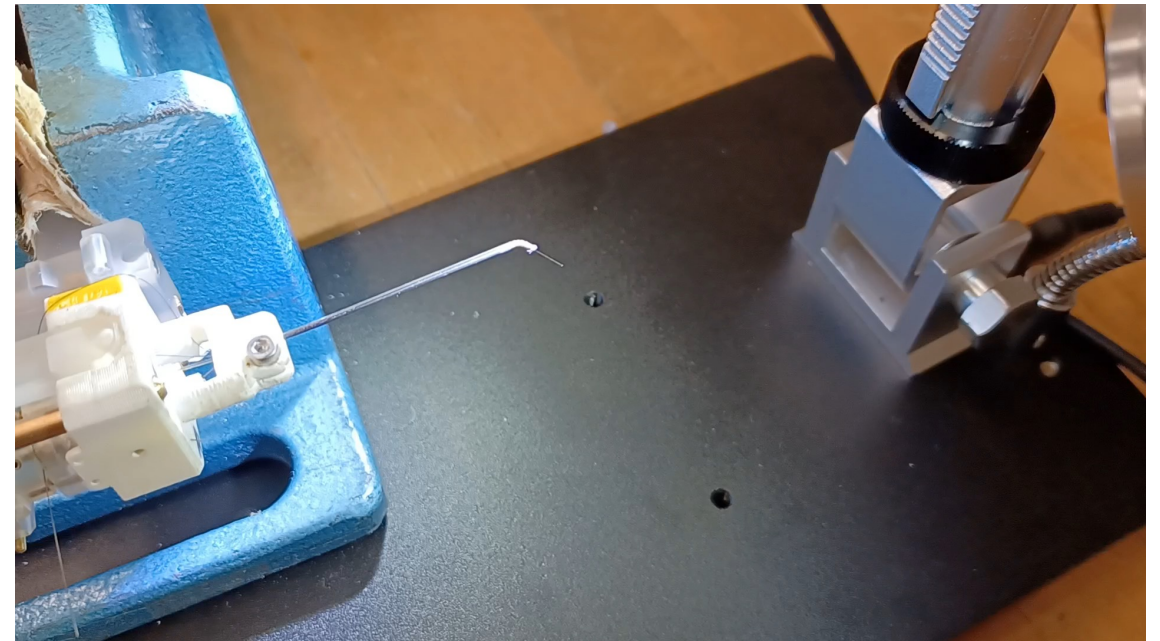
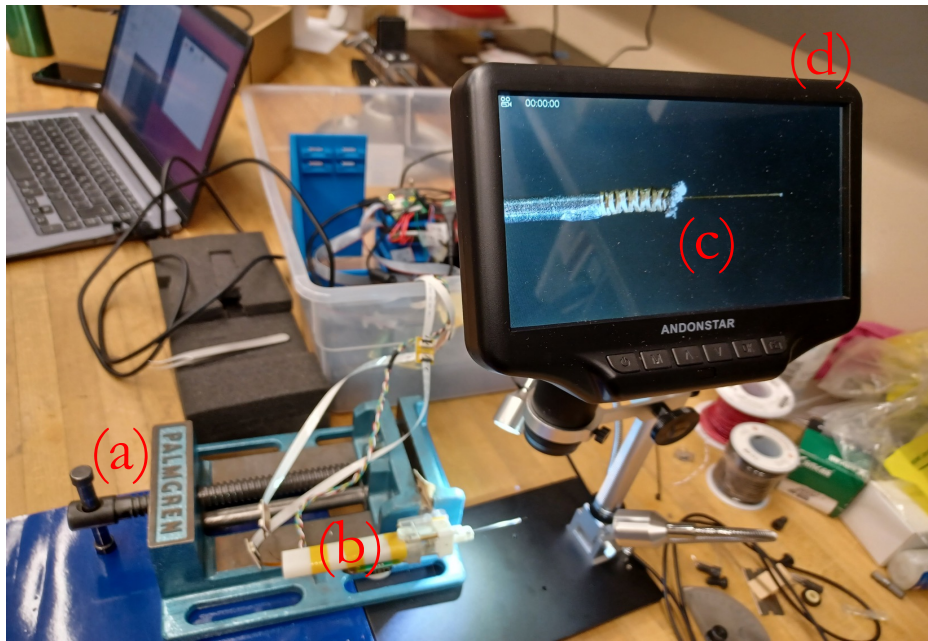
- Code package with successful control algorithms for the tele-operated system with constraint, with appropriate documentation for ease of future development
- A comprehensive report highlighting the results of experimental testing of the implemented teleoperation code

- Maximum

- Design and execution of experiment to evaluate complete teleoperation control vs cooperative control
- Academic paper on teleoperation control of hybrid system (Eye + Snake Robot).

Current Progress

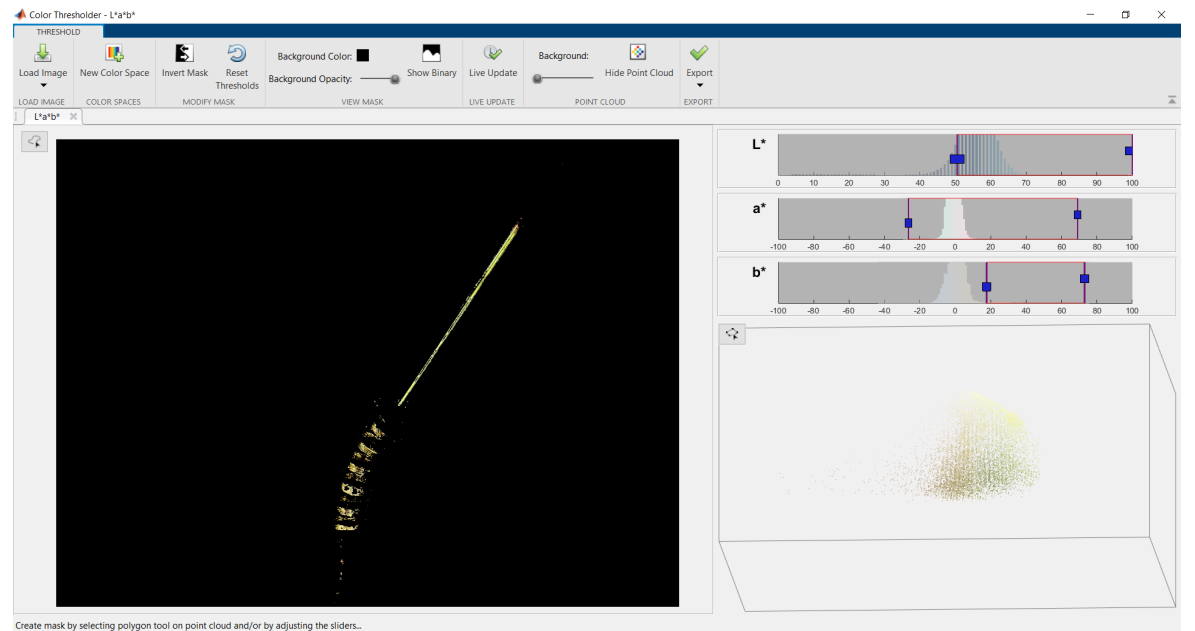
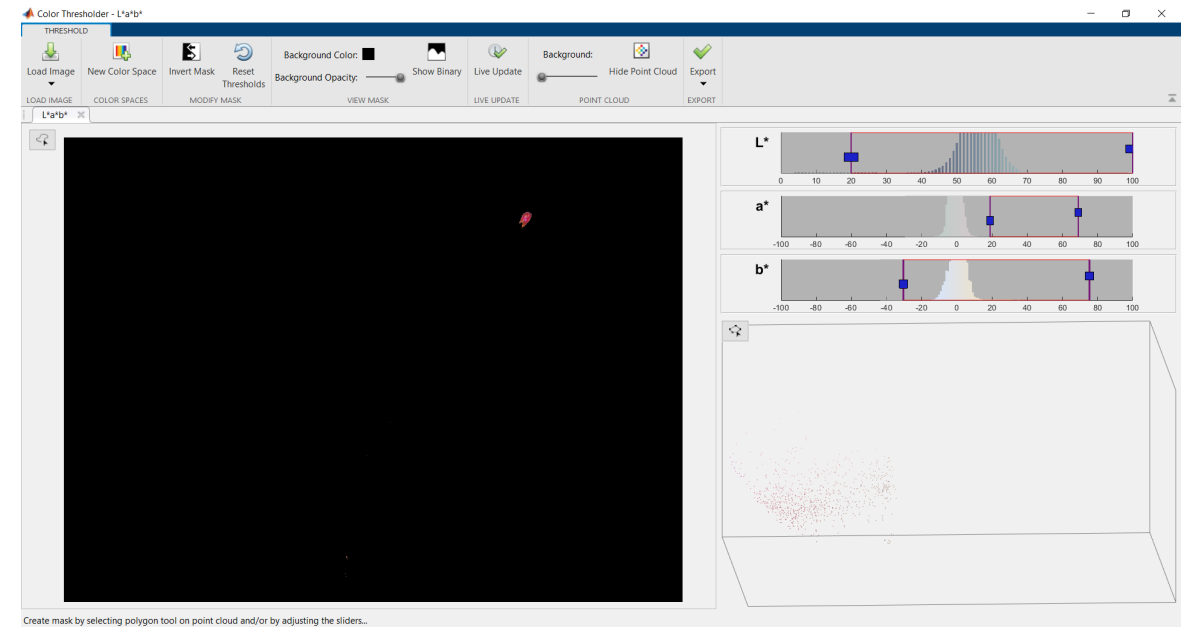
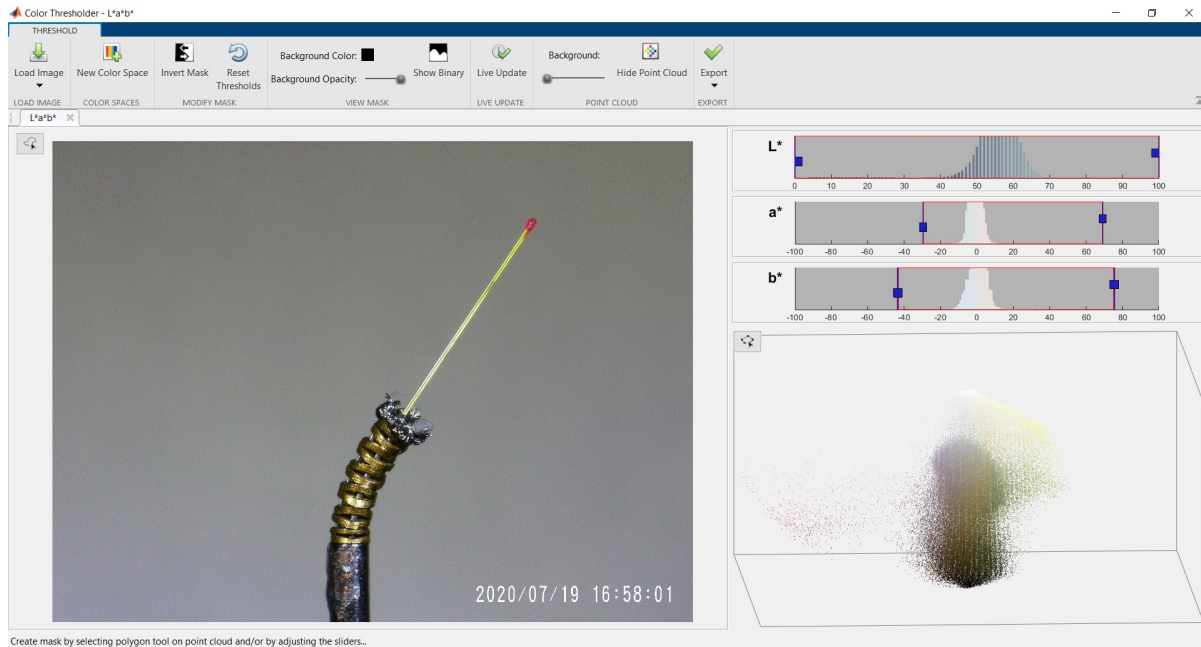
Snake Robot Calibration



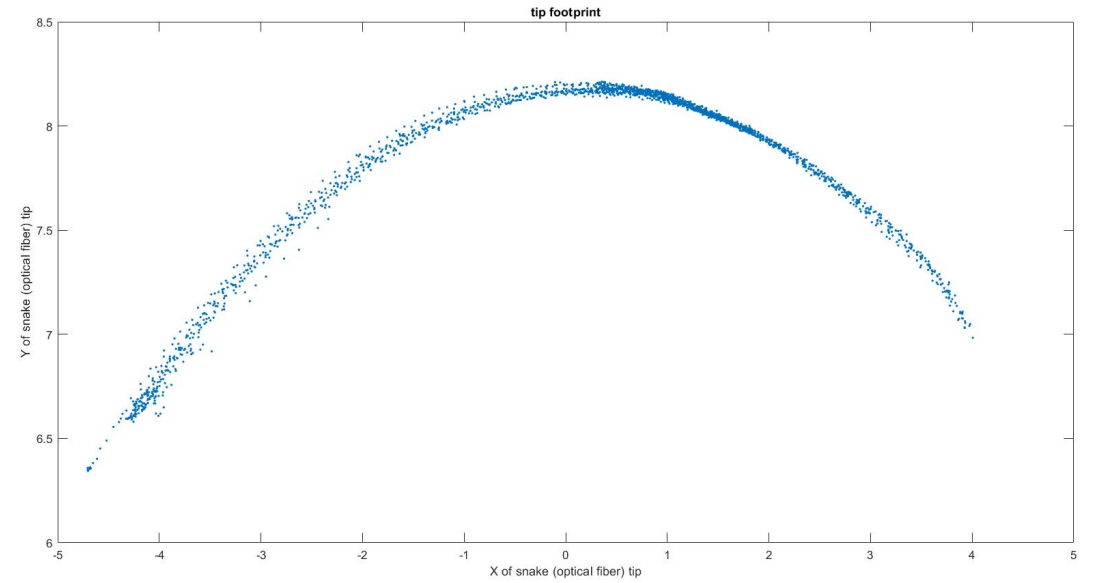
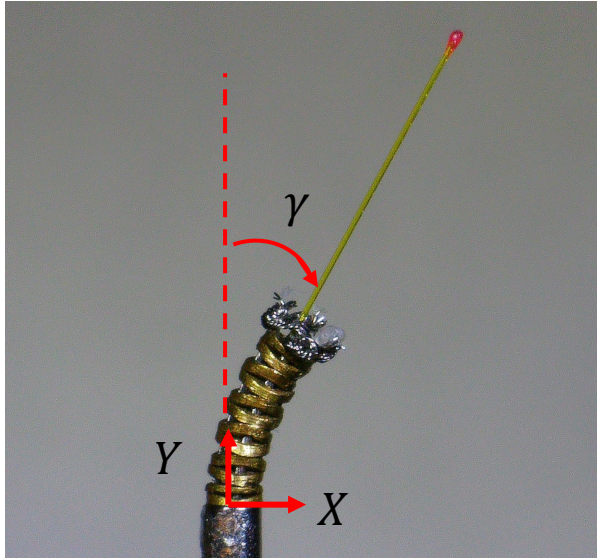
- a) Fixture
- b) Actuation unit
- c) Snake/optical fiber
- d) Microscope

Snake Robot Calibration contd.

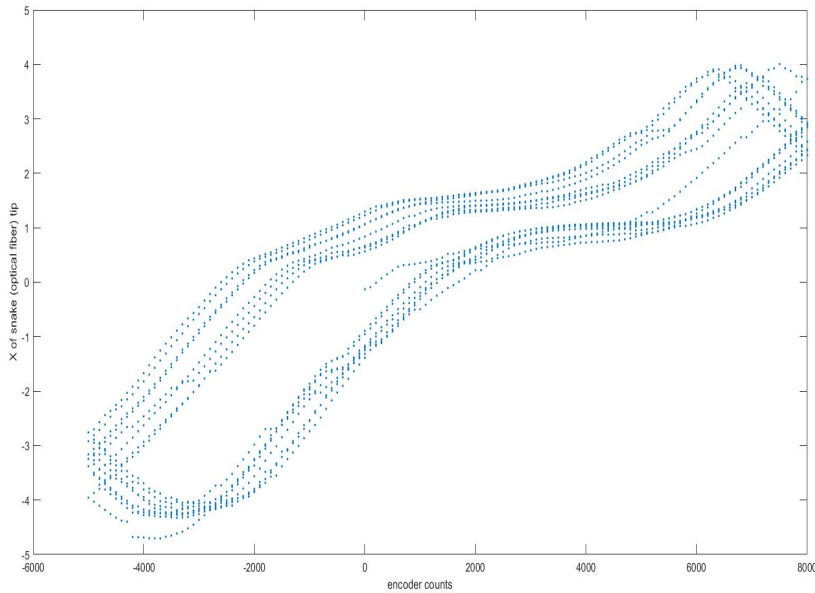
Color Thresholder (Matlab)



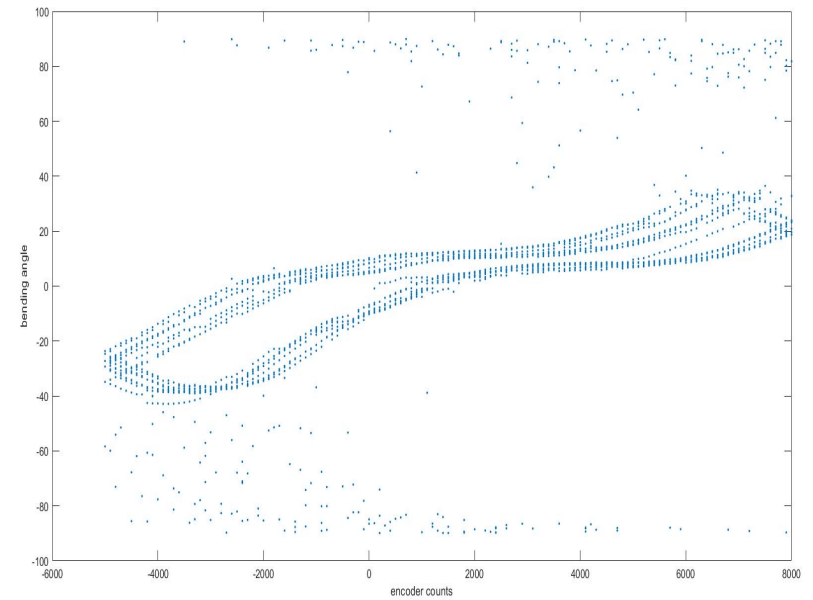
Snake Robot Calibration results



x (mm)
vs encoder counts



γ (deg) vs
encoder counts



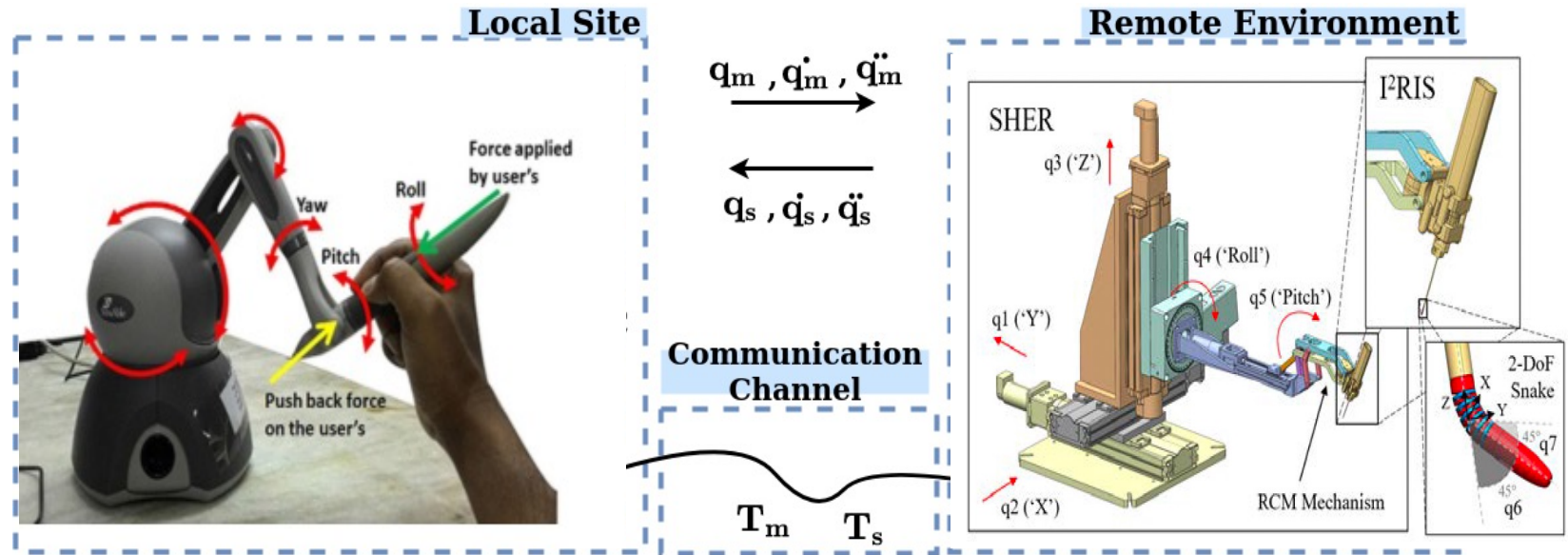
Updates: Expected deliverables

Establish communication between ROS and CIIST platforms

- CRTK messages

Possible C++ optimization libraries:

- NLOpt
- Roboptim



Proposed teleoperation algorithm:

Key assumptions:

1. Center of eye relative to robot base frame
 1. Target has undergone registration
2. Eye is perfect sphere
3. Location of RCM point/trocar in robot base coordinate system

Objective function:

$$\min_{\Delta q} \| J_{hybrid} \cdot \Delta q - \Delta x_{objective} \|^2$$

Where J_{hybrid} is the analytical jacobian from the robot base from to the snake tool tip
 Δq is the incremental change in the joint angles of the 7 DOF hybrid system
 $\Delta x_{objective}$ is the incremental change in the position of the Phantom Omni's end effector, scaled from the Omni's workspace to the hybrid robot's workspace

Δq scaled by a factor K as input for Galil controller

Constraints:

- 1) $\Delta q_{lower} \leq \Delta q \leq \Delta q_{upper}$
- 2) $J_{RCM} \cdot (q, \lambda) \begin{bmatrix} \dot{q} \\ \dot{\lambda} \end{bmatrix} \leq \epsilon$
- 3) $\theta_{lower} \leq \theta_{snake} \leq \theta_{upper}$
- 4) $2 \cdot r \cdot \cos(\theta_{insert}) - (l - \lambda) \leq \psi$
- 5) $d(p_{snake\ tip}, q_{eye\ center})^2 \leq \sigma$

Setbacks and Problems

Accuracy of snake forward kinematic model

- Repeat data collection

Verifying teleoperation control constraints

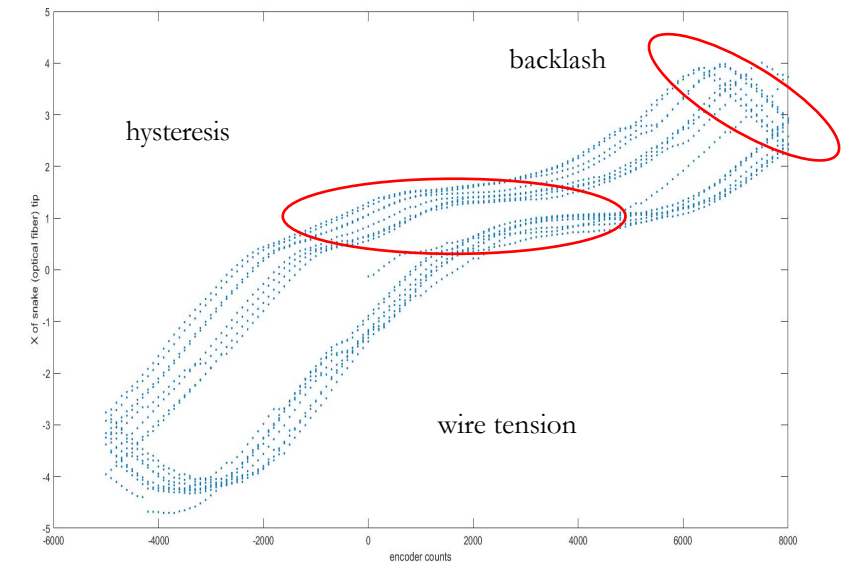
Delay in software implementation

- Subsequent delay in verifying testing platform

Validating C++ optimizers

Dated machine used for interfacing with Phantom Omni

Snake tip position X – Encoder counts



Updated Dependencies

Dependency	Status	Point of Contact	Fallback/Contingency measure	Need by date	Result in case of failure
Eye Robot accessibility	Readily available	Ali Ebrahimi/ Dr Iordachita	No contingency	N/A	N/A
Snake Robot accessibility	Readily available	Ali Ebrahimi/ Dr. Iordachita	No contingency	N/A	N/A
Phantom Omni	Obtained	Ali Ebhrami/ Dr. Iordachita	Utilize dVRK MTM	N/A	Failure to verify teleoperation algorithms
Phantom eye/experimental setup	Available (Subject to alterations)	Ali Ebhrami/ Dr. Iordachita	Verify via simulation	04/20/2022	N/A
Code packages	Partially available <ul style="list-style-type: none"> Snake Robot integration incomplete 	Ali Ebrahmi	No contingency	03/10/2022	Failure to accomplish any deliverable
Previous control algorithm and simulation teleoperation implementation	Obtained	Kaiyu Shi	No contingency	N/A	N/A
Mentor feedback	Available	Ali Ebrahimi, Dr Iordachita, Adnan Munawar, Alireza Alamdar	No contingency	ongoing	Delay in teleoperation implementation

Updated Timeline

Tasks	% complete	Feb.7	Feb. 14	Feb.21	Feb. 28	Mar.7	Mar.14	Mar.21	Mar.28	Apr. 4	Apr.11	Apr.18	Apr. 25	May.2
Project plan and webpage	100%	[Red bar]												
Understanding the Eye Robot code	65%			[Yellow bar]			[Yellow bar]	[Yellow bar]	[Yellow bar]					
Understanding the Snake Robot code	100%			[Grey bar]			[Grey bar]	[Grey bar]	[Grey bar]					
Integrate snake robot code into Eye robot code package	55%						[Orange bar]	[Orange bar]	[Orange bar]	[Orange bar]	[Orange bar]	[Orange bar]	[Orange bar]	[Orange bar]
Validate Snake robot control algorithms and reproduce movement tracking model	55%					[Green bar]	[Green bar]	[Green bar]	[Green bar]					
Develop kinematic model of hybrid system	0%							[Blue bar]	[Blue bar]					
Develop and implement control algorithm for teleoperation of hybrid system	0%								[Brown bar]	[Brown bar]	[Brown bar]	[Brown bar]	[Brown bar]	[Brown bar]
Verify testing platform	0%								[Red grid bar]	[Red grid bar]	[Red grid bar]	[Red grid bar]	[Red grid bar]	[Red grid bar]
Internal testing of hybrid system's teleoperation	15%										[Yellow bar]	[Yellow bar]	[Yellow bar]	[Yellow bar]
Final report and presentation	0%											[Blue bar]	[Blue bar]	[Blue bar]

Updated Milestones

Milestone	Start Date	End date	Buffer date	Status	New end date
Integrating code packages	03/14	03/27	04/3	Not complete	04/3
Calibrate snake model	03/07	03/20	03/27	complete	N/A
Kinematic model	03/21	03/27	04/03	Not complete	04/03
Implementing teleoperation algorithm	03/28	04/17	04/24	Not complete	04/26
Testing	04/11	04/24	05/08	Not complete	05/08
Report write up and code clean up	04/17	05/08	N/A	5%	05/08

Project management

- Mentors
 - Ali Ebrahimi
 - Prof. Iulian Iordachita
 - Adnan Munawar
 - Alireza Alamdar
- Weekly meetings with Prof. Iordachita and Ali Ebrahimi
- Shared OneDrive folder for all presentations, literature review, and code updates
 - Documentation includes, but is not limited to
 - Written report on snake calibration
 - Code documented well enough for future development
 - Well defined control algorithms, with justified constraints
 - Final report
 - Includes final teleoperation test results and subsequent analysis
 - Key meetings with mentors

QUESTIONS?

Reading list

- He, X., Van Geirt, V., Gehlbach, P., Taylor, R., & Iordachita, I. (2015, May). IRIS: integrated robotic intraocular snake. In *2015 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 1764-1769). IEEE
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