



JOHNS HOPKINS

WHITING SCHOOL
of ENGINEERING

DEEP LEARNING KINEMATICS FOR CONTINUUM WIRE MANIPULATOR

Wenxuan Li, Zheyu Zhou, Zheyuan Zhang

TEAM AND ROLES

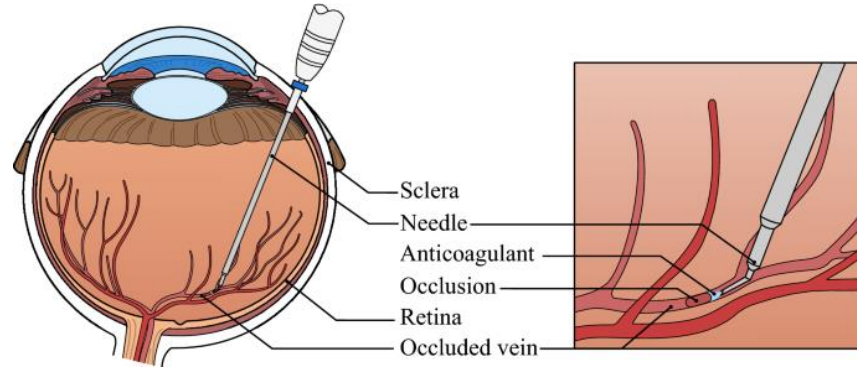
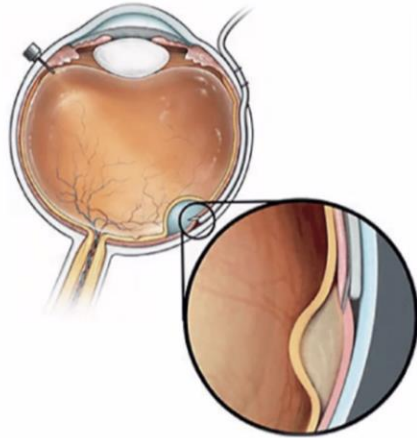
Team Member:

- Wenxuan Li:
 - Mainly focus on Deep Learning Model and Transfer Learning Design
- Zheyu Zhou:
 - Mainly focus on Computer Vision and Data Collection
- Zheyuan Zhang:
 - Mainly focus on Motor Control and Hardware setup

Mentor:

- Dr. David Usevitch
- Prof. Iulian Iordachita

SIGNIFICANCE/ MEDICAL MOTIVATION



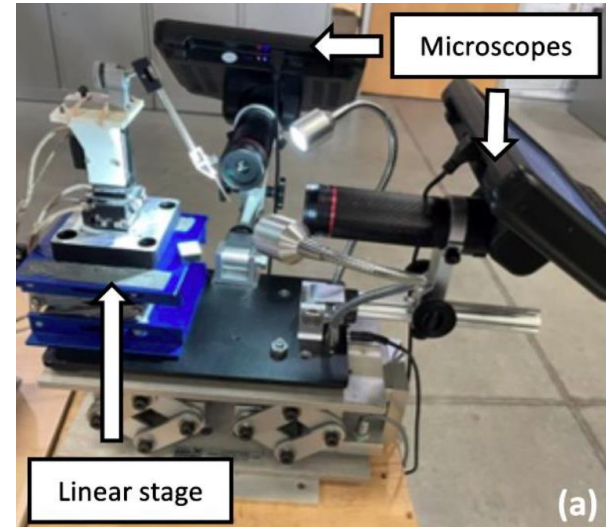
Retinal Surgery: Degenerative diseases affect 200M people.

Subretinal injection: Deliver effective gene therapy pharmaceuticals with continuum wire robot.

Retinal vein cannulation: Possibly implemented as actuated tools

STATEMENT

The project goal is to develop a Deep Learning based kinematics model for the novel continuum wire manipulator for future surgery implementation.



DELIVERABLES

MINIMAL (Milestone 1):

- Setup OpenCV tracking software and confirm track wire
- Develop and document basic ROS system control code for single motor actuation
- Code Wire control tests (motor positions) to move the system

EXPECTED (Milestone 2):

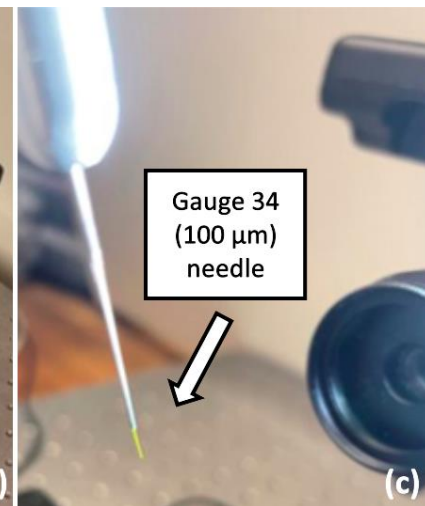
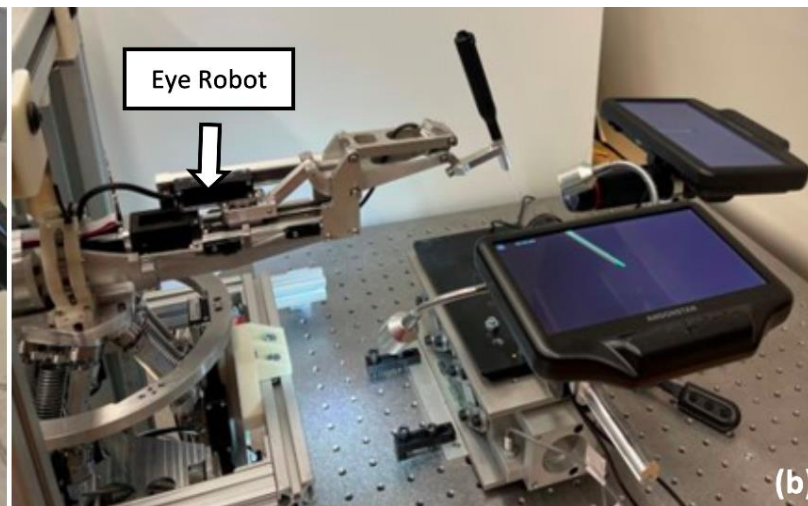
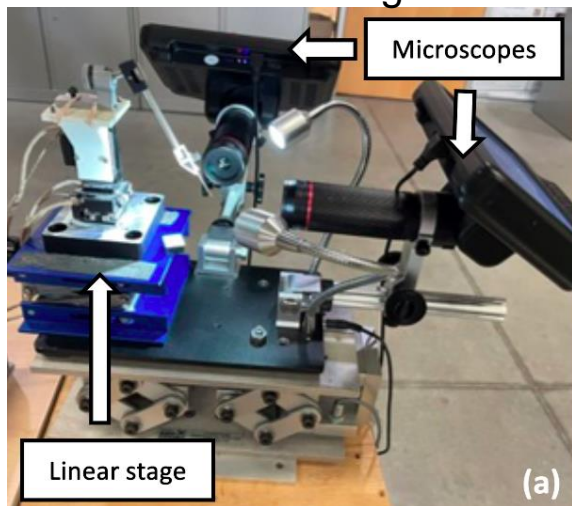
- Move the Wires and label results from the control tests
- Test Simple Deep Learning Algorithms for Tracking the wire
- Map Control of Motor to the output (Forward kinematics)

IDEAL (Milestone 3):

- Test and compare various several DL Nets for control of the system
- Repeat process with various other wire sizes
- Write IEEE format manuscript

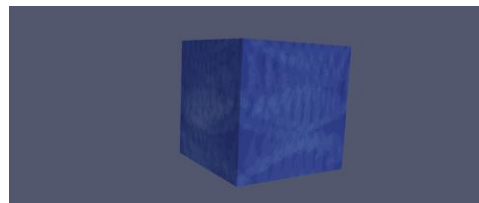
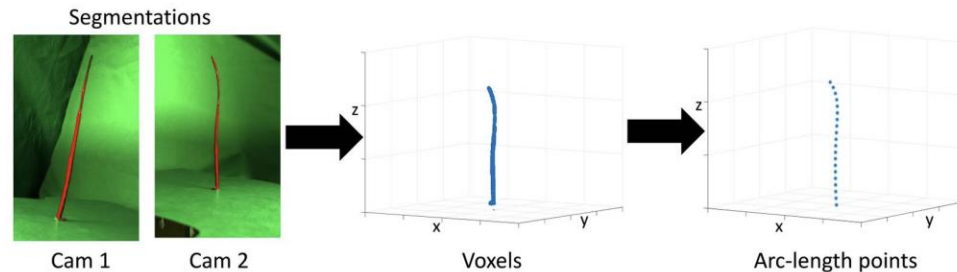
TECHNICAL APPROACH OVERVIEW

1. OpenCV wire tracking
2. Motor angle PID control
3. ROS integrated motor actuation, wire tracking, and data collection
4. Deep learning algorithms for CWM kinematics
5. Transfer learning fine-tune kinematics



TECHNICAL APPROACH: COMPUTER VISION

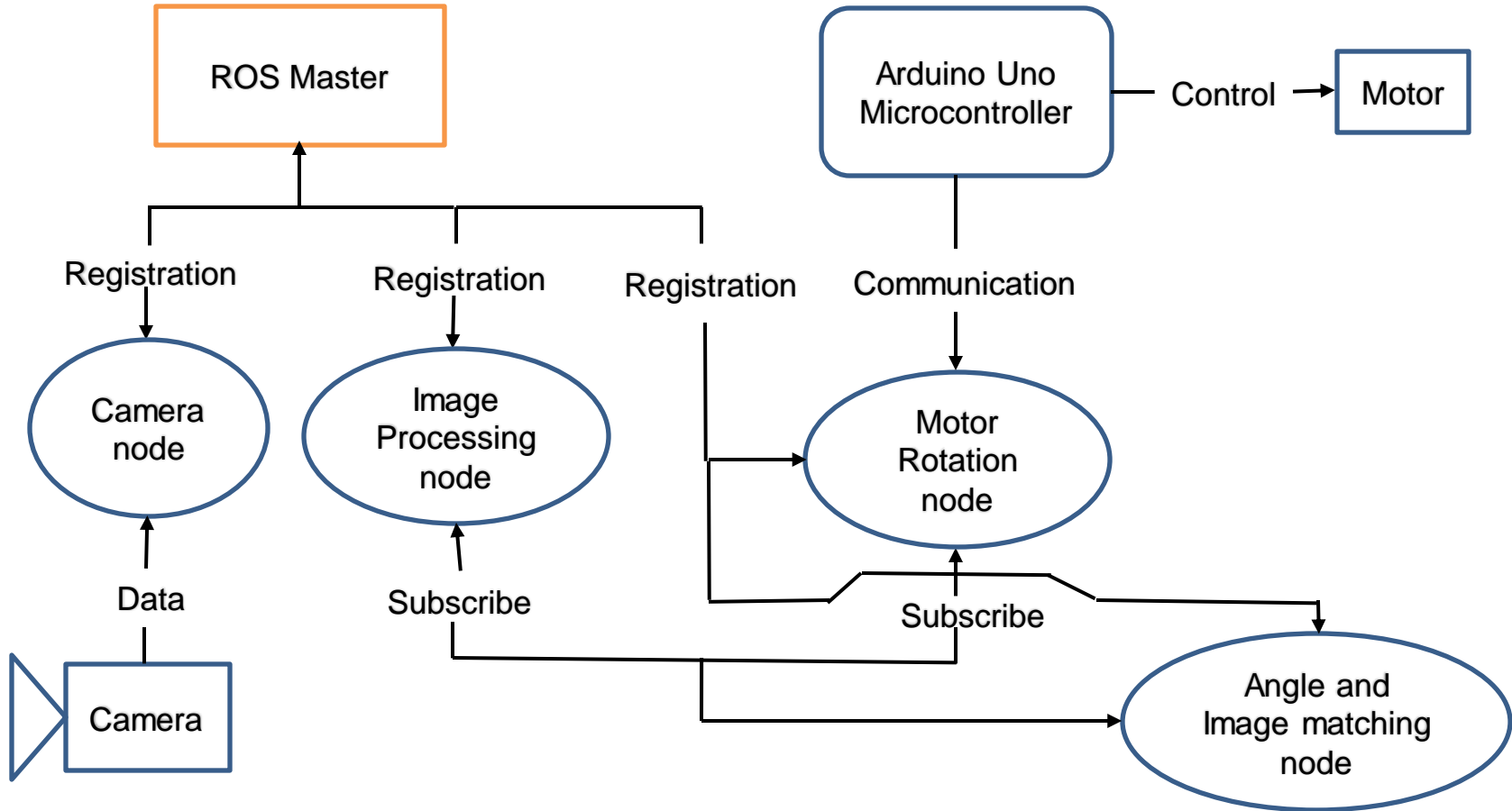
- Bilateral Filter
- Chroma Key Mask
- Dual-Camera Calibration
- Shape from Silhouette (aka Space Carving)



Related Work: A. Kuntz, A. Sethi, R. J. Webster and R. Alterovitz, "Learning the Complete Shape of Concentric Tube Robots," in *IEEE Transactions on Medical Robotics and Bionics*, vol. 2, no. 2, pp. 140-147, May 2020, doi: 10.1109/TMRB.2020.2974523.

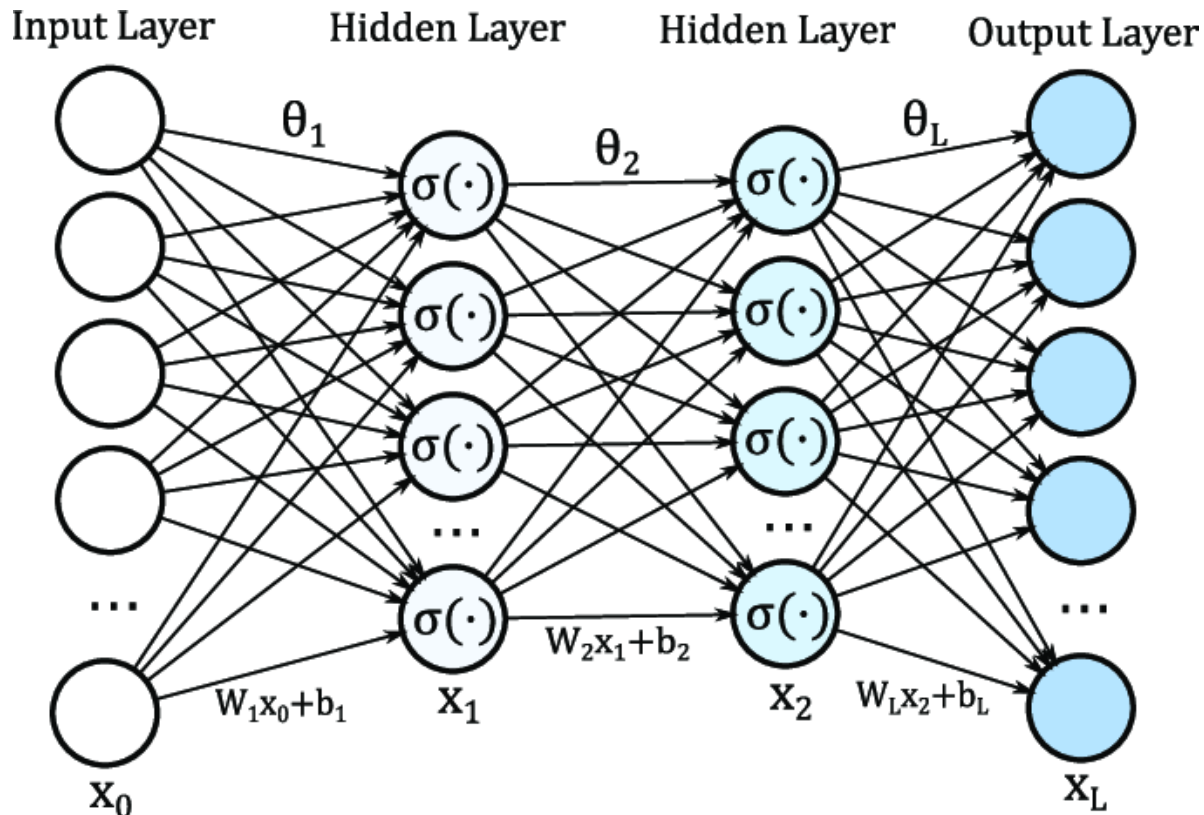
Image: <https://github.com/zinsmatt/SpaceCarving>

TECHNICAL APPROACH: ROS SYSTEM



TECHNICAL APPROACH

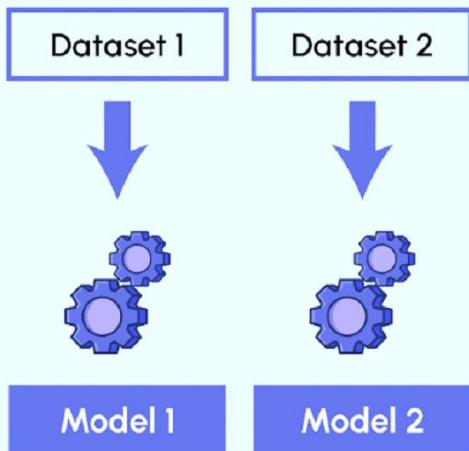
- Fully connected feed-forward neural network
- 2 hidden layers
- Using Adam Optimizer
- ReLU activation function



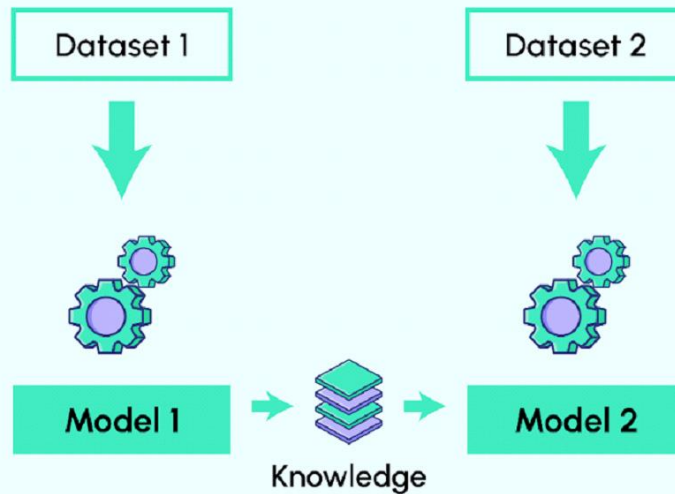
TECHNICAL APPROACH

Transfer Learning

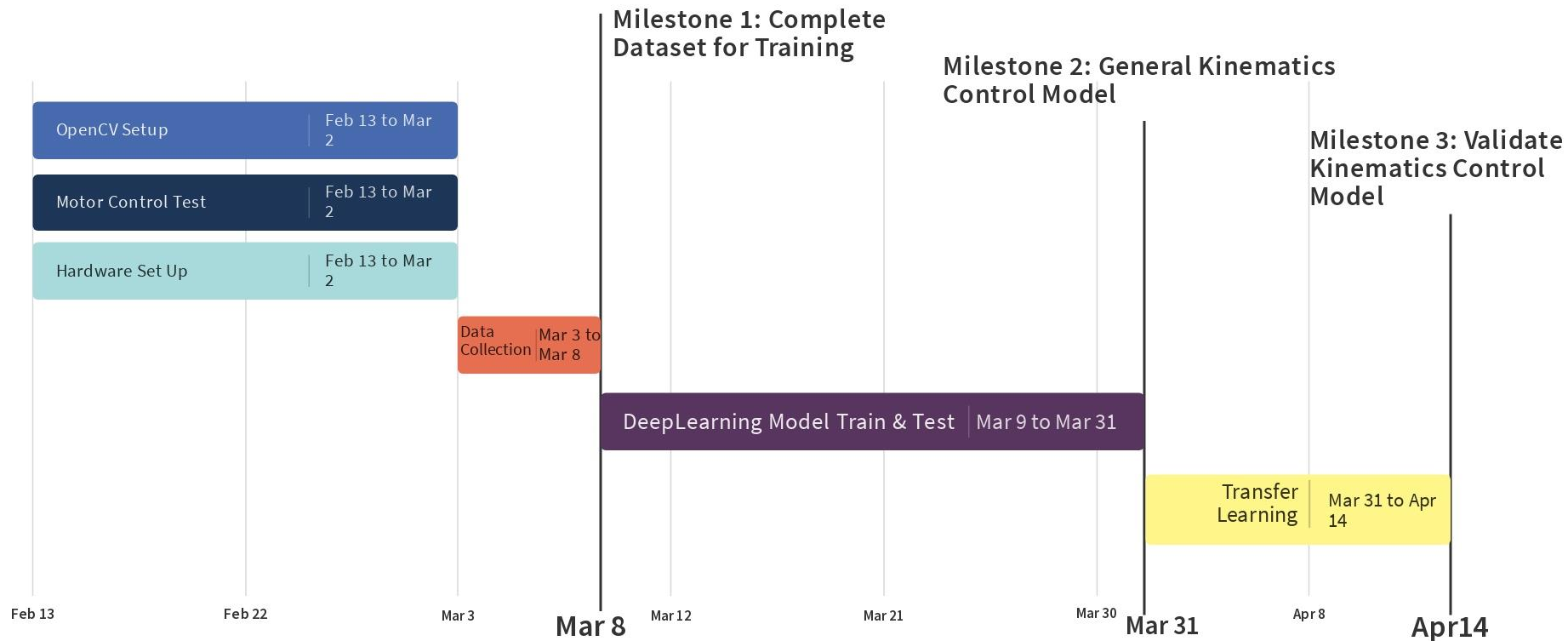
Usual Approach



Transfer Learning Approach



TIMELINE



MILESTONE 1:

CV Setup (-Mar. 2)

- Create Environment
- Image Capture
- Image Processing
- Data Output

Motor Control Test (-Mar. 2)

- PID Control
- Integrate ROS system
- Code and test

Hardware Setup (-Mar. 2)

- Nitinol Wires
- Camera mount
- Motor mount

Data Collection (Mar. 3 - Mar.8)

- Create datasets for DL and TL

Complete the Minimal Goal of Deliverable

COMPUTER VISION SETUP

now - Mar.2



CV Environment Setup



Image Capturing from Two Cameras



Processing Image and Shape Carving



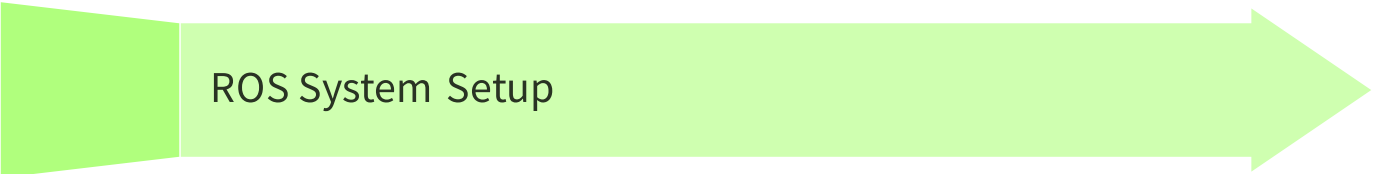
3D Data Output

MOTOR CONTROL TEST

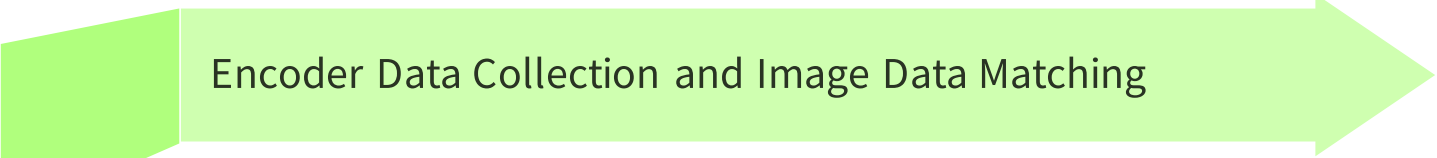
now - Mar.2



Motor Angle Control with PID



ROS System Setup



Encoder Data Collection and Image Data Matching

HARDWARE SETUP

now - Mar.2



Nitinol Wire Manufacturing

Motor Mounting

Camera Mounting and CV auxiliary parts

DATA COLLECTION

now - Mar.2

Deep Learning

- 10,000 data points
- One wire
- Rotation angle input + CWM configuration output

Transfer Learning

- 1,000 x 5 data points
- Five different wires
- Rotation angle input + CWM configuration output

MILESTONE 2

Mar.9 - Mar.31

Deep Learning Model Train & Test

- Fully connected feed-forward neural network
- Hypo: 2 hidden layers
- Using Adam Optimizer
- ReLU activation function
- Train on the general dataset
- Validate the performance of the above model

Goal of Milestone 2

- Build a general CWM kinematics control model
- As a pretrained model for transfer learning
- Complete the expected goal of deliverable

MILESTONE3

Mar.31 - Apr.14

Transfer Learning

- Fine-tune the pre-trained model for five specific wires
- Test and validate the performance of transfer learning over the corresponding datasets

Goal of Milestone 3

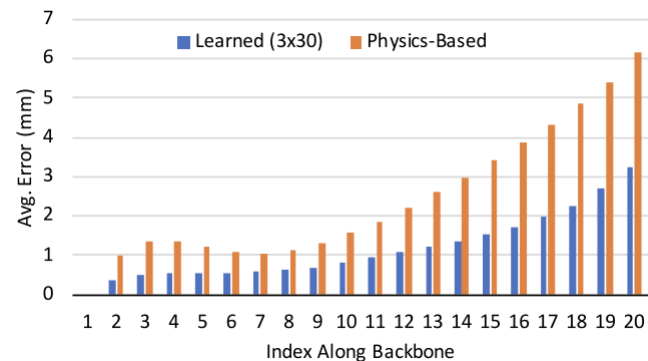
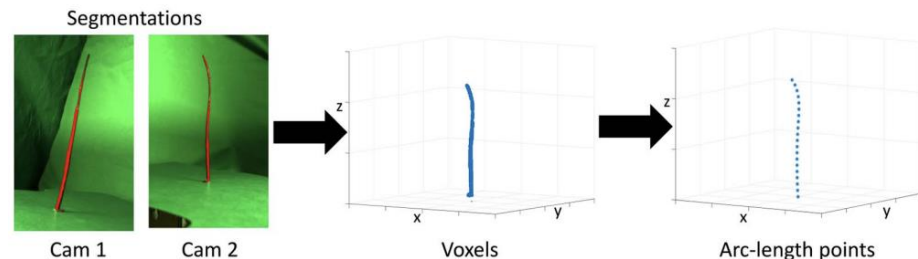
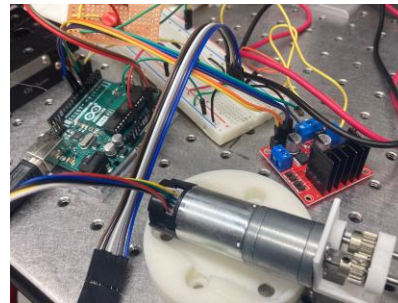
- Prove the transferability of previous DL-based kinematic model -> build general model successfully
- Complete the ideal goal of deliverable

DEPENDENCY

	Need	Status	Followup	Deadline
Nitinol Wires	Data Collection & Validation	Manufacturing	Fabricate	3/2/2023
Computation Resources (GPU)	Deep Learning Training	Comparing Google, Amazon educational grant	Rent GPU	3/16/2023
Camera Mounting	CV & Data Collection	Camera mount partially installed	3D print auxiliary mounting parts	2/28/2023
Motor Mounting	3D print auxiliary mounting parts	CAD Designing	3D print auxiliary mounting parts	2/28/2023
Chess Board	CV calibration	Chess Board Printed, 3D print ongoing	3D print auxiliary mounting parts	2/28/2023
ROS	CV, Motor, Data Integration	Installed and Testing	Integrate separate system	3/2/2023

TEST PLAN

- Motor Control Test
 - Encoder reading feedback
 - PID angle control test
 - ROS integration test
- Computer Vision Test
 - ROS integration test
 - Dual-Camera image capture
 - Image processing test
 - Shape Carving test
 - Data recording test
- Deep Learning Model Validation
 - Validate by validation dataset
- Transfer Learning Validation
 - Validate transferability by validation dataset



MANAGEMENT

- Weekly mentor meetings: Friday 2pm
- Platform construction and test lab: Prof. Iordachita's Lab
- Code files and documents: GitHub and the project wiki
- Daily Communication and updates: Teams
- Group meetings: Twice each week

REFERENCE

Grassmann, R.M., & Burgner-Kahrs, J. (2019). On the Merits of Joint Space and Orientation Representations in Learning the Forward Kinematics in $SE(3)$. *Robotics: Science and Systems XV*.

Kuntz, A., Sethi, A., Webster, R. J., 3rd, & Alterovitz, R. (2020). Learning the Complete Shape of Concentric Tube Robots. *IEEE transactions on medical robotics and bionics*, 2(2), 140–147.
<https://doi.org/10.1109/tmrb.2020.2974523>

Matthieu, Z. (2019). Space Carving. Github.
<https://github.com/zinsmatt/SpaceCarving>