# Deep-learning-based Kinematics for Continuum Wire Manipulator (CWM)

*Computer Integrated Surgery II*
*Spring, 2023*
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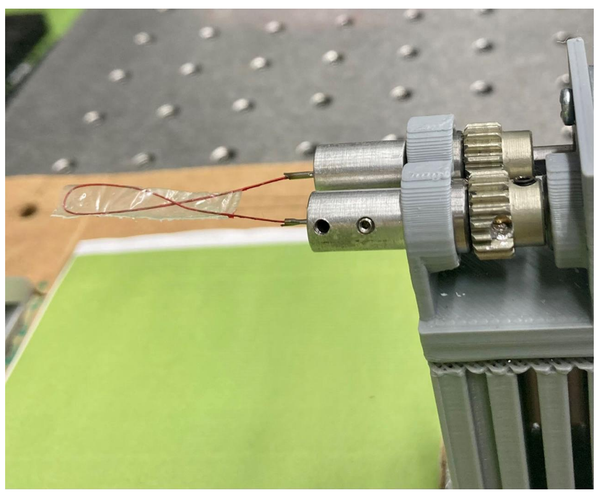
## Objective

- Explore **preliminary** and **pioneering** methods that could find breakthrough solution for the **200 million people** suffering from retinal diseases (Yasinski, 2022).



**Continuum Wire Manipulator Prototype**

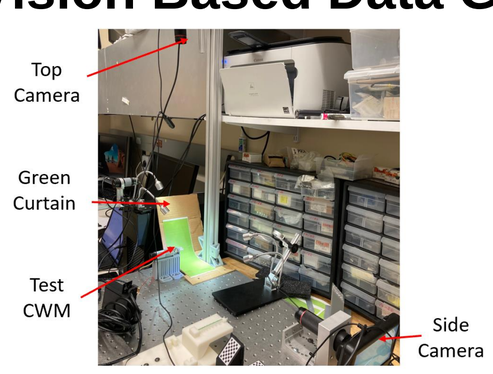
## Motivation

- Soft robots could perform safe and controlled surgery in the confined retinal structure
- Continuum Wire Manipulator could be an innovative soft robot solution
- Has unknown kinematics for practical control and use

## Solution

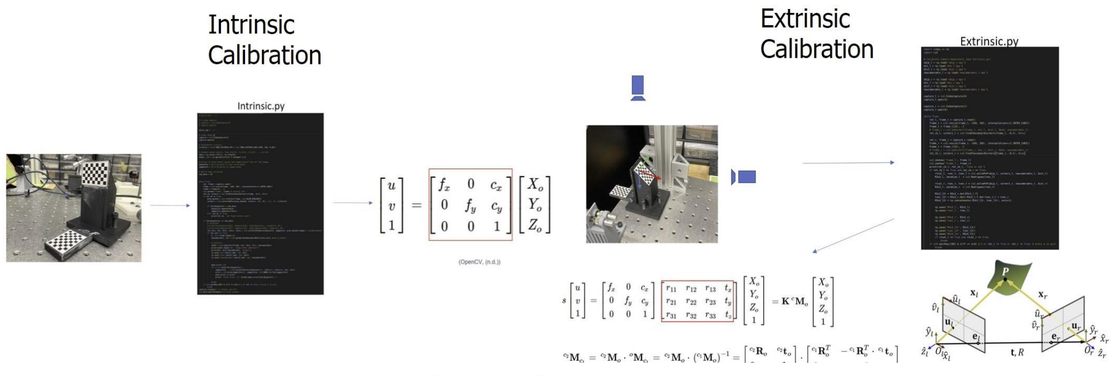
- Inspired by previous kinematics study on Concentric Tube System (Kuntz, 2020):
  - Cosserat rod equation based simulated pretrained data (100,000 sim-data)
  - Shape from Silhouette (SfS) algorithm 3D reconstructed transfer learning dataset (9,000 real-data)
- Proposed similar method for CWM kinematics study:
  - Shape from Silhouette algorithm 3D reconstructed dataset (9,556 real-data)
    - Generative deep learning (8752 real-data)
    - Transfer learning (804 real-data)

## Computer Vision Based Data Generation



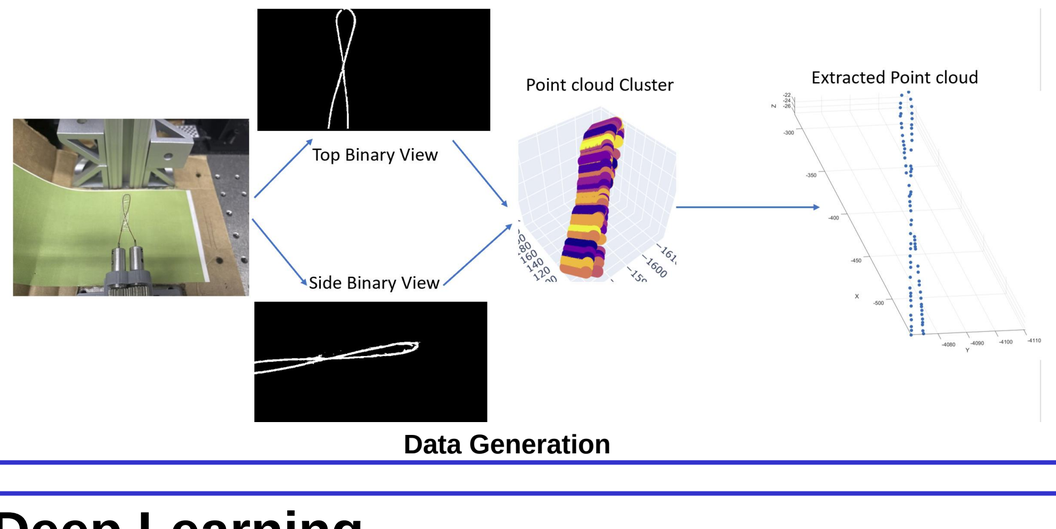

**Computer Vision Based Data Generation Testbed Setup**

- Camera calibration for intrinsic and extrinsic parameter




**Camera Calibration**

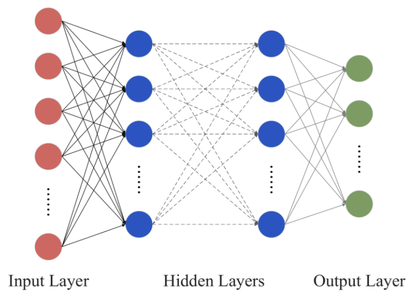
- Data Generation
  - Chroma Key Masking • SfS Algorithm
  - Gaussian Mixture Clustering



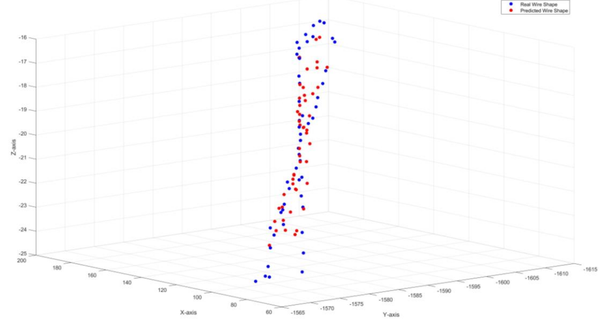

**Data Generation**

## Deep Learning

- Generative Deep Learning Model
  - Train-Validation-Test: 8,752 data samples
  - Multi-layer perceptron (MLP) model with 6 hidden layers
  - Input: left- or right-top / wire type /wire thickness / arc length of the wire / motor input angle
  - Output: 50*3 data point matrix represents wire shape
  - Error: 0.85 mm (improve to 0.82 mm)



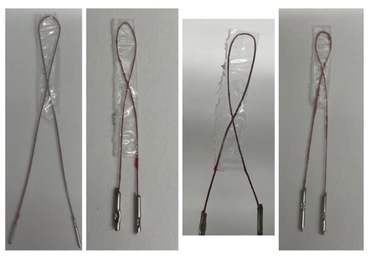

**Deep Learning Model**




**Comparison between Learned and Real Data Points**

## Transfer Learning

- Train-Validation-Test: 804 data samples (four various wires)



**Transfer Learning Wires**

| | 1 Sample | 5 Samples | 7 Samples |
|---|---|---|---|
| train from scratch | 122.248 | 81.067 | 61.793 |
| pre-training + fine-tuning | 27.255 | 21.143 | 20.789 |

## Future Work

- Generate more data points for learning
- Complex deep learning model for higher accuracy
- Prepare for paper publication

## Lessons Learned

- Rigorous documentation process

## Credits

- Zheyu: Computer Vision Based Data Generation
- Wenxuan: Generative Deep Learning + Transfer Learning
- Zheyuan: Motor Control + Mechanical Design

## Reference

[1] 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