Concentric Tube Robot – A Modular Design for Achieving Two Controllable Sections and a Stereo Tracking System

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Introduction

Background:

- Concentric Tube Robot (CTR) is slender and flexible, making it advantageous for navigating through complex areas during surgical operations [1], [2].
- When two "balanced" nitinol tubes are rotated, the combined curvature changes, adding more flexibility to the system [3].
- Researchers at KCL previously developed a system with one balanced pair of nitinol tubes, creating a single controllable section.
- No 3D tracking system for entire CTR is available.

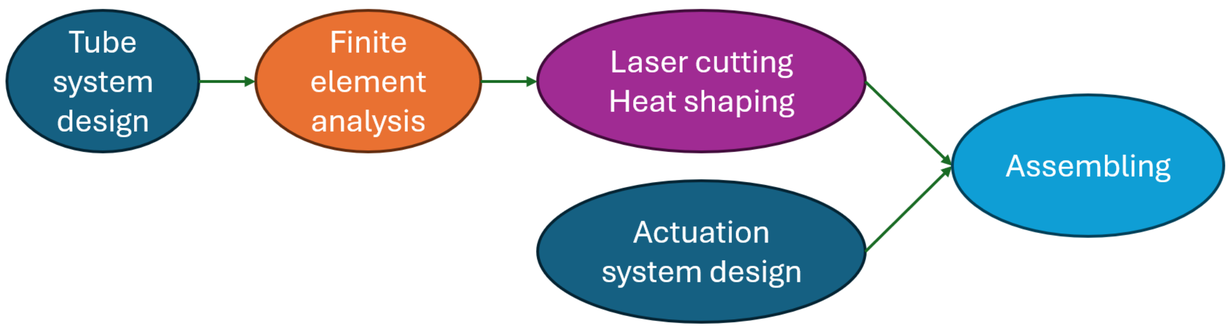
Aims:

- Add a second independently controllable section to the system.
- Develop a 3D stereo tracking for entire CTR.

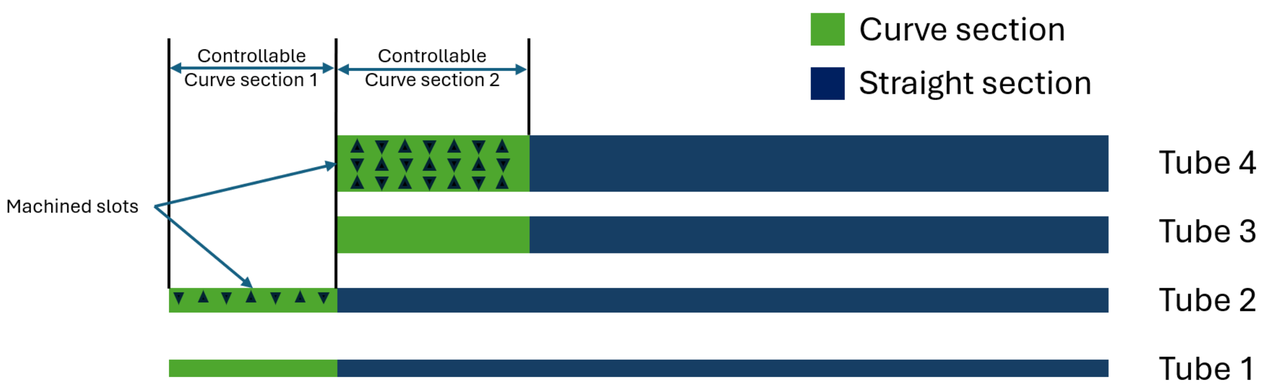
Methods

Design and Manufacture

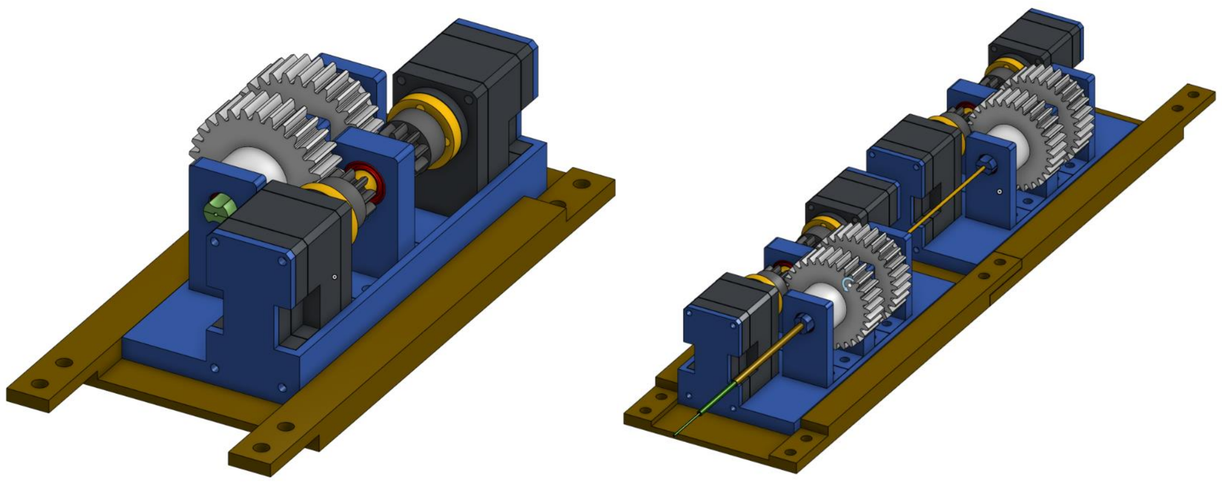
- *Design and manufacturing process for balanced pairs*



- *Arrangement of straight and curve sections in nitinol tube system*

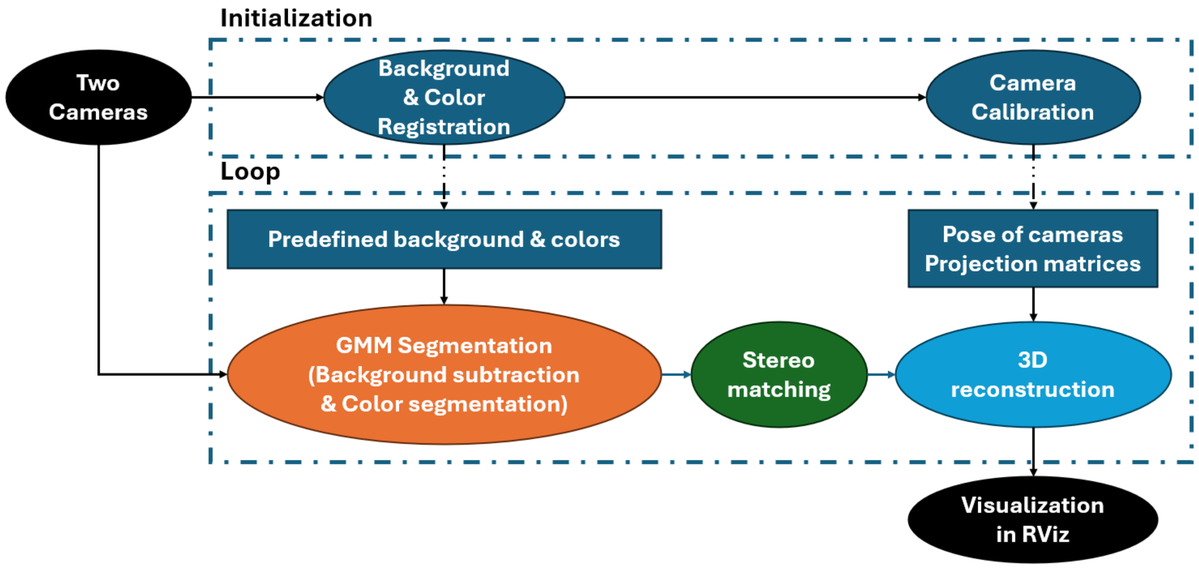


- *Modular design for the actuation system*



Stereo tracking

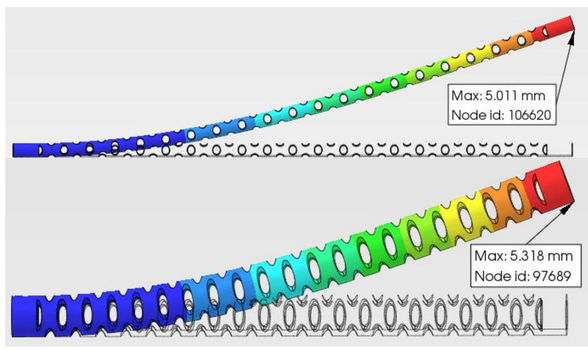
- *Tracking protocol*

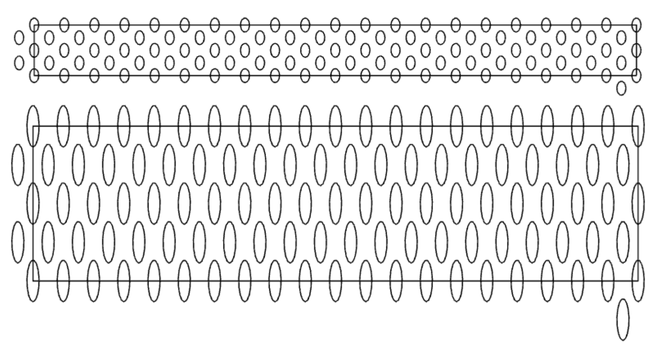


Results

Design and Manufacture outcomes

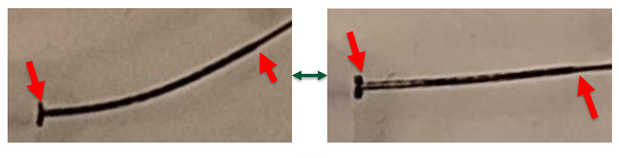
- *Finite elements analysis results and final slot patterns*





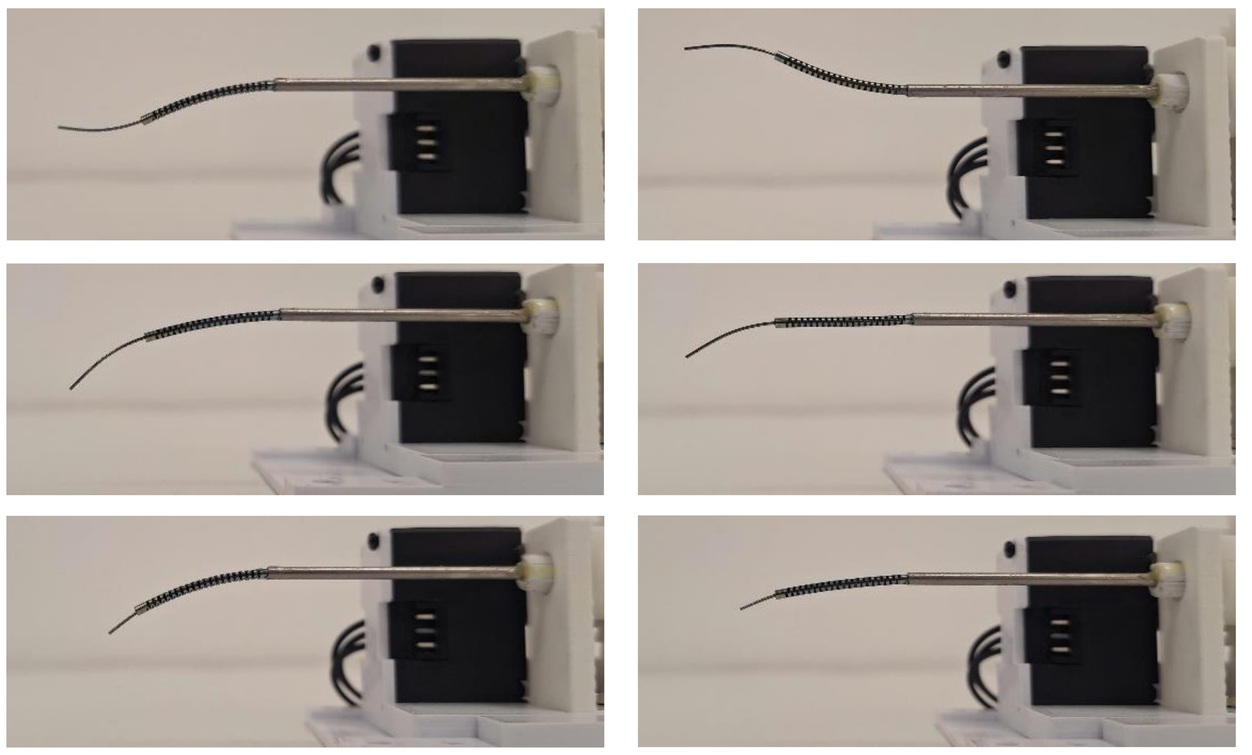
- *Balanced pair 1 and 2*

(The red arrows indicate the start and the end of each balanced pair)



(1) (2)

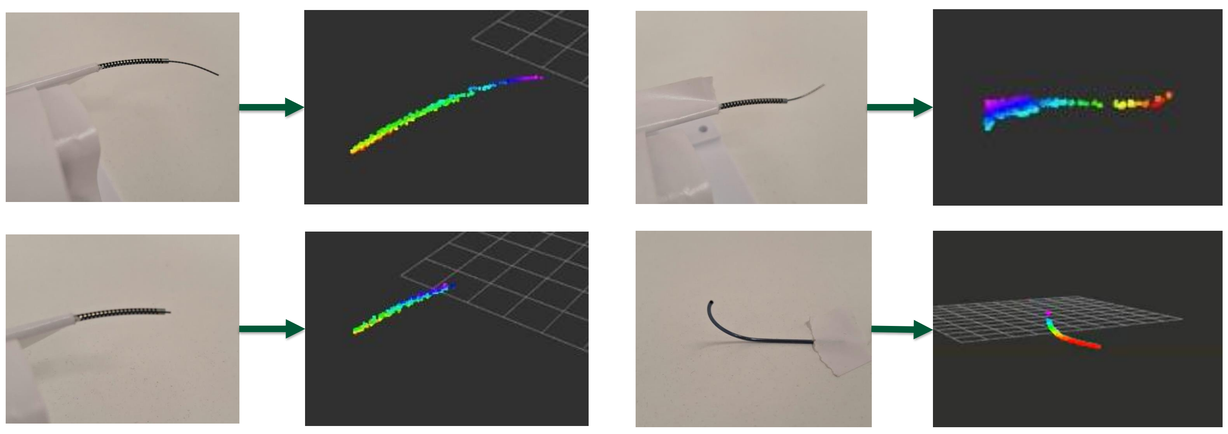
- *Decoupling of the second independent controllable section*



Stereo tracking performance

- *Segmentation*

- *3D reconstruction*



Conclusion

The project achieved the initial targets:

- Successfully developed an original design that adds a second independently controllable section to the system.
- Created a novel 3D tracking system for entire CTR.

However, the tracking system requires further improvement in precision and in its ability to detect subtle changes in the tube configurations.

References

[1] Incorporating volume-based objectives," in 2013 IEEE International Conference on Robotics and Automation, May 2013, pp. 1193–1198. doi: 10.1109/ICRA.2013.6630723.
[2] Z. Mitros et al., "Optic Nerve Sheath Fenestration With a Multi-Arm Continuum Robot," IEEE Robot. Autom. Lett., vol. 5, no. 3, pp. 4874–4881, Jul. 2020, doi: 10.1109/LRA.2020.3005129.
[3] P. E. Dupont, J. Lock, B. Itkowitz, and E. Butler, "Design and Control of Concentric-Tube Robots," IEEE Trans. Robot. Publ. IEEE Robot. Autom. Soc., vol. 26, no. 2, pp. 209–225, Apr. 2010, doi: 10.1109/TRO.2009.2035740.