

## Master Thesis Proposal

### Shape/Whole-Body Estimation of Continuum Robots

#### Motivations and general objectives:

Continuum robots (Fig. 1) are miniaturized, flexible structures that can describe complex 3D motion and navigate in narrow spaces [1]. Continuum/soft robots have major advantages allowing to access constrained environments and interaction safety for intracorporal/endoluminal medical applications [2].

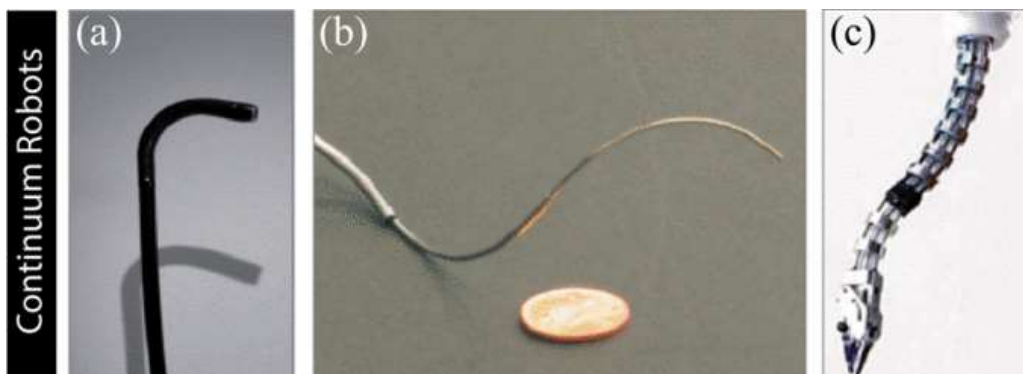


Fig. 1. Examples of continuum robots [5].

The same advantages represent, conversely, important challenges in terms of perception and control [3]. Indeed, interpreting continuum robot motion and localizing them in the environment is far from being intuitive. In contrast with human-scale, rigid-link standard robots, integrating as many sensors as required to grasp their body shape is not possible for continuum robots due to dimensional, structural, and environmental constraints. State-of-the-art approaches rely on (medical) image processing, discrete sensor integration (inertial and magnetic sensors [4]), or emerging shape sensors which efficiency is yet to be proved [5, 6].

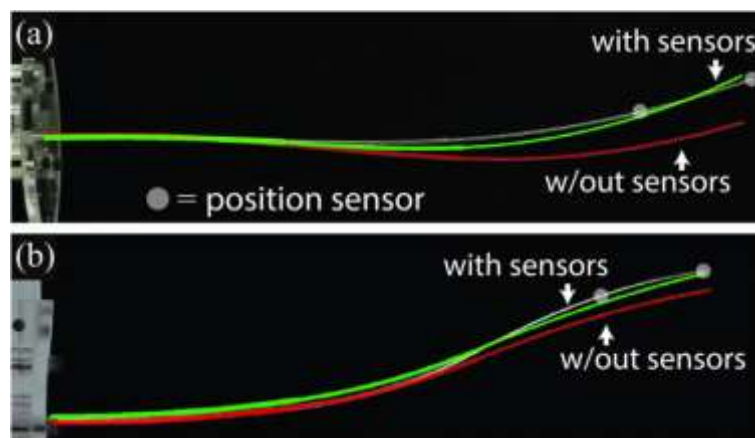


Fig. 2. Shape estimation of a concentric tube continuum robot using electromagnetic sensors [5].

Such techniques show limited reliability and transparency with respect to shape reconstruction (Fig. 2). On the other hand, accurate mechanical models were developed and allow to describe continuum robots' motion [7].

This Master thesis will focus on developing a hybrid approach, combining robot proprioception, sensor feedback, and model knowledge.

#### References:

- [1] J. Burgner-Kahrs, D.C. Rucker, H. Choset (2015): "Continuum Robots for Medical Applications: A Survey". IEEE Transactions on Robotics, 31(6): 1261-1280. DOI: [10.1109/TRO.2015.2489500](https://doi.org/10.1109/TRO.2015.2489500)
- [2] P.E. Dupont, N. Simaan, H. Choset, D.C. Rucker (2022): "Continuum Robots for Medical Interventions". Proceedings of the IEEE, 11(7): 847-870. DOI: [10.1109/JPROC.2022.3141338](https://doi.org/10.1109/JPROC.2022.3141338)
- [3] M.T. Chikhaoui, J. Burgner-Kahrs (2018): "Control of Continuum Robots for Medical Applications: State of the Art". International Conference on New Actuators, pp. 154-164. <https://ieeexplore.ieee.org/document/8470787>
- [4] M. Zmitri, H. Fourati, C. Prieur (2022): "BiLSTM Network-Based Extended Kalman Filter for Magnetic Field Gradient Aided Indoor Navigation". IEEE Sensors Journal, 22(6): 4781-4789. DOI: [10.1109/JSEN.2021.3091862](https://doi.org/10.1109/JSEN.2021.3091862)
- [5] C. Shi, X. Luo, P. Qi, T. Li, S. Song, Z. Najdovski, T. Fukuda, H. Ren. (2016): "Shape Sensing Techniques for Continuum Robots in Minimally Invasive Surgery: A Survey". IEEE Transactions on Biomedical Engineering, 64(8): 1665-1678. DOI: [10.1109/TBME.2016.2622361](https://doi.org/10.1109/TBME.2016.2622361)
- [6] A.W. Mahoney, T.L. Bruns, P.J. Swaney, R.J. Webster. (2016): "On the inseparable nature of sensor selection, sensor placement, and state estimation for continuum robots or "where to put your sensors and how to use them"". IEEE International Conference on Robotics and Automation, pp. 4472-4478. DOI: [10.1109/ICRA.2016.7487646](https://doi.org/10.1109/ICRA.2016.7487646)
- [7] Chikhaoui M.T., Lilge S., Kleinschmidt S., Burgner-Kahrs J. (2019): "Comparison of Modeling Approaches for a Tendon Actuated Continuum Robot with Three Extensible Segments". IEEE Robotics and Automation Letters, 4(2): 989-996. DOI: [10.1109/LRA.2019.2893610](https://doi.org/10.1109/LRA.2019.2893610)

#### Desired experiences or qualification:

The candidate should ideally be in preparation of a Master degree (or equivalent) in Mechanical engineering, mechatronics, robotics, or a similar field.

#### Host institution:

[CAMI \(Computer-Assisted Medical Interventions\) team](#) has been pioneering the development of medical devices assisting medical interventions for the past three decades. Added to our expertise and contributions in terms of perception, reasoning, and action, our team is closely collaborating with clinicians of CHUGA (University Hospital Grenoble Alps) and deeply involved in clinical transfer. Added to [CamiTK](#), a rapid prototyping toolbox for software solutions in CAMI, our team is extending such approach to continuum robotics simulators, as well as prototypes.

DANCE (Dynamics and Control of Networks) team is located at GIPSA-Lab on the campus of the University Grenoble Alpes. One of the team's expertise is related to inertial and magnetic navigation using sensors as accelerometer, magnetometer or gyroscope to estimate attitude, velocity and position of bodies moving on land for example (pedestrian navigation). Several approaches were developed based on Kalman filters and observers.

**Prospective starting date:** February 2023

**Duration:** Five to six months

**Funding:** Cross-Disciplinary Program of Université Grenoble Alpes, Robots for Real-World Interaction (BOOT) project.

Financial support offered to the student: Total bonus of approximately 3439.00€ for the whole duration (for further details, visit <https://www.service-public.fr/simulateur/calcul/gratification-stagiaire>, official simulation website in French)

#### Application and Contact:

To apply, please send an email to the following contact people, attaching **a single PDF** file that contains a brief cover letter, your curriculum vitae, and a transcript of your current and previous study year grades, with "*Master Thesis Application TIMC-GIPSA*" in the subject.

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