

## MASTER'S THESIS ASSIGNMENT

Name of candidate: Katla Maria Gudmundsdottir  
Topic: Engineering Cybernetics  
Title (English): Closed-Loop Navigation of a Ribbon-Shaped Robotic Device in Brain Tissue  
Title (Norwegian): Lukket-sløyfe-navigering av en båndformet robot i hjernevev

### Motivation

Navigating biomedical instruments inside the brain remains challenging and high-risk. Robotic-assisted surgery has transformed many fields, but its application in neurosurgery remains limited by current technology [1]. The traditional rigid instruments are restricted in their ability to navigate delicate and structurally complex soft tissues such as the brain [2]. Steerable, flexible devices offer a potential solution, improving access and safety while enabling new procedures [3]. Additionally, advancements in microfabrication have enabled the production of microscopic probes capable of monitoring biological activity and delivering stimulation or therapy [4], [5]. Yet, no steerable device has been developed that can both navigate brain tissue and utilize this technology for real-time sensing and targeted therapy.

### Context

To address this unmet need the MICROBS lab has developed a novel ribbon-shaped, tendon-driven continuum microrobot for minimally invasive neurosurgical interventions. This design allows for agile 3D navigation by achieving configuration unattainable by traditional rod-like instruments [2]. Enabling precise navigation through soft tissue, capable of safely avoiding critical structures and reaching multiple targets in a single insertion. However, this unique geometry introduces new challenges in modeling and control, requiring specialized solutions.

### Assignment

The aim of this master thesis is to develop a closed-loop control system for this novel robotic device by integrating real-time 3D tip tracking, path planning and navigation in order to enable precise and adaptive movement in minimally invasive neurosurgical applications. The work will be structured into two main areas:

#### System Integration and Code Refinement

1. Establish a robust codebase: Restructure and optimize the code for readability, testability and scalability.
2. Interface with the 3D tip tracking algorithm: Establish a robust connection between the Python-based tip tracking system and the C++/Qt-based control system to enable real-time feedback.
3. Integrate path planning: Incorporate the existing 2D path-planning algorithm and modify it such that it can be used as the reference path for 2D control.

#### Control System Development

4. Enhance tendon-driven actuation: Improve individual tendon tension control for better precision and stability.
5. Develop closed-loop 2D navigation: Implement a control system to minimize the error between the microrobot's path and the planned trajectory.
6. Develop closed-loop 3D navigation: Extend the control framework to support full three dimensional movement.

Assignment given: 13. February 2025

Submission deadline: 17. July 2025

[1] J. J. Doulgeris, S. A. Gonzalez-Blohm, A. K. Filis, T. M. Shea, K. Aghayev, and F. D. Vrionis, "Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises," *Cancer Control J. Moffitt Cancer Cent.*, vol. 22, no. 3, pp. 352–359, Jul. 2015, doi:10.1177/107327481502200314.

[2] L. Nosedà, A. Liu, L. Pancaldi, and M. S. Sakar, "A Flat Tendon-Driven Continuum Microrobot for Brain Interventions," in *2024 IEEE International Conference on Robotics and Automation (ICRA)*, Yokohama, Japan: IEEE, May 2024, pp. 13466–13471. doi: 10.1109/ICRA57147.2024.10611399.

[3] T. da Veiga et al., "Challenges of continuum robots in clinical context: a review," *Prog. Biomed. Eng.*, vol. 2, no. 3, p. 032003, Jul. 2020, doi: 10.1088/2516-1091/ab9f41.

[4] R. Chen, A. Canales, and P. Anikeeva, "Neural recording and modulation technologies," *Nat. Rev. Mater.*, vol. 2, no. 2, pp. 1–16, Jan. 2017, doi: 10.1038/natrevmats.2016.93.

[5] J. A. Frank, M.-J. Antonini, and P. Anikeeva, "Next-generation interfaces for studying neural function," *Nat. Biotechnol.*, vol. 37, no. 9, pp. 1013–1023, Sep. 2019, doi: 10.1038/s41587-019-0198-8.