

Master's Thesis / Engineering Internship: Real-time Magnetic Localization of a Capsule for Minimally Invasive Surgery

Duration: 5–6 months

Supervision: Hugo Daguerre, Redwan Dahmouche, Omar Tahri (permanent researchers) and Ayman Ayoub (PhD student)

Location: Institut FEMTO-ST, département AS2M, Besançon, France

1 Context

FEMTO-ST is the largest CNRS unit in engineering and Information sciences, comprising more than 700 people working in 7 scientific departments (www.femto-st.fr). The “Automatic control and Micro-Mechatronics Department” has international expertise in Micro-Nano-Robotics, Automatic Control, and Data PHM; it offers a highly stimulating and fruitful working environment. The AS2M department, specializing in microrobotics and micro-mechatronics investigated for more than 10 years the design, modeling, fabrication, and control of microsystems and microrobots. Various systems have been designed and controlled for micro-assembly and biomedical applications with smart actuators, and sensors on a small scale.

The ColoscoBot project in collaboration with the Carnot Institute of Burgundy (ICB), supported by the Bourgogne Franche-Comté region, aims to develop a magnetically actuated robot for minimally invasive colonoscopy. A PhD student is currently working on the magnetic actuation of a small magnetic capsule that will navigate inside the colon. In parallel to the work on magnetic actuation and design, the goal of this internship/Master's thesis is to develop a real-time localization system for the magnetic capsule. Catheter localization is usually achieved using x-ray fluoroscopy, which, while effective, induces exposure to ionizing radiation and the injection of contrast agents. Additionally, fluoroscopy provides only a two-dimensional projection of the inherently three-dimensional path of the robot. To address these limitations, the emergence of magnetic localization techniques holds great promise as described in the literature (e.g., [CSF⁺23, AMM⁺19, FKBMU23, GSNR23, KAM⁺19, MAK⁺22, PSTVK⁺25, VIQ⁺24, FGJQ24]). It can provide enhanced spatial information (6 degrees of freedom) compared to fluoroscopy and eliminate the need for both contrast agents and x-ray exposure, thereby reducing patient risk and radiation dose.

2 Objectives and successive steps

The goal is to develop a system capable of tracking the position and orientation (6 DoFs) of a magnetic capsule moving in space due to the magnetic actuation generated by a magnetic tool composed of an array of 4 permanent magnets as described in [ZBTF19, HDT25]. The work will successively focus on:

- Reviewing and comparing existing magnetic localization technologies;
- Defining and implementing a magnetic measurement setup suitable for integration in the ColoscoBot, in particular it must be capable of distinguishing between the contribution of the 4 actuation permanent magnets and the capsule;
- Developing a real-time 3D position and orientation estimation algorithm (based on dipole modeling, inverse field computation, or filtering);
- Build and test a laboratory prototype for validation on a phantom;
- Evaluate the performance of the localization setup in terms of relevant criteria, e.g. accuracy, update rate, robustness;

3 Required profile

The successful applicant is a motivated and curious Master's or final-year engineering student with a solid background in mechatronics, robotics, applied physics, or instrumentation. He or she has strong knowledge of electromagnetism and signal processing and demonstrates strong skills in mathematical modeling, simulation, and programming using tools such as MATLAB, Simulink, and/or Python. Familiarity with control systems, estimation algorithms, or experimental prototyping is highly valued. Previous experience in magnetic sensing or magnetic actuation is appreciated but mandatory. The candidate is expected to work independently and rigorously, with good analytical skills and a genuine interest in experimental research. Strong communication and technical writing abilities in French or English are required.

4 Practical Information

- Duration: 5–6 months
- Start date: February 2026 at the latest
- Compensation: around 500 to 600 euros per month
- Location: Institut FEMTO-ST, département AS2M, 26 rue de l'építaphe, 25000 Besançon, France

For application, send your CV and cover letter (mentioning your availability and relevant experience) to hugo.daguerre@femto-st.fr and redwan.dahmouche@femto-st.fr

References

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- [ZBTF19] Azaddien Zarrouk, Karim Belharet, Omar Tahri, and Antoine Ferreira. A Four-magnet System for 2D Wireless Open-Loop Control of Microrobots. In *2019 International Conference on Robotics and Automation (ICRA)*, pages 883–888, May 2019. ISSN: 2577-087X.