MNRLab
Medical Micro & Nano Robotics

GUC German University in Cairo
الجامعة الألمانية بالقاهرة

Clearing of Blood Clots *in vivo* under Hall Effect Sensor Guidance

Helical microrobots have the potential to swim inside Newtonian fluid (e.g., silicon oil and blood) and viscoelastic environment (e.g., tissue). Therefore, these microrobots have diverse biomedical applications, such as targeted drug delivery, cell sorting, cell characterization, and clearing of clogged arteries. In this work, we will focus on the motion control of helical robot under Hall effect sensor guidance. Since the ultimate goal of this project is to clear blood clots *in vivo* and that camera feedback would not be possible then, Hall effect sensor feedback would prove more beneficial.

Objective

In this work, we will focus on the closed-loop motion control of helical microrobots [1] based on Hall effect sensor feedback (Fig. 1). This should enable targeting of blood clots in vivo using two rotating dipole fields [2].

Tasks

- Fabrication of helical microrobots [3];
- Motion control of helical microrobots using the HeliMag system
- Preparation of biological samples (blood vessels and bloot clots);
- Closed-loop motion control of helical robot under Hall effect sensor guidance [4];
- Clearing of blood clots *in vitro* and *in vivo*.

Materials

- HeliMag is available in MNRLab;
- Hall effect sensor is available in the MNR lab
- Helical microrobots have to be fabricated;
- Catheter segments and phosphate buffered saline.

PREREQUISITES

Students are expected to have a working knowledge of control theory, differential equations, linear systems, statics, kinematic and dynamics, dynamics at low Reynolds numbers. Familiarity with programming, especially with Matlab, LabVIEW, and C++.

OTHER NOTES

This project will involve a weekly meeting with the instructors and progress reports have to be prepared. All reports should be written in academic paper format.

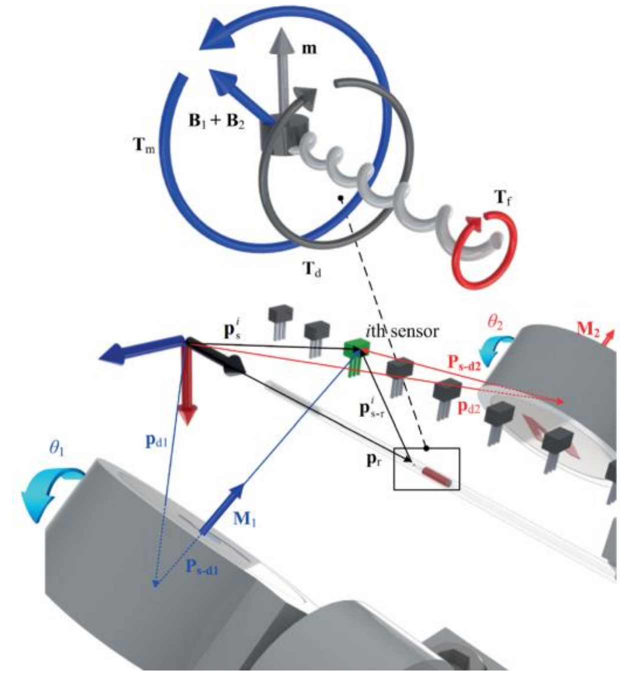

Figure 1. Dipole models of the helical robot (shown magnified) and the two rotating permanent magnets are used to localize the helical robot. The helical robot (with magnetic moment m) is contained inside a catheter segment between the two rotating permanent magnets with magnetic moment M1 and M2. p^i_s is position vector to the ith sensor from a reference frame and p^i_{s-r} is position vector to the ith sensor from the robot frame of reference.

1. References

[1] A. W. Mahoney and J. J. Abbott, “Control of untethered magnetically actuated tools with localization uncertainty using a rotating permanent magnet," in *Proceedings of the IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, pp. 1632-1637, Rome, Italy, June 2012.

[2] M. E. Alshafeei, A. Hosney, A. Klingner, S. Misra, and I. S. M. Khalil, “Magnetic-Based motion control of a helical robot using two synchronized rotating dipole fields," in *Proceedings of the IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, pp. 151-156, São Paulo, Brazil, August 2014.

[3] A. Hosney, J. Abdalla, I. S. Amin, N. Hamdi, and I. S. M. Khalil, “*In vitro* validation of clearing clogged vessels using microrobots," in *Proceedings of the IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, pp. 272-277, Singapore, June 2016.

[4] I. S. M. Khalil, A. Adel, D. Mahdy, M. M. Micheal, M. Mansour, N. Hamdi and S. Misra, ‘‘**Magnetic localization and control of helical robots for clearing superficial blood clots**,’’ *APL Bioengineering*, vol. 3, no. 2, 026104, May 2019