MNRLab
Medical Micro & Nano Robotics

GUC
German University in Cairo
الجامعة الألمانية بالقاهرة

Trajectory Planning and Control of Magnetotactic Bacteria

Magnetotactic bacteria have the potential to execute nontrivial tasks, such as microactuation, micromanipulation, and microassembly, under the influence of the controlled magnetic fields. Closed-loop control characteristics of these magnetic microorganisms depend on their self-propulsion forces (motility) and magnetic dipole moments. These properties can be controlled through the growth conditions of magnetotactic bacteria. We provide a comparison between two species of magnetotactic bacteria, i.e., *Magnetospirillum magnetotacticum* strain MS-1 and *Magnetospirillum magneticum* strain AMB-1. This comparison includes the characterization of their morphologies, magnetic dipole moments, and closed-loop control characteristics in the transient and steady states.

Objective

In this project, we will focus on the motion control of magnetotactic bacteria inside fluidic chips with several bifurcations and channels. The ultimate goal of this project is to demonstrate the ability of the directional control using magnetic fields to move the bacteria towards a reference position along a pre-specified path.

Tasks

- Control of magnetotactic bacteria in a stationary medium;
- Path planning and trajectory generation;
- Demonstration of closed-loop control along a path inside a chip with several bifurcations.

Materials

- Capillary tubes have to be ordered (VitroCom, VitroTubes 3520-050, Mountain Lakes, USA);
- An electromagnetic system is available;

PREREQUISITES

Students are expected to have a working knowledge of control theory, differential equations, linear systems, statics, kinematic and dynamics. Familiarity with programming, especially with Matlab 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.

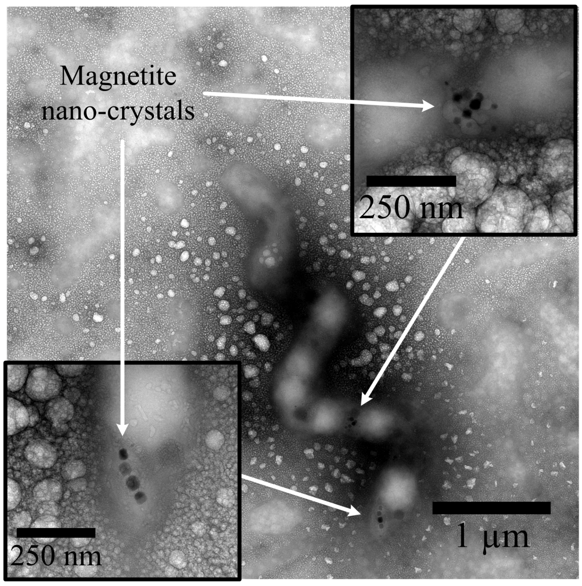

Figure 1. Scanning/Transmission Electron Microscope (SEM/TEM) images of the Magnetotactic Bacterium (MTB), i.e., *Magnetospirillum magnetotacticum* MS-1. The SEM image shows the spiral membrane of the MTB which envelopes chains of magnetite nano-crystals. This membrane has an average diameter and length of 0.5 μm and 5 μm, respectively.

1. References

[1] S. Martel and M. Mohammadi, "Using a swarm of self-propelled natural microrobots in the form of flagellated bacteria to perform complex micro-assembly tasks," in *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, pp. 500-505, Alaska, USA, May 2010.

[2] H. A. Hassan, M. Pichel, T. Hageman, L. Abelmann, and I. S. M. Khalil, "Influence of the magnetic field on the two-dimensional control of *magnetospirillum gryphiswaldense* strain MSR-1," in *Proceedings of the IEEE/RSJ International Conference of Robotics and Systems (IROS)*, pp. 5119–5124, Daejeon, Korea, October 2016.

[3] I. S. M. Khalil, J. D. Keuning, L. Abelmann, and S. Misra, "Wireless magnetic-based control of paramagnetic microparticles," in *Proceedings of the IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, pp. 460-466, Rome, Italy, June 2012.