MASTER'S PROJECT INVITATION

SUPERVISOR: ISLAM S. M. KHALIL

SURGICAL ROBOTICS LABORATORY
www.surgicalroboticslab.nl

Project title: Actuation and Control of a Tetherless Electromagnetic Robot using Static Magnetic Fields

Background: In this project we will develop a miniature tetherless electromagnetic robot. This robot will consists of a tri-axial electromagnetic coils, embedded control system, power source, and an independent propulsion mechanism. The robot will be contained inside an electromagnetic configuration and static magnetic fields (Figure) will be used to achieve directional control and propulsion inside fluids characterized by low Reynolds numbers. The ultimate goal of this project is to demonstrate the capability of the miniature robot to swim controllably using static magnetic fields.

Tasks:
- Model, design, and develop an autonomous electromagnetic robot under 2 cm in length
- Study the controllability of robot under the influence of a static magnetic field
- Motion control of the robot using visual feedback

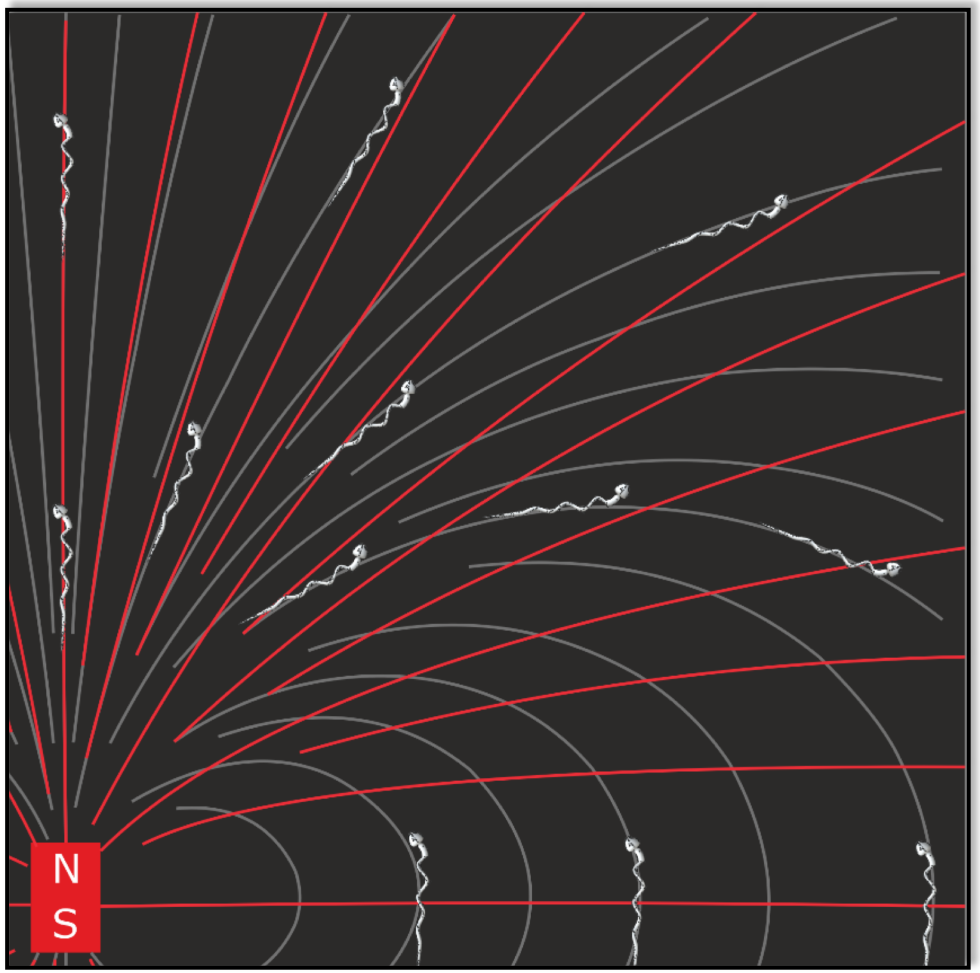

FIGURE : Magnetic field (white) and magnetic force (red) lines of a dipole enable microrobots to align and move using magnetic torque and force, respectively.

Suited for: *BME, ME, 4TU Systems and Control*

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Project title: Localization and Control of IRONSperm

Background: IRONSperm is a hybrid micro-bio-robot powered by external magnetic field and actuated using passively propagated wave along its flexible flagellum. It consists of an organic body and magnetic coating. The organic body can be loaded with a drug, whereas the magnetic coating enables directions control and flagellar propulsion under the influence of controlled magnetic fields. In addition, the magnetic coating increases the echogenicity of the cells and enables minimally invasive localization (Figure). The ultimate goal of this project is to localize IRONSPerm samples using ultrasound feedback and achieve motion control using magnetic fields.

Tasks:

- Localization of IRONSperm using ultrasound feedback and optimize the contrast to noise ratio (CNR) in the ultrasound images
- Study the influence of the magnetic coating on the CNR and implement magnetic-based motion control

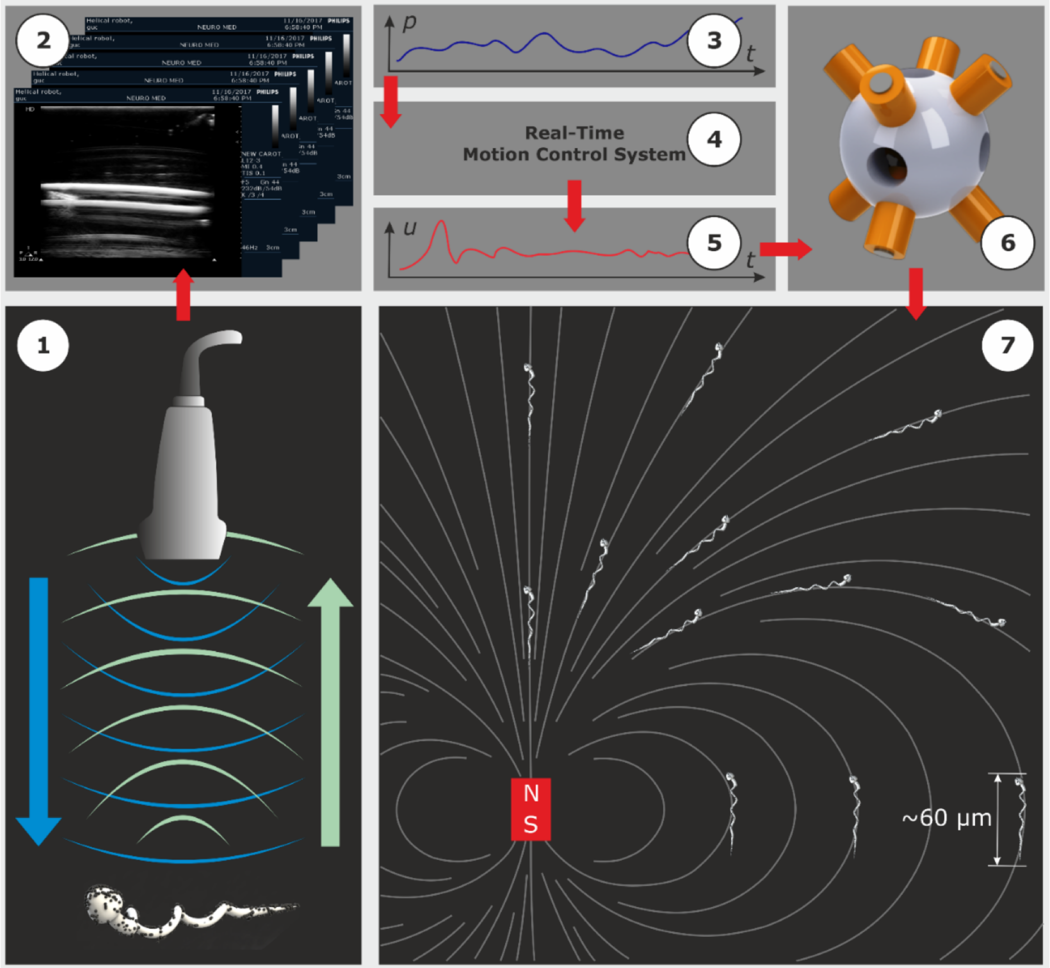

FIGURE : The magnetic coating of sperm cells enables localization and directional control using ultrasound feedback and under the influence of external magnetic fields, respectively.

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SUPERVISOR: ISLAM S. M. KHALIL

Project title: Flagellar Propulsion in a Heterogeneous Medium

Background: Propulsion enhancement is observed when soft microrobots swim in a medium with colloidal suspension. This enhancement is attributed to the asymmetric pressure gradient along the propulsion axis of the soft microrobot (Figure). Therefore, in this project we will study the influence of the size and concentration of immersed obstacles on the propulsion of a soft tetherless microrobot during flagellar propulsion. Analytical and numerical models will be developed to predict the relation between the thrust force, wave-pattern, and the concentration and size of obstacles in the medium.

Tasks:

- Actuation of soft microrobots in a fluid with colloidal suspension
- Study the influence of the concentration and size of obstacles on the flagellar wave-form and the thrust force
- Control of soft microrobots in biologically relevant fluids such as oviduct fluids, blood, and other bodily fluids.

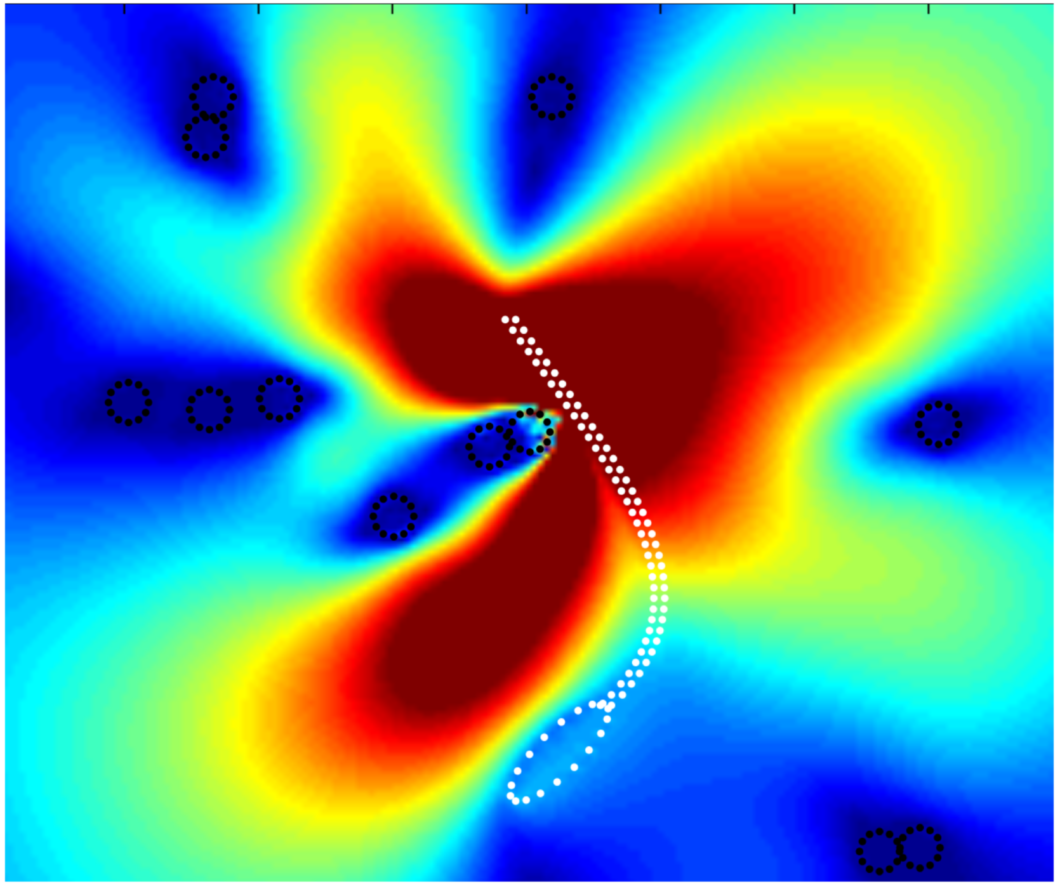

FIGURE : The immersed obstacles in the medium create asymmetric pressure field and result in propulsion enhancement of a soft microrobot. The microrobot and the obstacles are indicated by the white lines and black circles, respectively.

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SUPERVISOR: ISLAM S. M. KHALIL

Project title: Non-Contact Manipulation of Multiple Microbeads Orbiting Two-Tailed Microrobots

Background: Rotation of two-tailed microrobots about its center of mass enables nonmagnetic microbeads to follow sprocketlike trajectories and orbit, as shown in the Figure. Our objective is to achieve simultaneous closed-loop control of multiple microbeads using soft two-tailed microrobots. These microrobots swim using oscillating magnetic field and rotate under the influence of rotating magnetic field. Therefore, it is possible to change the center of rotation to allow the microbeads to orbit about any arbitrary point in 2-D space.

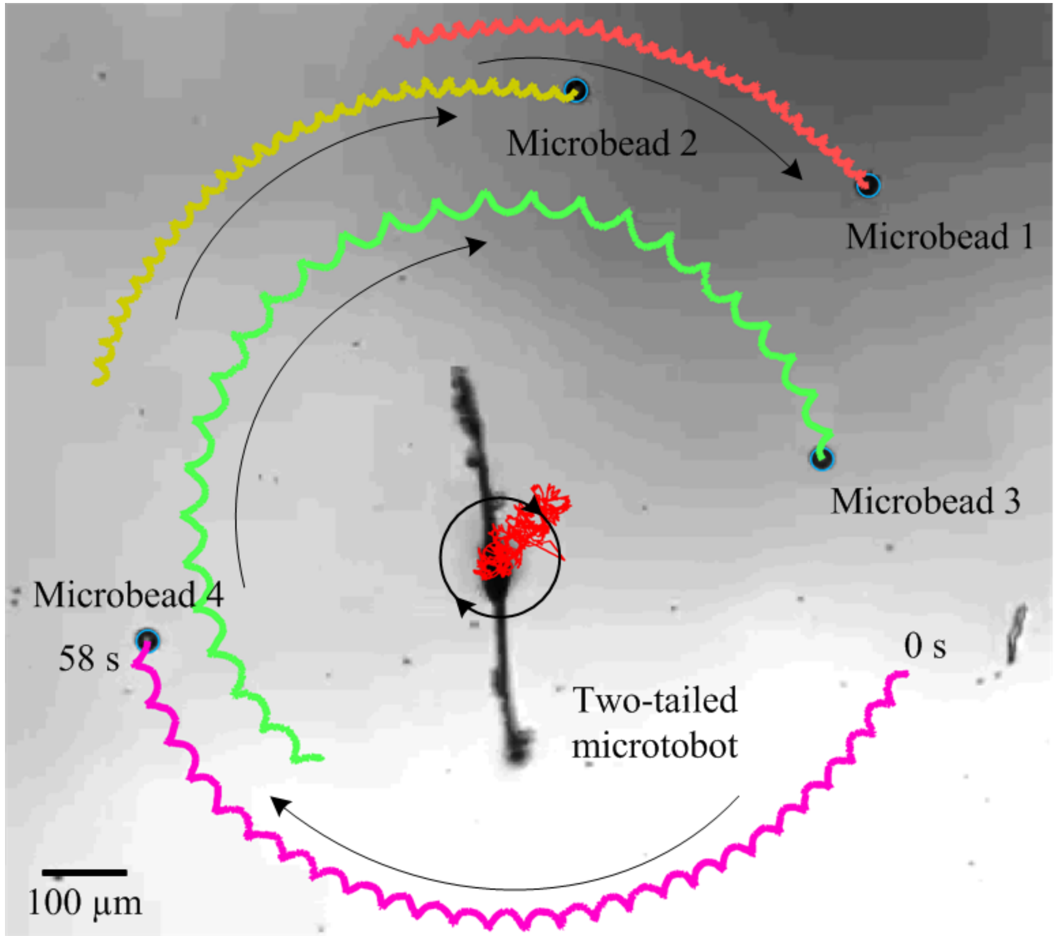

FIGURE : Nonmagnetic microbeads follow sprocketlike trajectories while orbiting a two-tailed soft microrobot.

Task:

- Simultaneous closed-loop control of multiple microbeads in 2-D space by minimizing the sum of squared differences between the prescribed target positions and the final position of the microbeads.

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SUPERVISOR: ISLAM S. M. KHALIL

Project title: Modeling and Control of a Swarm of Soft Microrobots

Background: Soft microrobots swim by passively propagated wave along an ultra-thin tail. Control of a single microrobot is not likely to yield the same efficiency as a group of microrobots. However, the travelling waves along their flagella are likely to influence each other. In this project, we will study the interaction between multiple beating flagella and the resulting wave-patterns. This study will allow us to understand how soft microrobots should swim in groups to improve the net thrust force.

Task:

- Modeling of a soft microrobot using the resistive-force theory and the regularized Stockeslets methods
- Modeling of groups of microrobots
- Experimental characterization of the swimming speeds in fluidic channels.

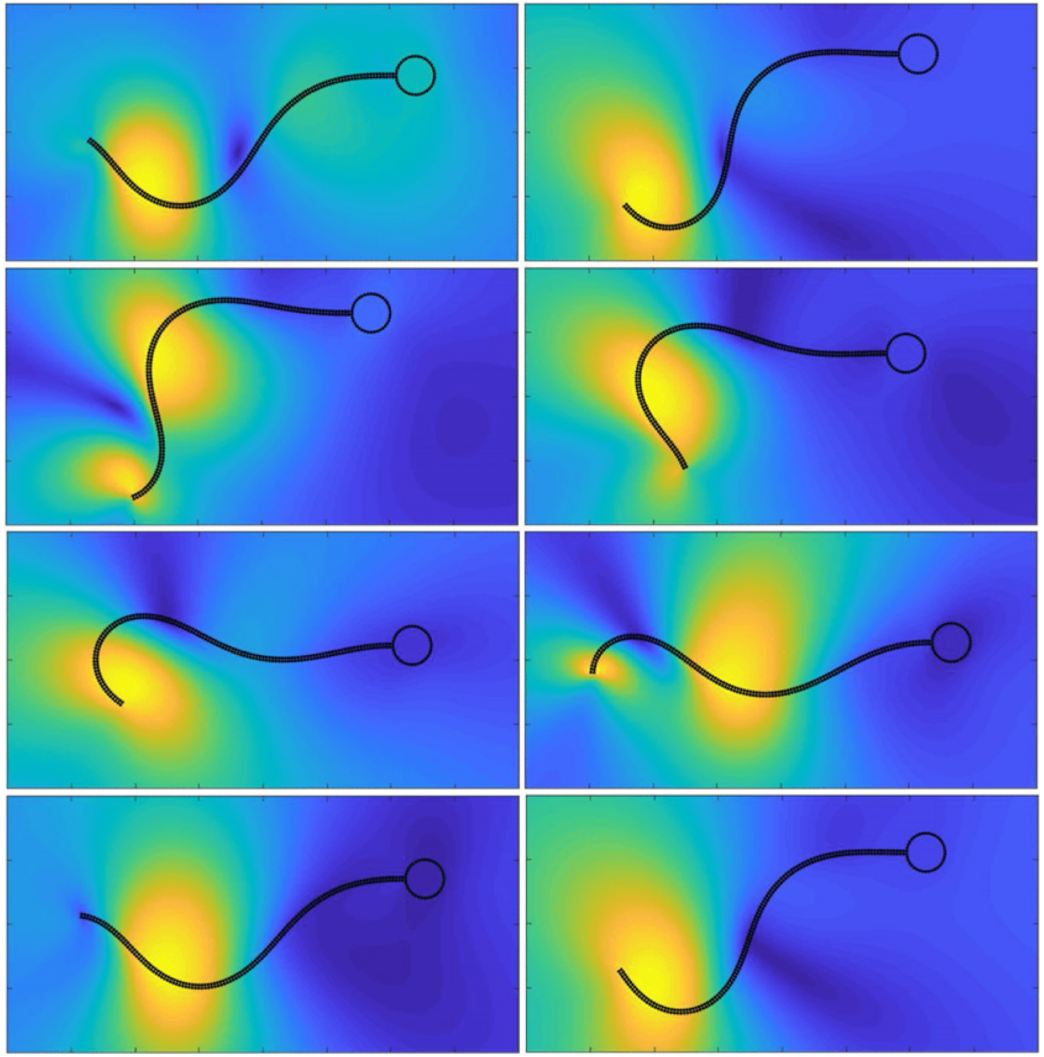

FIGURE : Soft microrobots swim by flagellar wave propagation.

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MASTER'S PROJECT INVITATION

SUPERVISOR: ISLAM S. M. KHALIL

Project title: Fabrication, Modeling and Characterization of Soft Microrobots with Multiple Flexible Flagella

Background: Soft microrobots generate thrust by a beating flexible flagellum. To improve their thrust force, and consequently their ability to swim against the flowing streams of bodily fluids, additional tails are likely to improve their frequency response. In this project, we will investigate the influence of multiple flagella on the traveling-wave propulsion. The project will include theoretical and experimental work to characterize the thrust force of multiple flagella.

Task:

- Design and modeling of a soft microrobot with multiple flagella
- Fabrication and actuation of the microrobot
- Experimental characterization of the frequency response
- Characterization of the wave-pattern of each flagellum

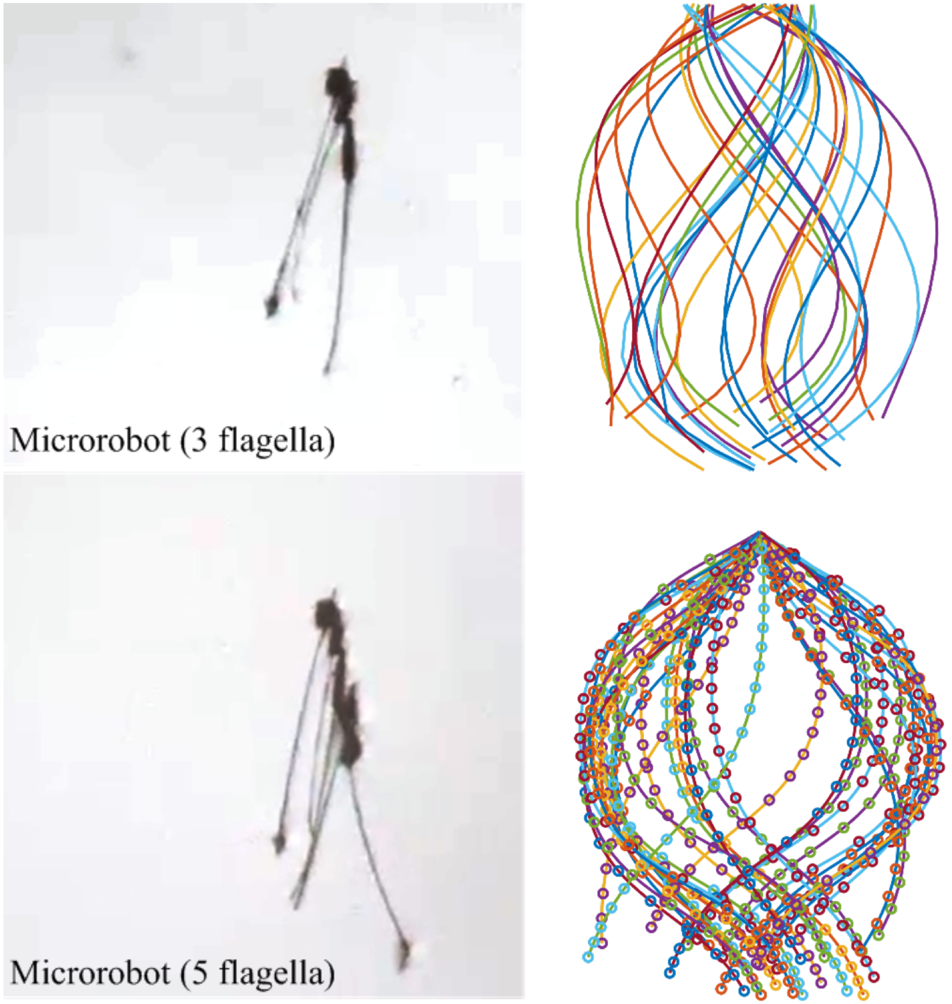

FIGURE : Soft microrobots with multiple flexible flagella

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