PhD Grants from the China Scholarship Council
– Details of the PhD proposal -

1. Supervision

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2. Title

Modeling, Closed-loop Control and Ultrasound Imaging of a Medical Magnetic Microrobotic System.

3. Keywords

Dynamic Modeling, Control of nonlinear systems, ultrasound imaging, medical micro-robotics.

4. Subject

4.1 Context

Recently, robotics at small scales has drawn lots of attention in research both in the fundamental aspects as well as their applications in biomedicine. Many organs in the human body, such as blood vessels and ventricles, are filled with fluid. For efficient actuation in a fluid environment, bioinspired swimming robots, such as the fish, tadpole, and jellyfish, have been proposed. As the characteristic dimensions of the microrobot scaling down to the microscale or even smaller, they have high potential to be navigated in hard-to-reach regions inside human body inaccessible to regular devices and may serve as microrobotic tools for *in vivo* applications such as health monitoring, early diagnosis, targeted therapy and minimally invasive medicine. To avoid the embedded power supplies load, deported magnetic actuation is considered. We developed a electromagnetic system (EMA) to actuate intro three-dimensions a magnetic microrobot by magnetic gradient coils (see Figure 1). Through the control of the magnitude and direction of the current applied to each coil in the EMA system, the microrobot is aligned and propelled in the desired direction.

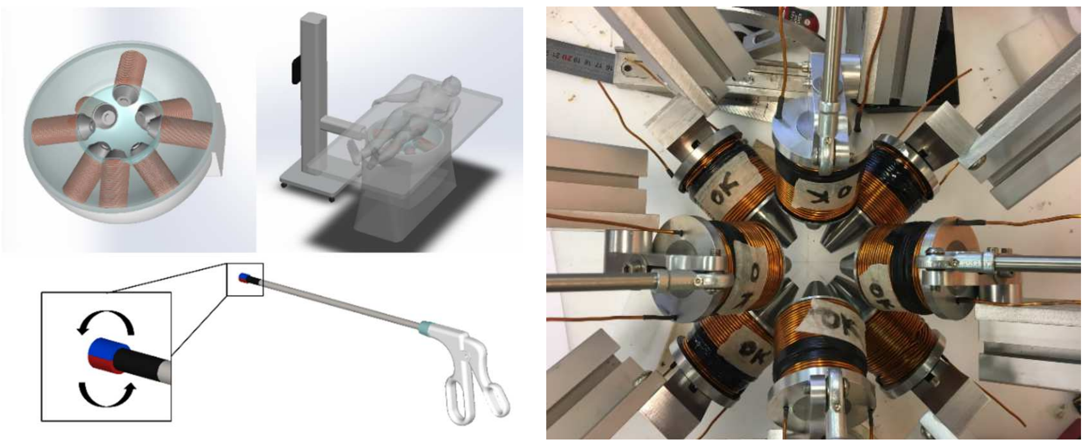

Figure 1. (a) Conceptual illustration of the electromagnetic system and laparoscopic magnetic tool for the magnetic navigation and control of magnetic microrobots for drug delivery.(b) Experimental medical eclectromagnetic platform that has been developed.

The goal is to stabilize the microrobots along a pre-planned reference trajectory, from the robot release point to the medical target. Real-time tracking of the microrobots is essential for the magnetic navigation in blood vessels. Our preliminary results indicate that real-time tracking of the microrobot using ultrasound and the magnetic actuation using an electromagnetic system is feasible. It has been demonstrated that the real-time magnetic navigation of a paramagnetic nanoparticle-based microrobot using guidance of ultrasound imaging is possible. The microrobot can be generated and navigated using steering gradients or simple rotating magnetic field.

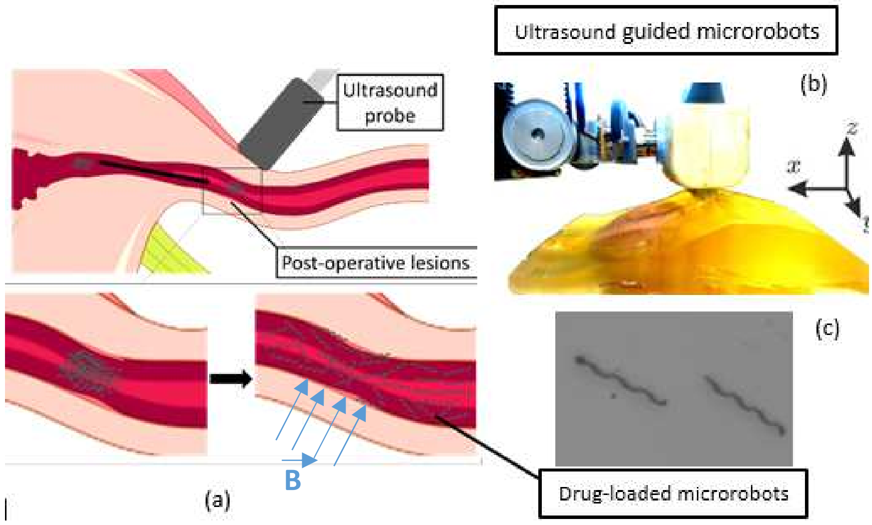

Figure 2. (a) Conceptual illustration of magnetic microrobots navigating in blood flow controlled by an electromagnetic system and guided by an ultrasound probe. (b) Robotic ultrasound imaging probe with two rotational degrees of freedom and (c) spiral flagella- type magnetic microrobots (length: 2µm).

Actually, due to the strong nonlinear models of the microrobots and the lack of imaging modality, it is difficult to control efficiently the microrobots shown in Fig.2 for targeted therapy. Closed-loop control of microrobot locomotion using ultrasound imaging feedback is a promising solution.

4.2 Research Workplan

The objectives of this PhD thesis are to investigate the following closed-loop control a magnetically-actuated microrobot using two-dimensional ultrasound images. The essential technical objectives of this proposed PhD work are essentially focused on :

i) Literature review on magnetic-field-generation systems using electromagnetic coils. [1].
ii) Study existing references on magnetic propulsion and microrobots dynamics modeling. [2][3]
iii) Dynamic modeling of multi-dof magnetic-field-generation EMA system based on orthogonal arrangement of electromagnetic coils for helical magnetic microrobot propulsion (See Fig..1b) [4].
iv) Nonlinear microrobot position control taking into account model uncertainties, sensing noise and external perturbations in biological fluids (blood vessels) [5][6]
v) Closed-loop navigation control using two-dimensional ultrasound imaging.
vi) Experimentation and validation of prototype for safe, controlled and robust propulsion of magnetic microrobots will be carried out [7].

Brief collaboration plan, including also information on the following:

The collaboration will focus on the development of microrobotic platform as well as the microrobotic swarms which is capable of performing stem cell delivery in specific areas. The French supervisor is working in collaboration with the Chinese University of Hong Kong (CUHK) that are responsible for the design and mass production of the artificial magnetic microrobots. Afterwards, a collaboration with the medical school at CUHK and the Prince of Wales Hospital, will be in charge of the animal tests of using the magnetic microrobotic drug-delivery system.

References:

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