Mechanical Engineering Doctoral Defense

Modeling and Control of Shapeshifting Ferrofluidic Robots

School for Engineering of Matter, Transport and Energy

Reza James Ahmed

Advisor: Hamidreza Marvi

Abstract

Due to its unique combination of material properties, ferrofluid has been used in applications ranging from audio speaker cooling fluid and rotary pressure seals, to a tool for retinal detachment surgery and as a material in implantable artificial glaucoma valves. Recently, ferrofluid has been investigated as a material for use in magnetically controllable liquid droplet robotics. Liquid droplet robotics is an emerging technology that aims to apply controls theory to manipulate fluid droplets as robotic agents to perform tasks, while magnetically controlled micro-robotics is a popular area of study regarding manipulating a magnetic field to control a magnetized micro-robot. Both of these emerging fields have potential for impact towards medical applications: liquid characteristics such as being able to dissolve various compounds, be injected via needle, and the potential for the human body to automatically filter and remove a liquid droplet robot, etc make liquid droplet robots advantageous for medical applications; while the ability to remotely control the forces and torques on an un-tethered microrobot via magnetic field and magnetic field gradient is also advantageous.The research described in this dissertation explores applications and advances methods for the electromagnetic control of individual ferrofluid droplet robots. First, basic electrical components built from fluidic channels containing ferrofluid are made remotely magnetically variable via the placement of ferrofluid within the channel. Second, a ferrofluid droplet is shown to be fully controllable in position, stretch direction, and stretch length in two dimensions. Third, control of a ferrofluid's position, stretch direction, and stretch length is extended to three dimensions and control gains are optimized for accuracy via a bayesian optimization process. Finally, magnetic control of both single and multiple ferrofluid droplets in two dimensions is investigated via a visual model predictive control approach based in machine learning. All positional control methods are validated via path following or trajectory tracking experiments.

June 14, 2022; 9 AM;

Zoom Link: https://asu.zoom.us/j/4431823582