Mechanical Engineering Doctoral Defense

Model-Predictive Optimal Control of Ferrofluid Droplet Microrobots

School for Engineering of Matter, Transport and Energy

Olga Skowronek

Advisor: Hamid Marvi

Abstract

Ferrofluidic microrobots have emerged as promising tools for minimally invasive medical procedures, leveraging their unique properties to navigate through complex fluids and reach otherwise inaccessible regions of the human body, thereby enabling new applications in areas such as targeted drug delivery, tissue engineering, and diagnostics. This thesis develops a model-predictive controller for the external magnetic manipulation of ferrofluid microrobots.

Several experiments are performed to illustrate the adaptability and generalizability of the control algorithm to changes in system parameters, including the three-dimensional reference trajectory, the velocity of the workspace fluid, and the size, orientation, deformation, and velocity of the microrobotic droplet. A linear time-invariant control system governing the dynamics of locomotion is derived and used as the constraints of a least squares optimal control algorithm to minimize the projected error between the actual trajectory and the desired trajectory of the microrobot. The optimal control problem is implemented after time discretization using quadratic programming. In addition to demonstrating generalizability and adaptability, the accuracy of the control algorithm is analyzed for several different types of experiments. The experiments are performed in a workspace with a stationary surrounding fluid and extended to a workspace with fluid flowing through it. The results suggest that the proposed control algorithm could enable new capabilities for ferrofluidic microrobots, opening up new opportunities for applications in minimally invasive medical procedures, lab-on-a-chip, and microfluidics.

April 13, 2023; 9 AM; WXLR A109;

Zoom Link: https://asu.zoom.us/j/85380811000