Control System Design for Wireless Electromagnetic-Based Micromanipulation System

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Abstract

Control strategy to accomplish precise point-to-point positioning and trajectory tracking of magnetically-guided microparticles is analyzed in this work. External disturbances and model mismatch were modeled as inputs to the magnetic force governing equation. First, the problem is formulated by modeling the magnetic force experienced by the microparticles in the presence of viscous drag, buoyancy force, force due to gravity, external disturbances and model mismatch [1]; the resulting model is utilized to design an observer to estimate the mismatch over the nominal and actual values of these forces. Hereafter, the current-magnetic force map is derived by minimizing the two-norm square of the magnetic field-to-current map constrained with the magnetic force equation. The result of this minimization problem along with the designed observer were utilized in the realization of a control input for the attainment of robustness by compensating for the model mismatch of the electromagnetic system and rejecting the disturbance forces on the microparticles.

The proposed control strategy is based on designing two control loops, an inner-loop for the robustness attainment and an outer-loop to achieve stability of the overall electromagnetic system. In the inner-loop, the force-current map and its inverse were utilized for estimating the disturbance forces and the model mismatch, in addition to computing the required current to reject the disturbances and compensate for the model mismatch. On the other hand, the outer-loop enforces stability by achieving stable error dynamics without the necessity to identify the actual system parameters and exact model. This was shown to be valid in the electromagnetic system's low frequency range through analyzing the tradeoffs between robustness and stability using frequency response analysis [2].

In order to examine the validity of the control strategy and the performance of the overall electromagnetic-based micromanipulation system, experiments were conducted on an experimental setup consisting of four electromagnets as shown in Figure 1. The electromagnets are oriented around a reservoir at which microparticles with average diameter of 100 μm navigate in a fluidic body with unknown parameters and in the presence of external disturbance forces [3].

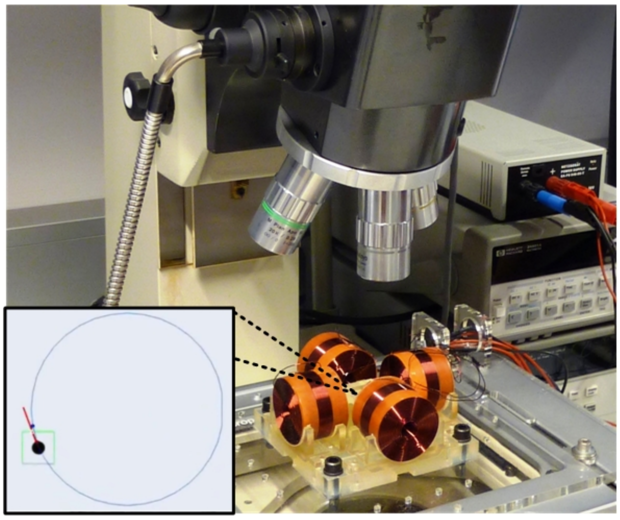

Figure 1: The electromagnetic system developed for the wireless control of microparticles under magnetic field. The inset shows a 100 μm spherical microparticle in a reservoir tracking a circular trajectory through the controlled magnetic fields.

References

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