ME – PhD Thesis Colloquium

Development of a Planar Robotic Platform with Localized Magnetic Actuation and its Applications for Untethered Ferromagnetic Robots and Shape-morphing Compliant Robots

Mr. Sudhanva Bhat, PhD Student, Department of Mechanical Engineering, IISc, Bengaluru

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ABSTRACT

This thesis focuses on the development of a solenoid-grid-based setup for independent planar actuation of multiple ferromagnetic robots referred to as ferrobots, by locally varying the magnetic field in different regions of the workspace. The use of ferromagnets rather than the commonly used permanent magnets allows multiple robots to come into contact and consequently separate away, facilitating relatively sophisticated maneuvers. In contrast, the permanent magnets irreversibly stick together in such situations. Our system is motivated by the use of magnetic robots for minimally invasive medicine and other biomedical applications.

For actuating the ferrobots along the required path, we need to calculate the currents in the solenoids, which will result in prescribed forces on the ferrobots. However, the field-dependent magnetization of the ferrobots makes the real-time calculation of force challenging. We show that when the external applied field varies as a polynomial, the exact closed-form expressions for the force and magnetization of a ferromagnetic ball can be obtained. These expressions can be used for calculating the force on a ferromagnetic ball placed in any arbitrary field by approximating the said field as a polynomial. We further extend this methodology to calculating forces on two ferrobots that are mutually influencing each other's magnetization. This is one of the main contributions of this thesis.

Using the developed force calculation methodology, we incrementally move the ferrobots along the required paths. We demonstrate the independent motion of multiple ferrobots, including coordinated manoeuvres such as bringing them together and subsequently separating them. We also demonstrate the motion of the ferrobots in a formation to mimic swarm motion. We use the ferrobots to change the shape of a planar elastic band to demonstrate a planar shape-changing robot. It can navigate obstacles and manipulate arbitrarily shaped objects.

We use the ferrobots to actuate compliant bipod, tripod, and quadruped systems to realize untethered compliant parallel robots. These compliant systems convert the planar motion of the ferrobots to motion in the 3D space. We demonstrate multiple such robots collaborating with each other, highlighting the capacity of our system to actuate many nonplanar robots within the workspace. We can also vibrate these robots with a prescribed frequency. Our parallel robots can be used to test microelectromechanical sensors.

ABOUT THE SPEAKER

Sudhanva Bhat is a PhD student in Department of Mechanical Engineering at IISc Bengaluru. He is working with Prof. G. K. Ananthasuresh in Multidisciplinary and Multiscale Design and Device (M2D2) laboratory. He completed Dual Degree in Mechanical engineering from IIT Madras in 2017. His research interests include robotics, soft robotics, magnetic and micro robotics.