Magnetically Controlled Modular Cubes with Reconfigurable Self-Assembly and Disassembly

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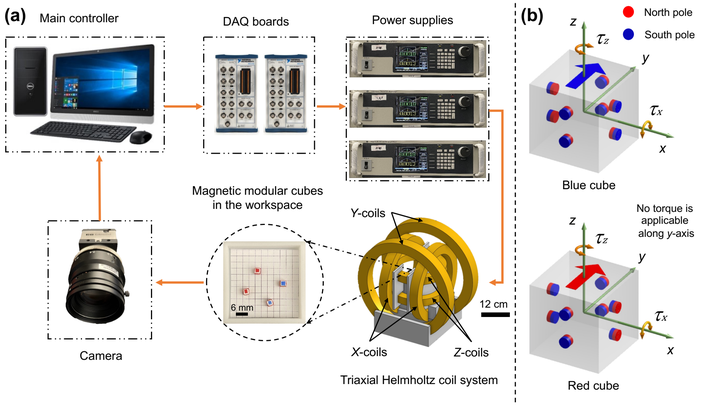
Motivations

- Seeks a new type of mesoscale[1] manufacturing method
- Design of a scalable modular robotic platform and techniques for controlled self-assembly, disassembly, and reconfiguration
- The control methods developed in this program will be applicable in other mesoscale research areas for exploring structures, dynamics, and interactions of integrated materials

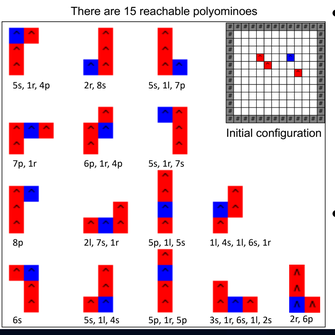
[1]mesoscale = 1μm to 10mm

Electromagnetic Control and Module Design



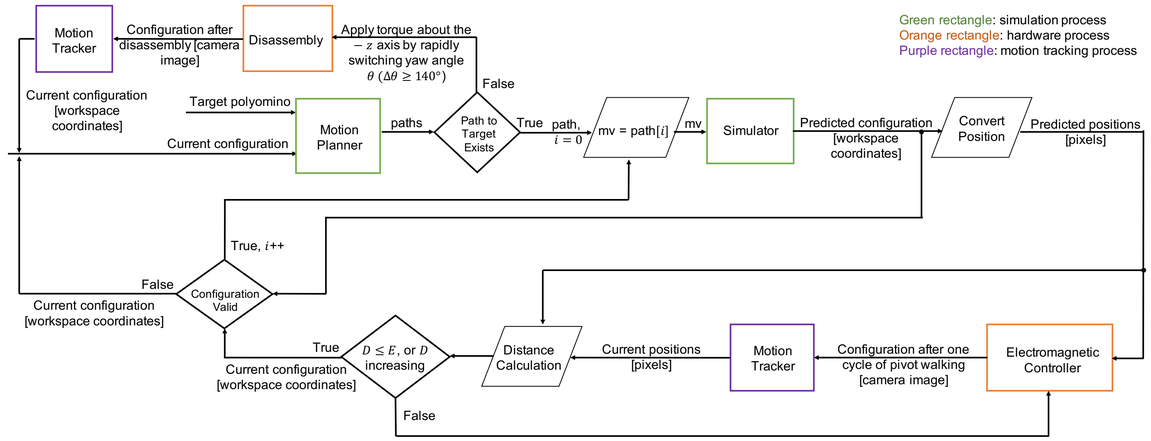
(a) Experimental setup (b) Designs of modular cubes with embedded cylindrical magnets in faces

Motion Planner

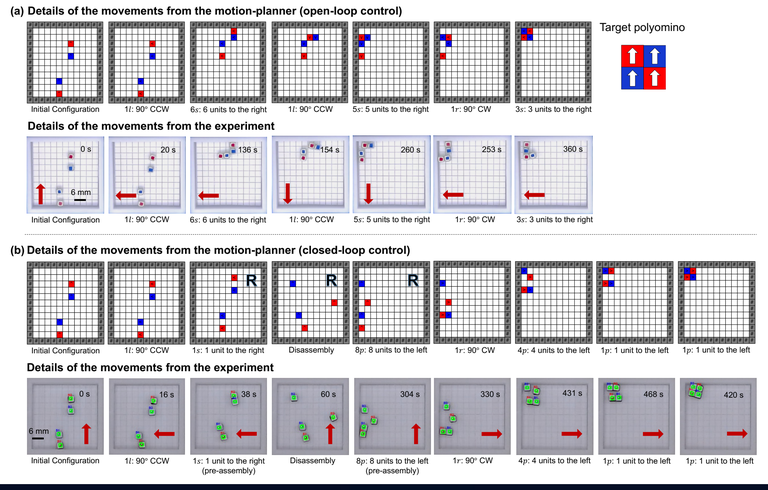


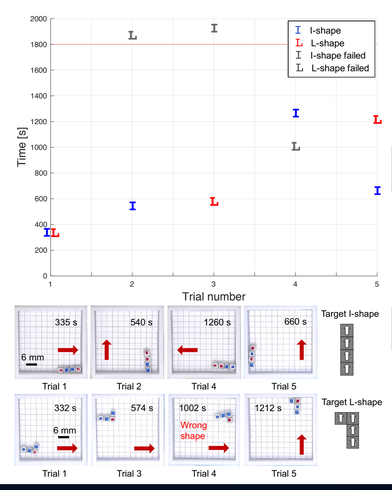
- The self-assembly algorithm takes as input the initial configuration and returns all reachable polyominoes and their shortest construction sequence
- The rotation checker checks *edge events* and *collision events* and terminates paths that produce collision events

Self-Assembly with Motion Planner in Closed-Loop Control



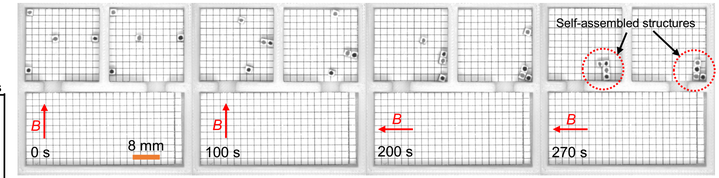
- The 2D ***motion planner*** computes all reachable polyomino configurations from an arbitrary initial configuration and provides the shortest path to form target polyominoes
- Magnetic **motion controller** actuates magnetic cubes with visual feedback control
- The closed-loop control method was tested using cubes with 10 mm and 2.8 mm edges; experiments demonstrated that the closed-loop method can construct polyominoes that could not be constructed using open-loop control with disassembly and re-planning
- By solving for only target *shape* rather than *color,* the success rate was improved by 60-80%



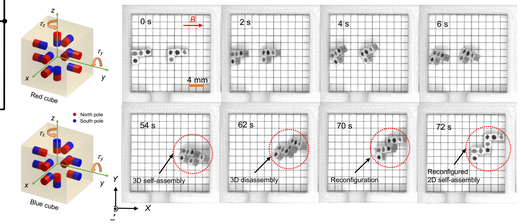


2D and 3D Self-Assembly in Multiplex

Parallel 2D self-assembly with global inputs:



3D self-assembly and 3D to 2D reconfiguration:



A reconfigurable 3D assembly process in a multiplex can create 3D structures first, then reconfigure and further assemble into 2D structures

Microcubes: Design, Motion, Self-Assembly

900-micron cubes 3D printed by PμSLA, embedded 250-micron cube magnets

Future Work

Making a high-fidelity simulator for motion planning, increasing robustness of the self-assembly process, and testing microscale self-assembly and reconfiguration

Representative Publication

Y. Lu†, A. Bhattacharjee†, C. C. Taylor, J. Leclerc, J. O'Kane, M. J. Kim*, A. T. Becker*,"Closed-Loop Control of Magnetic Modular Cubes for 2D Self-Assembly," 2023. (†Co-first authors, *Co-corresponding authors) [under review]

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