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# High-Resolution Automated Fabrication of 3D Magnetic Soft Microrobots

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## Abstract

The advent of additive manufacturing has transformed many industries. The fabrication of soft robots has seen similar improvements, but many challenges continue to persist as these functional devices often need extra features. Magnetic soft robots require the addition of magnetic particles oriented in specific directions to output the desired motions in an externally applied magnetic field. This can introduce technical bottlenecks related to high resolution printing. This research seeks to address the problem of limited printing precision in fabricating soft magnetic microrobots, aiming to overcome the barriers in producing high-resolution, three-dimensional (3D) magnetized structures necessary for complex microrobot designs and motion modes. To achieve this, a fully automated stereolithography (SLA) printing system with a resolution of approximately 50μm was developed to print high-fidelity magnetic soft microrobots.

The printer's design features a print bed with three translational degrees of freedom to ensure flexibility and precision. Each motor is independently driven, optimizing control accuracy. An updated optical system is used to achieve higher resolutions. This configuration optimizes the optical system and reduces the spot size for curing each individual voxel from 1.6mm to about 0.05mm. The addition of a beam shaper ensures well-defined curing boundaries, eliminating the tapered solidification at the voxel edges, and significantly improving the structural stability of the printed structure. The integration of the external current drive system ensures precise control of the laser power, effectively preventing the laser diode from overheating, and ensuring the stability and consistency of the system operation.

The optical components are precisely aligned along the same axis through a modularized fixed board structure, ensuring the stability and consistency of the optical path. The system's automation integrates magnetization and geometric data of the voxels which is obtained through the interface with COMSOL. The code is implemented by Raspberry Pi to realize the automatic control of the entire printing process, which has greatly improved the operational efficiency and system stability. Optical validation and performance evaluation of various soft magnetic robots are used for testing the printer capabilities. These designs include a "worm", "grabber", and "zipper" to test the system's performance under different geometric complexities and motion patterns. This research provides new possibilities for the high-precision fabrication of magnetic soft microrobots, paving the way for applications in medical continuum robots, micromanipulation, and flexible electronic devices.