Open Research Hardware: A Modular 3D printed Toolkit for Positioning and Micromanipulation

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SUMMARY
Scientific experiments frequently require precise translation, rotation and manipulation of small objects, yet the mechanical tools used for these tasks can be expensive and specialized. This work presents a collection of open-source, 3D-printed mechanical tools developed as low-cost building blocks for microscopy and small-scale experimentation. The toolkit comprises one-, two- and orthogonal-axis translation stages, in-plane and out-of-plane rotation stages, a three-axis micromanipulator, and switchable magnetic and suction mounting bases. The designs combine FDM-printed structures with inexpensive standardized components such as rods, springs, screws and ball bearings, to provide sub-100-micron positioning. Rather than a single instrument, the collection enables researchers to assemble customized positioning systems from modular components. The work explores how desktop additive manufacturing and open hardware can provide accessible precision mechanisms for research environments while allowing designs to be reproduced, modified and further developed by their users.

KEYWORDS
Open hardware; 3D printing; micromanipulation; microscopy; positioning

1 INTRODUCTION

Small-scale experimental setups often require controlled translation, rotation or manipulation of components, samples and probes. While common in laboratory instrumentation, positioning mechanisms can introduce significant cost. Open Science Hardware provides an alternative approach in which mechanical components can be fabricated, shared and modified by researchers according to their specific requirements.

The objective of this work was to develop a modular set of accessible positioning mechanisms that could be combined according to the requirements of individual experiments. The approach focuses on using additive manufacturing to produce the structural and geometrically complex elements while relying on simple, widely available hardware. The resulting devices were designed all possible degrees of freedom and allow fast fixation and assembly.

2 METHODS

The toolkit was developed around the constraints of fused deposition modelling (FDM), minimizing the need for additional components. Translation mechanisms use metallic rods as sliding guides, while rotational stages use ball bearings. Spring preloading is implemented to minimize backlash. M3 leadscrews provide 0.5 mm displacement per revolution on translation axes, while M4 screw/printed worm gear interfaces provide 1.6° and 0.65° angular displacement per revolution for the in-plane and out-of-plane stages, respectively.

Except for the micromanipulator, all modules share a 65 × 65 mm footprint and a 20 mm mounting grid, allowing arbitrary combinations to provide six-degree-of-freedom positioning. Magnetic and suction bases provide mounting on ferromagnetic and smooth substrates, respectively. M3 fasteners are used throughout, with heat-set inserts added where required by the geometry.

3 RESULTS AND DISCUSSION

Following those design principles, we designed 5 translation/rotation stages to be combined into multi-axis configurations, an integrated three-axis micromanipulator and quick-mounting bases using magnets and suction cups. The files for all devices are available online under CC BY-SA licenses with STL, STEP and native SolidWorks format available. Detailed assembly tutorials and bills of materials are also provided.

This toolkit was used sample holder for microscopy, and to assemble a low-cost wafer probe station. It allowed an experienced user to test electronic devices with 50 micron contact pads.

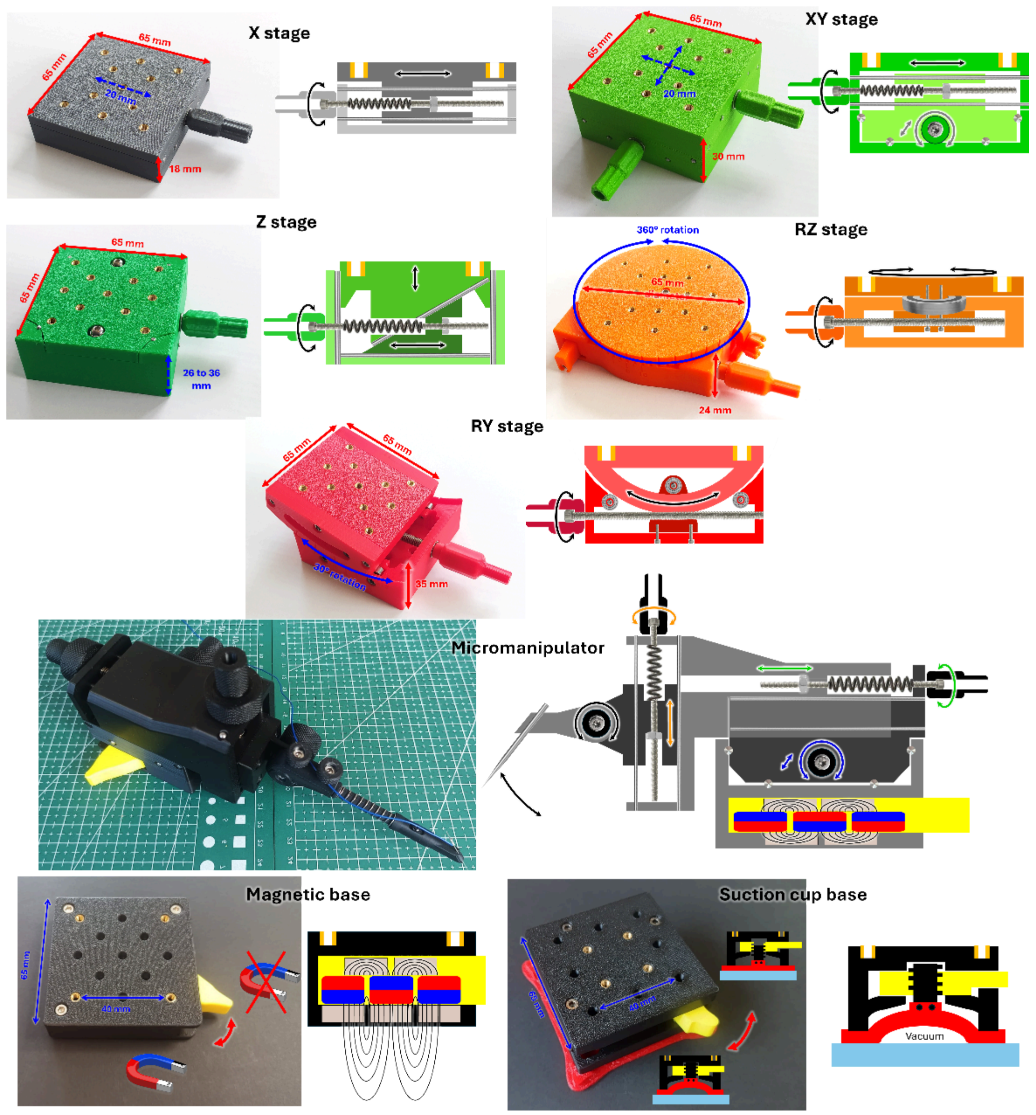

Figure 1. Photograph and schematic representation of the modular toolkit

4 CONCLUSIONS

The modular approach allows researchers to adapt positioning hardware to specific experimental setups without requiring a dedicated commercial instrument for each application. The open designs can therefore serve as reusable building blocks for developing customized laboratory equipment.

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