Prototype micromanipulator for space robotics applications

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ABSTRACT—Piezoelectric actuators offer dramatic improvements to a variety of space-based robotics applications. Bending piezoelectric actuators offer a simple, lightweight, and reliable means for actuating end effectors. This research produced a single degree-of-freedom micromanipulator prototype that can be used to solve open issues in bending actuator control, particularly hysteresis modeling and control.

PREMISE OF THE PROJECT

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Piezoelectric actuation is ideal for space-based robotics applications because of its light weight, its inherent simplicity, and its immunity to magnetic fields. End effectors for miniature space-based robots must also be simple and lightweight, and can also benefit from immunity to magnetic fields. Therefore, a piezoelectric actuator is an ideal candidate for an end effector.

A piezoelectric bending actuator consists of two layers of piezoelectric material bonded together with opposite polarity in the form of a cantilever beam. The application of an electric field to the actuator causes one layer to extend slightly and the other layer to contract slightly.[1] The differential length causes the beam to bend toward the contracting layer. By controlling the applied electric field precisely, it is possible to control the movement of the beam tip. The tip of this particular actuator has a range of motion of ±0.5 millimeters. LabVIEW 6.0 is used to generate voltages in the range +5V to –5V which are in turn supplied to a piezo-linear amplifier. The piezo-linear amplifier is used as a high-voltage drive source for the piezoelectric actuating device. The capacitive sensor[2] senses the motion and produces an analog voltage proportional to the distance between the capacitive probe and the piezoelectric actuator. LabVIEW 6.0 is used to record the capacitive sensor output.

LABORATORY APPARATUS

The UHCL micromanipulator system facilitates research in dynamics and control of micromanipulators. The device uses a piezoelectric bending actuator that has a range of motion of approximately ±0.5mm. The apparatus consists of the piezoelectric bending actuator mounted on a mechanical breadboard and driven by a linear amplifier. The manipulator position is measured using a commercial high-resolution capacitive position sensor (Series 4000 Capacitec amplifier) mounted on the mechanical breadboard. LabVIEW 6.0 is used to generate drive voltages to the piezo driver and measure capacitive sensor output. The experimental laboratory setup is shown in Figure 1.

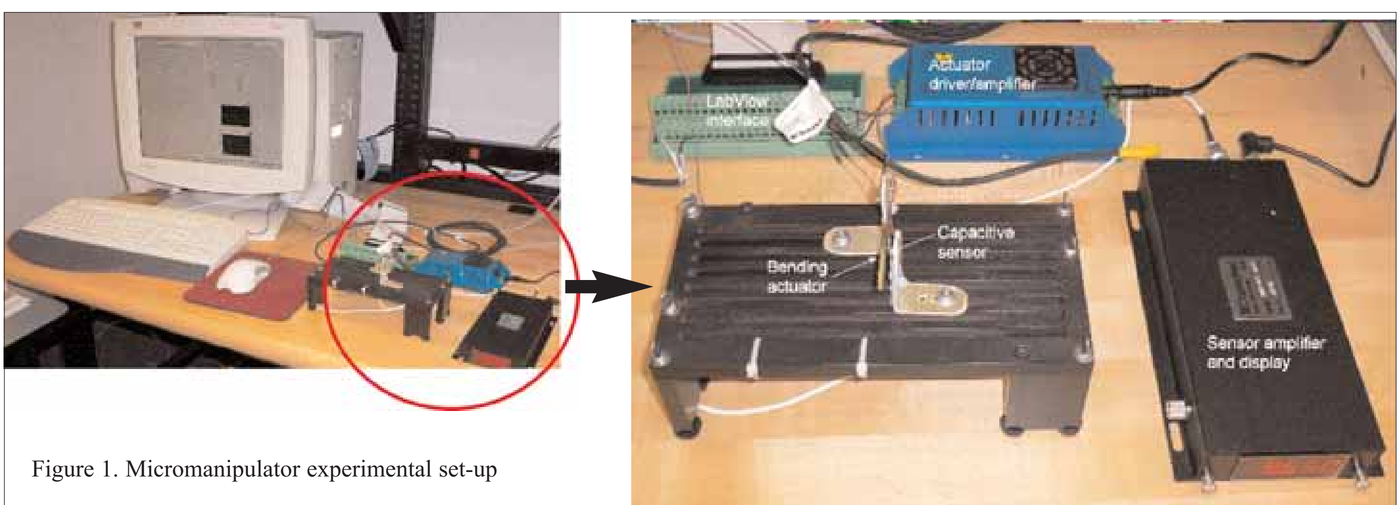

Figure 1. Micromanipulator experimental set-up

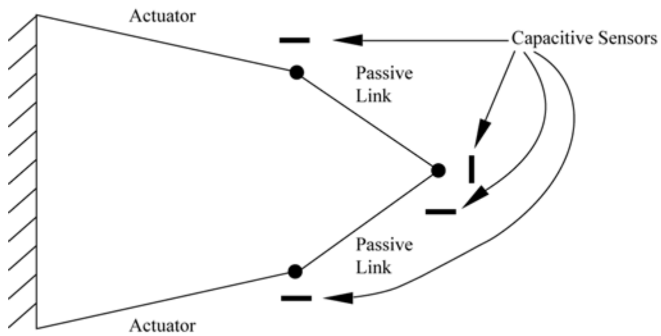

Figure 2. Piezoelectric bending parallel micromanipulator layout

GRADUATE RESEARCH—Anjana Garud, M.S. student, studies proportional control of the piezoelectric actuator in James Dabney's lab. Ms. Garud received her B.S. in electrical engineering from the Manipal Institute of Technology in Manipal, India.

RESULTS

The actuator, capacitive position sensor, actuator driver, and sensor amplifier were assembled as shown in Figure 1. LabVIEW 6.0 software was developed to control the actuator driver and capture the sensor amplifier output. Using the LabVIEW software, open-loop control was implemented to characterize the input-output behavior, particularly hysteresis. Based on these results, a preliminary design for a piezoelectric bending parallel micromanipulator was developed (Figure 2). This system will demonstrate the viability of a large range-of-motion, high-precision micromanipulator suitable for medical and space applications.

ACKNOWLEDGMENTS

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2. Ayer, M.A. Operation/maintenance manual: Series 4000 Capacitec amplifiers and rack accessories (Ayer, MA, Capacitec, Inc., 1998).

PROPOSALS

Dabney, J.B. and Harman, T.L. Piezoelectric bending parallel micromanipulator prototype, Texas Advanced Research Program, $145,000 (2008) (*not funded*).