# Pneumatic Brakes and Phantom Tissues for Steerable MRI Needle with Haptic Feedback

Biomimetics Dexterous Manipulation Laboratory

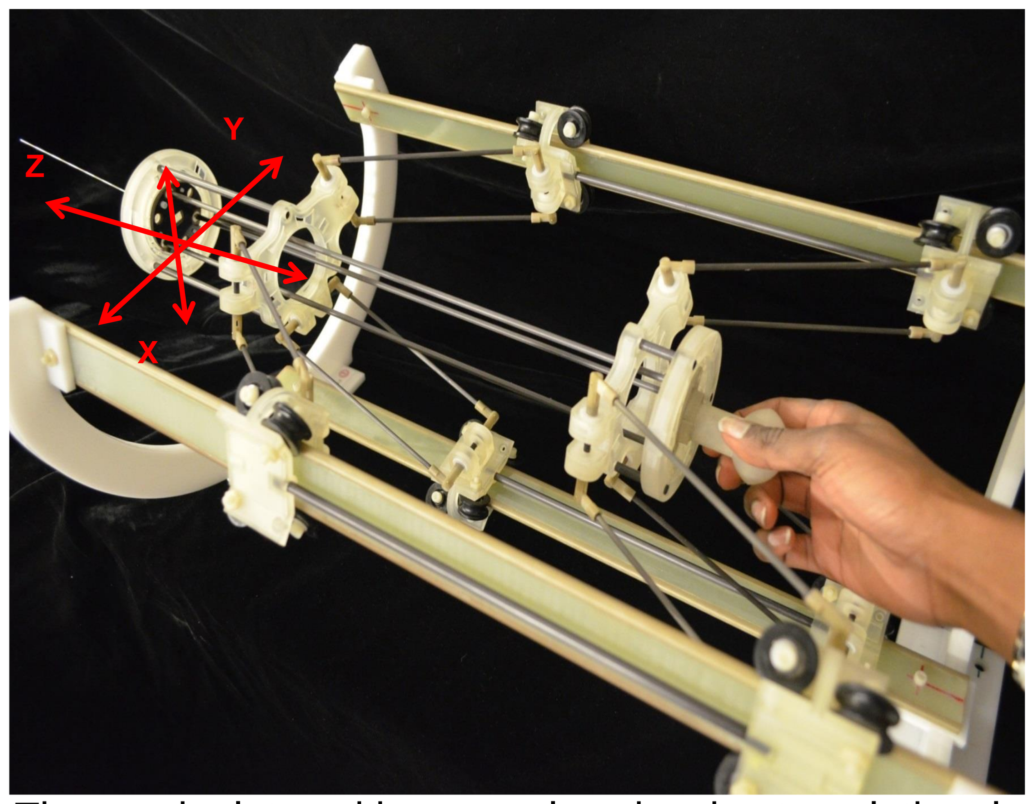
Stanford University

Richie Tran, Andrew Parlier, Santhi Elayaperumal, Jung Hwa Bae, Bruce L. Daniel, Mark. R. Cutkosky

## Pneumatic Brakes

### Purpose

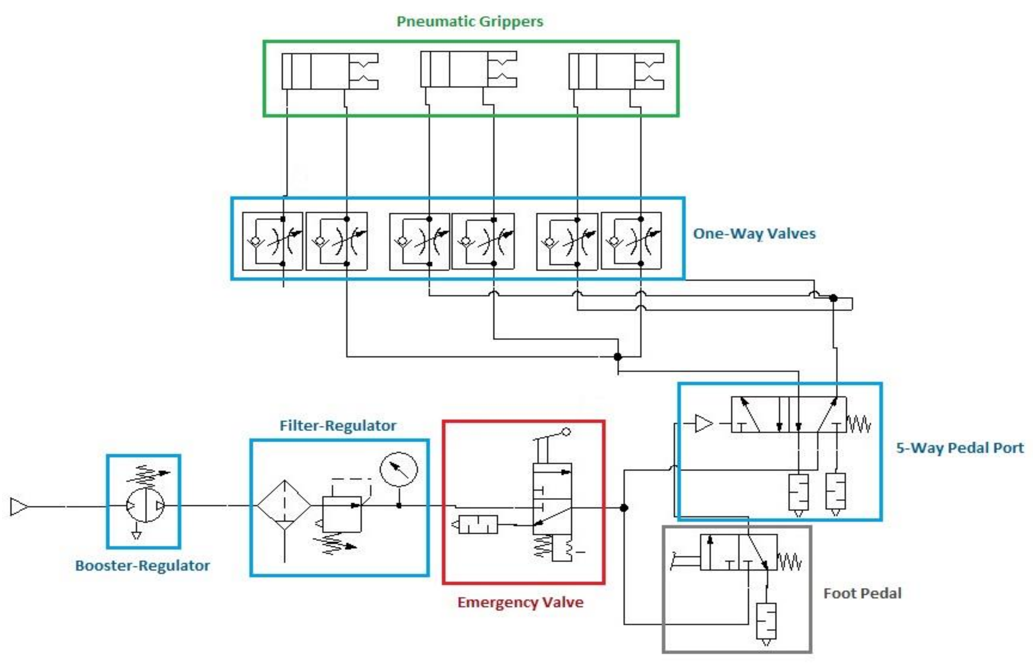
The objective is to brake a passive master-slave manipulator used for MRI-guided interventions. Braking allows the physician to lock the manipulator in place after reaching a target site, to provide a stable platform for biopsies and other procedures.[1]




The manipulator with an overlay showing translational degrees of freedom.

### Design

Because the manipulator has three degrees of translational freedom, three brakes are needed to lock it in place. Given the proximity of medical air lines, pneumatic brakes are logical solution. The brakes consist of modified pneumatic robot grippers connected to a pneumatic circuit with a pressure amplifier, valves, and foot pedal for the physician.

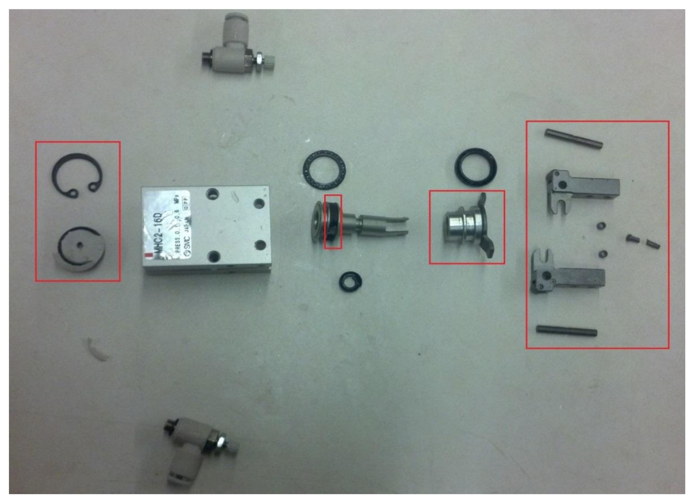



The pneumatic design for a three gripper, pedal-controlled circuit.

### Challenges

- Magnetic parts in found standard pneumatic components must be eliminated
- 3D Printed parts, while convenient for prototyping, have low strength and low braking friction.
- The brakes and tubing must not restrict the manipulator workspace.

A second iteration of the brake finger design. The problem of low coefficient of friction was solved by designing a mold into the part and casting urethane into the portion of the finger that comes in contact with the acetyl and acrylic manipulator.



A disassembled gripper. The parts in red boxes are ferromagnetic and must be replaced.

### Integration

The MRI-compatible brakes work by squeezing plastic fins attached to linear bearings on the three main axes of the manipulator. Other, non-MRI compatible, pneumatic components are located a safe distance from the bore. The entire apparatus was tested in an MRI and did not appreciably affect image quality.

Dr. Bruce L. Daniel using the manipulator with the pneumatic brake in the MRI bore. In the future, the parts of the brakes that were 3D printed will be machined from aluminum for robustness.

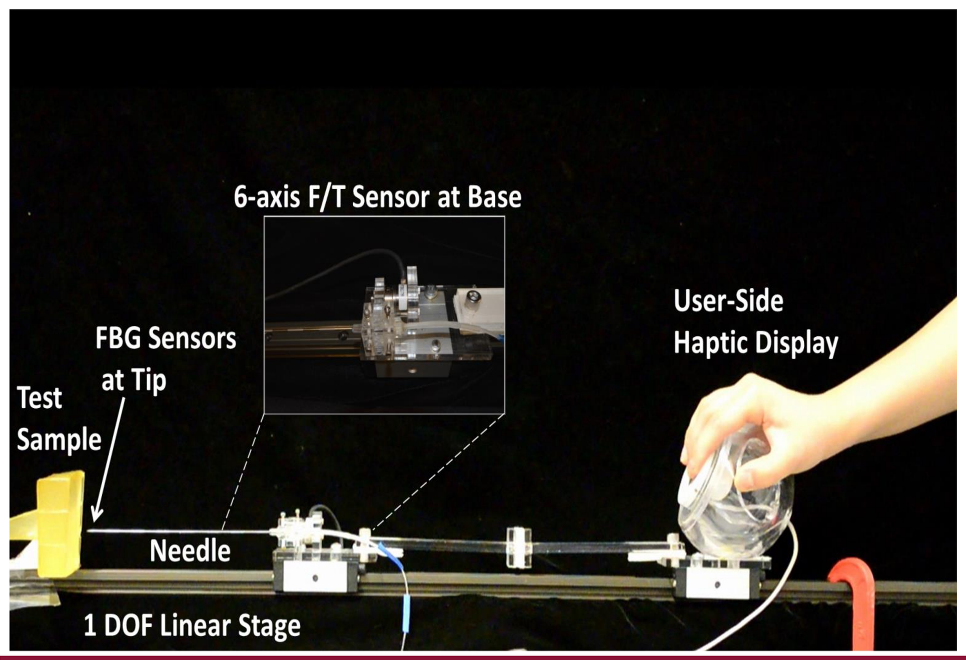
## Background

The physician wishes to control tools such as biopsy needles while standing outside the MRI bore, experiencing forces and vibrations encountered at the tool tip as though his or her fingertips were in contact with the needle. The manipulator project is divided into two components: one that focuses on the steering and supporting the needle and another that focuses on testing the ability to sense forces at the needle tip.

• The needle **manipulator requires brakes** to provide a stable platform when desired by the physician.

• The needle is instrumented with optical fibers to measure forces at its tip. These forces are displayed through a **haptic feedback system** that augments forces felt through the master-slave manipulator with high frequency vibrations.[2]

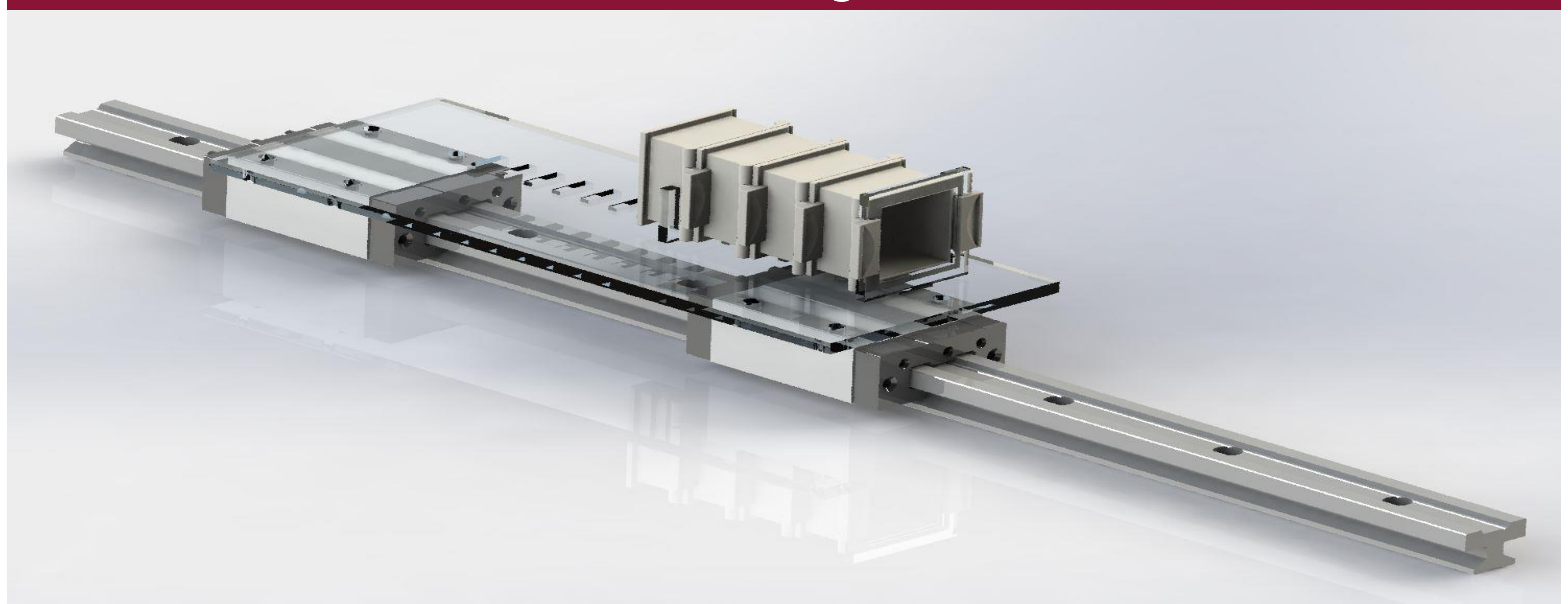
## Phantom Tissues




### Objective

The force feedback needle was designed to provide a physician with haptic response to give him/her a sense of where the needle is with respect to tissue in the body. The goal was to test the use of such feedback for example, to detect when the needle tip encounters a membrane in the tissue.

### Design



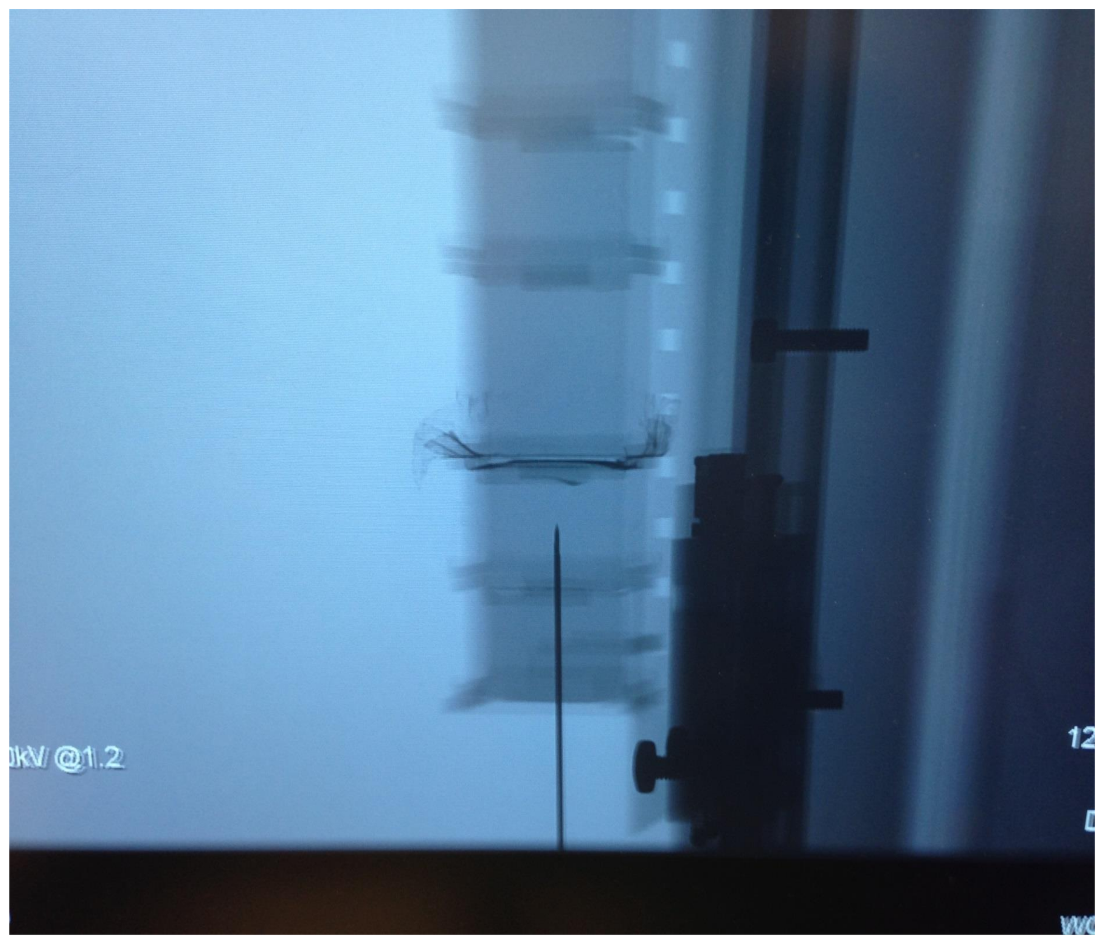
Artificial tissue substitutes, or "phantoms," were fabricated using 3D printing as interchangeable snap-together molds, each of which could be filled with a different polymer and/or membrane material, corresponding to a different kind of tissue. Experiments were conducted with physicians to determine how realistic the various tissue phantoms felt when inserting a needle, and how easily the membranes could be detected.

### Experiment

Experiments involved placing membranes at various distances and using CT to visualize and measure actual distances versus perceived distances with haptic feedback. Preliminary testing with radiologists revealed that haptic feedback was useful for detecting transitions in materials. The materials used for the phantom and the membrane played a major role in the ability to detect membranes.

### Future Direction

Experiments will be scaled up and extended to a larger pool of physicians to gather statistical data.



CT Scan of force-feedback needle in PVC phantom with contrast coated membrane

## References

1. S. Elayaperumal, K. E. Johnson, J. H. Bae, P. Renaud, B. L. Daniel, and M. R. Cutkosky, "A Novel Translation Decoupled 5DOF P-U-U Manipulator for Image-Guided Interventions." Image-Guided Interventions Symposium at Stanford, CA, May 24, 2012.
2. S. Elayaperumal, J. H. Bae, D. Christensen, et al. "MR-compatible biopsy needle with enhanced tip force sensing." Proceedings of the IEEE World Haptics Conference, April 14-17, 2013, Daejeon, Korea.

## Acknowledgements

This work was supported in part by a NIH P01 grant on "Magnetic Resonance Imaging-Guided Cancer Interventions" and a grant from Intuitive Surgical Inc.