Needle Steering

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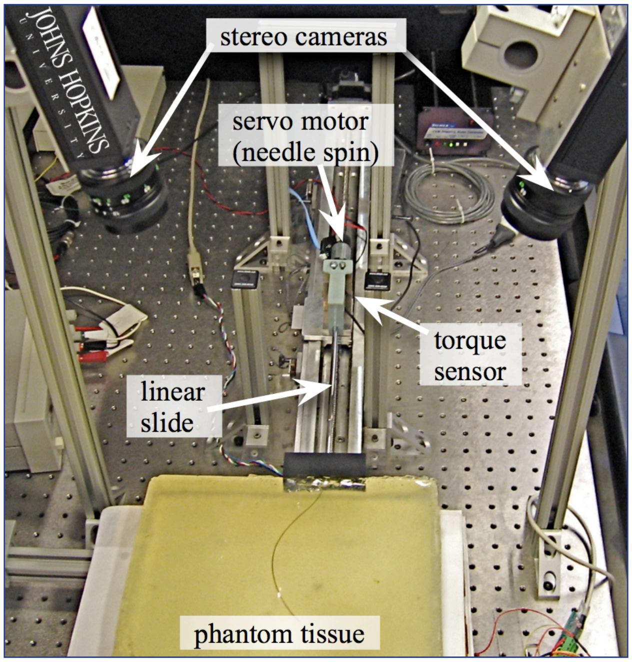

Fig. A1: A needle steering robot can insert needles autonomously or be teleoperated by a surgeon or interventional radiologist.

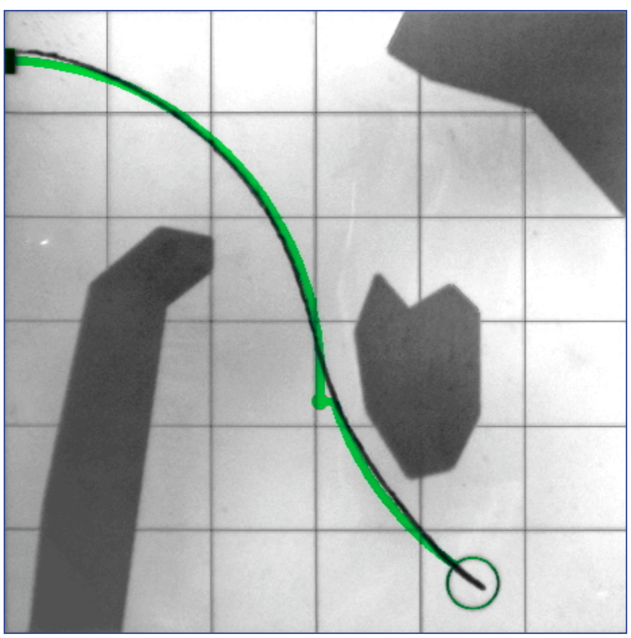

Fig. A2: A needle (black line) closely follows a planned trajectory (green line) around obstacles in transparent artificial tissue.

Minimally invasive surgical techniques are highly successful in improving patient care, reducing risk of infection, and decreasing recovery times. Needle steering robots aim to further reduce invasiveness by developing techniques to insert thin, flexible needles into the human body and steer them from the outside. New results in needle and tissue modeling, robot motion planning, and image-based control have enabled steering of flexible needles inside soft tissue. This can improve both targeting accuracy and the ability to steer around delicate areas or impenetrable anatomic structures.

Our method uses simple, flexible needles, with asymmetric bevel tips or pre-bent tips, which cause the needle to adjust when it is inserted into tissue. By pushing the needle forward from the outside and spinning it around its main axis, a robot can control the needle to acquire targets in a three-dimensional space, while avoiding obstacles, with minimal trauma to the tissue. We have developed a needle steering robot that inserts the needle either autonomously or via human input to a teleoperator (Figure A1). High-level motion planning algorithms are used to determine an optimal path into deformable tissue, one which acquires the target while avoiding pre-defined regions of workspace (Figure A2). Image-based controllers use computer vision tracking and feedback control to maintain the needle's motion along the desired path.

By enhancing the physicians' abilities to accurately maneuver inside the human body, needle steering could potentially improve a range of procedures from chemotherapy and radiotherapy to biopsy collection and tumor ablation, all without additional trauma to the patient. The results of this project could significantly improve public health by lowering treatment costs, infection rates, and patient recovery times. By increasing the dexterity and accuracy of minimally invasive procedures, anticipated results will not only improve outcomes of existing procedures, but also enable percutaneous procedures for many conditions that currently require open surgery. This is a collaborative project between Johns Hopkins University, University of California at Berkeley, and Queen's University.

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