Ultrasound-Guided Robot for Flexible Needle Steering

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There are many different clinical procedures that require needle insertion for diagnostic or therapeutic purposes. Such procedures include biopsies, local anesthesia, blood sampling, prostate brachytherapy and ablation.

Physicians who perform needle insertion procedures mainly freehand the insertion of the needle into the body. They use force feedback methods along with 3D models of the anatomical structure. Unfortunately the precision and accuracy of the procedures are limited and required steep learning curves of physicians who are involved with the procedures.

An ultrasound based devise would cut imaging costs and radiation exposure, and increase mobility through its more compact design. Compared to CT or MRI methods. CT-guided needle biopsy follow-ups have shown a 14% failure rate. Leading to repeated procedures.

This ultrasound guided needle insertion device includes a robot designed to insert the needle tip through a predetermined, curved trajectory, through maneuvering the needle base. All while considering anatomical obstacles. This system includes image processing algorithms, which would continuously detect the needle tip location allowing a closed-loop system for controlled needle insertion.

The detection of the needle tip is very important to the closed-loop steering mechanism. Movement of the needle-tip can be detected through image subtraction. Where the needle tip movement is found in the difference of each frame.

Following this is tissue stiffness classification. A virtual spring model was used to calculate the required needle base movements depending of the tissue stiffness coefficients. Elastic tissue properties can be determined through the ultrasound, and can be put into an algorithm to better guide the needle tip.

There were a variety of experiments preformed to test this new system. There were three main needle steering experiments. Open-loop, closed-loop, and closed-loop with updated tissue stiffness. The closed loop with tissue stiffness systems proved to the most accurate with a tracking error of maximum 1mm, which betters the 6-8mm error range of free hand procedures.

Over all the system has proven to decrease error ranges, thus improving the procedure success rate.

Work Cited:

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