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Smart needle systems: delivering drug or recovering tissue biopsies by steering through ultrasound tracking, force and shape sensing, image processing, control and manipulation

To successfully perform minimally invasive procedures Doctors frequently use thin, hollow needles where accurate location is crucial. Examples of this minimally invasive procedures include complex surgeries such as colon and rectal, heart, cancer, video-assisted thoracoscopic surgery (VATS), etc. and "simpler" procedures such as anesthetizing specific nerves, collecting amniotic fluid samples, etc. Regardless of the complexity of these procedures, their success relies on the accurate targeting of instruments on the selected tissues, and in turn, a successful targeting depends on its guidance system. Here we present smart guiding systems (US 2020/0060772 A1) and 3D image processing for control and manipulation of surgical needles (Provisional application filed 10/30/2020).

Shape Memory Alloy Actuated "Smart" Needle: Smart active needles will assist positioning the tip of the needle close to desired target. A smart active needle that could bend in multiple directions with clinically sufficient accuracy will significantly improve the procedure's accuracy. This novel smart needle prototype with clinically feasible size is capable of 3D manipulation and control to reach the target location via robotic instruments. The smart needle features a flexible joint and three shape memory alloy actuators. The novel robotic needle insertion system guides the smart needle in a pre-planned path inside the tissue towards the target avoiding obstacles and sensitive organs. This system works with four major steps: 1) a path planning program to generate an optimized path with minimum tissue rupture to reach the target, 2) a control program to move the needle, 3) a control program to move the ultrasound probe on the needle tip, and 4) a needle position tracking program to receive the images from the ultrasound machine, process the images to find the actual needle tip, and calculate its deviation from the planned path.

The 3D steerable active biopsy needle can bend inside tissue with control and shape and force sensing. The needle tube is made from a superelastic compounds and is slotted with a cutout pattern in three principal directions (120 degrees apart) for higher flexibility and improved bending in 3D directions. The cutout pattern has been made and tested for safety under static and dynamic loading conditions. The active needle bends inside the tissue via actuation forces of multiple (three or four) shape memory alloy (SMA) wires and can realize needle deflection in any direction. Stiffness and viscoelasticity can be evaluated while the needle advances inside the tissue. Online estimation of tissue parameters is useful to develop better model-predictive control algorithm in robotic needle steering. A biopsy mechanism is made and inserted in the needle tube that bends with the needle structure inside the tissue. This mechanism enables extraction of tissue sample.

Potential Applications

- Biopsy collection
- Targeted drug delivery
- Minimally invasive surgeries/procedures

Benefits and Advantages

- Higher targeted efficiency for biopsy collection and/or drug delivery.
- Less trauma to the muscles, nerves and tissues.
- Less bleeding and scarring as well as reduced use of narcotics.

For more information about this opportunity, please see

Gerboni et al - Robotic Needle - 2017

Khadem et al - Semi-Automated Needle - 2016