MRI-GUIDED FLEXIBLE NEEDLE STEERING USING FIBER BRAGG GRATING-BASED TIP TRACKING

Pedro Moreira* and Sarthak Misra†

*Surgical Robotics Laboratory, Department of Biomechanical Engineering, University of Twente, The Netherlands.

†Surgical Robotics Laboratory, Department of Biomedical Engineering, University of Groningen and University Medical Center Groningen, The Netherlands.

e-mail: pedro.moreira@ieee.org

Web page: www.surgicalroboticslab.nl

ABSTRACT

Prostate cancer is the fifth cause of cancer death and the second most common type of cancer in men worldwide [1]. Early detection and treatment are of significant importance in reducing mortality rate. Prostate biopsies are usually guided by transrectal ultrasound (TRUS) images. However, early stage lesions are not visible in ultrasound (US) images. Magnetic resonance (MR) images have higher tissue contrast and larger spatial resolution than US images. However, MR-guided interventions face challenges related to space constraints and electromagnetic (EM) compatibility of surgical devices. Moreover, the needle induces artifacts in the MR images, which makes the implementation of an online MR-based needle tip tracker a challenging task.

This work presents a flexible needle steering system that combines the MIRIAM robot and a needle tip tracker based on Fiber Bragg Grating (FBG) sensors. The MIRIAM robot is an MR-compatible robot that combines piezoelectric and pneumatic actuation methods to achieve precise prostate interventions. The pre-operative MR images are used to localize obstacles and targets, while the FBG sensors provide strain measurements used to estimate the needle tip position and the force applied at the needle base during the insertion. The experiments are performed with a flexible bevel-tipped Nitinol needle integrated with an array of 12 FBG sensors, located along three optical fibers [2].

The experimental validation of the system is divided into two experimental cases: (1) The needle is steered towards a target while avoiding obstacles in a gelatin phantom. The obstacles and targets are spheres of radius 3 mm, fabricated from Polyvinyl chloride (PVC). (2) The needle is steered towards a target placed inside an *ex-vivo* biological tissue (chicken breast). Eight insertions experiments are performed for each experimental case. The experiments are performed in the Esaote G-Scan Brio scanner (Esaote SpA, Italy). In all 16 trials, the needle reaches the target. The average targeting error is 1.95 ± 0.38 mm for Case 1 and 1.53 ± 0.67 mm for Case 2. The FBG sensors can also estimate the force exerted at the needle base during the procedure to be used as force feedback to the clinician.

REFERENCES

[1] R. Siegel, D. Naishadham and A. Jemal, Cancer statistics, 2013, CA Cancer J Clin. 2013;63(1) :11-30.

[2] R. J. Roesthuis, M. Kemp, J. J. van den Dobbelsteen, and S. Misra, “Three-dimensional needle shape reconstruction using an array of fiber bragg grating sensors,” *IEEE/ASME Trans. on Mech.*, vol. 19, no. 4, pp. 1115–1126, 2014.