FORCE SENSING IN MINIMALLY INVASIVE MEDICAL DEVICES

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Minimally invasive procedure is the preferred option for many treatments because compared to open procedures they lead to less complications, reduced blood loss and shorter recovery time for the patient [1]. The procedures can be safer when devices equipped with force sensors are used. This is because the operator is aware of the force exerted thus can avoid excess force minimizing the chance of tissue damage [2]. As a result, there exists a research effort to develop force sensors for minimally invasive devices.

This abstract presents work that uses optical fibers with Fiber Bragg Gratings (FBGs) for sensing forces at the tip of a flexible minimally invasive device. The work is directly applicable to devices such as catheters and flexible needles. Optical fibers are used because they are small in diameter, capable of withstanding high temperatures and are compatible with imaging modality such as MRI [3]. FBGs are etched on short segments of the optical fiber, and they behave as strain sensor for those segments [4]. Shape reconstruction of a flexible needle has been successfully conducted using FBGs [3]. This work focuses on detecting forces at the tip of a flexible device based on measurement from FBGs. Two methods have been developed; one utilizes a Cosserat rod model and the other a rigid link model. Both methods were tested using a flexible continuum manipulator that was 210 mm in length and had a 3 mm diameter backbone. Two tests were conducted; one involved moving the robot linearly towards a commercial force sensor (ATI Nano43) such that the tip of the robot exerts force on the force sensor and the other test involved applying a pull force at the tip of the robot by attaching a string from the commercial force sensor to the tip of the robot. The method using the Cosserat rod theory could calculate force along the longitudinal axis of the robot and the moment along one transverse axis. The average error between the measurement from the commercial force sensor and the force calculation using Cosserat rod theory was 0.089 N (30%) for the force along the longitudinal axis and 0.366 Nm (25%) for the moment around one transverse axis. The method using rigid link model could calculate force along the two transverse axis. The average error, calculated the same manner as the results for the previous model, in the two transverse direction was 0.010 N (45%) and 0.008 N (16%), respectively. These results show that force measurement is possible using Fiber Bragg Gratings as sensors. For future work, the current methods will be further developed and the force/moment calculations will be used to control continuum manipulators.

REFERENCES

[1] A. J. Koffron, G. Auffenberg, R. Kung, and M. Abecassis, "Evaluation of 300 minimally invasive liver resections at a single institution: less is more." Annals of Surgery, 385-394 (2007).

[2] C. R. Wagner, N. Stylopoulos, and R. D. Howe, "The role of force feedback in surgery: Analysis of blunt dissection." Haptic Interfaces for Virtual Environment and Teleoperator Systems, 68–74, (2002).

[3] R. J. Roesthuis, S. Janssen, and S. Misra, "On using an array of fiber Bragg grating sensors for closed-loop control of flexible minimally invasive surgical instruments." IEEE/RSJ International Conference on Intelligent Robots and Systems, 2545–2551, (2013).

[4] R. Kashyap, "Fiber Bragg Gratings" Elsevier, (2010).