2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
September 24–28, 2017, Vancouver, BC, Canada

Shape Sensing for Flexible Medical Instruments using Fiber Bragg Grating Sensors in Multicore Optical Fibers

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***Abstract*— Medical procedures such as angioplasty, endovascular coiling and angiogram use a flexible instrument in conjunction with clinical imaging modalities (e.g. magnetic resonance, computed tomography, fluoroscopy and ultrasound) for information on the shape and the tip location of the instrument. This work aims to acquire shape information and tip location using a multicore optical fiber with Fiber Bragg Grating, so as to alleviate real-time constraints, radiation exposure or limited spatial resolution commonly associated with clinical imaging modalities. The techniques developed will be applicable to a range of instruments like catheters, endoscopes and guidewires.**

I. INTRODUCTION

This research will develop and validate algorithms to reconstruct the shape of a flexible medical instrument in real time based on measurements from Fiber Bragg Grating (FBG) sensors. These sensors have been used in previous studies to acquire the shape information of flexible instruments [1] [2]. This research will extend the previous studies to multicore fibers. Compatibility of optical fibers in medical environment enables this work to be applicable to a wide range of medical instruments.

II. FIBER BRAGG GRATING SENSORS IN MULTICORE FIBER FOR SHAPE SENSING

Fiber Bragg Grating (FBG) sensors are etched in optical fibers with germanium doped core. At any particular circular cross section of the fiber, the number of FBG sensors are equal to the number of cores in the fiber. In order to acquire curvature at a point on the axis of the fiber, the algorithm used in this work requires at least three FBG sensors on the circular cross section at that point. Thus, if a fiber has one core than multiple fibers are required to determine the curvature. However, if the fiber has three or more cores then only one fiber is sufficient, as a result multicore fibers require less space than single core fibers. For medical instruments, particularly for minimally invasive instruments, space is limited, thus multicore fibers are better suited. In addition, axial alignment of the sensors is more accurate in multicore fibers than in single core fibers, this improves the accuracy of the shape reconstruction. Preliminary reconstruction using multicore fiber with FBG sensors is shown in Figure 1.

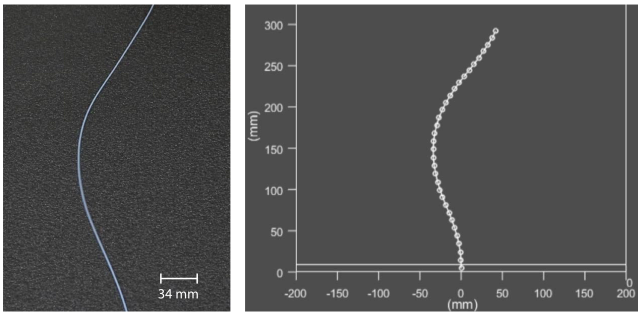

Fig. 1. Shape reconstruction of 32 cm long tube (left) implemented in MATLAB R2015b. The right image is the reconstruction of the flexible tube which contains a multicore fiber with Fiber Bragg Grating sensors. Measurements from the sensors is used to determine the curvature, which is required to reconstruct the shape.

Optical fibers are ideal for medical instruments because they are biocompatible, small in size, and compatible with medical imaging modalities. Due to these benefits of the multicore fiber, this study will investigate shape reconstruction algorithms for a flexible medical instrument using multicore fibers with FBG sensors [3].

III. ONGOING AND FUTURE WORK

Further work will involve developing a calibration algorithm and validating the reconstruction using FBG sensors in multicore fiber. The validation can be done by comparing the reconstruction from FBG sensors to the reconstruction from another sensor such as stereo images or 3D Ultrasound. Once validated, it can be utilized for position control of medical instruments. An application for this is in beating heart cardiovascular procedure. The instrument can be controlled to track the motion of the beating heart such that the surgeon does not have to compensate for the beating heart motion. In addition, feasibility of force sensing using multicore fibers will also be studied, with the aim to provide force feedback. In general, techniques to enhance capabilities of flexible medical instruments using optical fibers will be explored.

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