MULTICORE OPTICAL FIBERS AS SHAPE SENSORS FOR FLEXIBLE MEDICAL INSTRUMENTS

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Introduction

Spatial information of flexible medical instruments such as catheters is commonly acquired using fluoroscopy which has the negative effects of exposing the patient to ionizing radiation and disrupting the medical procedure as the medical staff must leave the operating space at the time of imaging. A potential strategy to further reduce use of fluoroscopy is to use optical fibers with Fiber Bragg Grating (FBG) sensors. The fibers are very well suited for medical applications as they are small (0.3 mm in diameter), sterilizable, chemically inert and compatible with medical imaging modalities. In this study we validate the sensing capabilities of the optical sensors on multicore fibers.

Methods

The fiber used for the experiments has four cores and each core has 32 FBG sensors. The data from the sensors is retrieved using the FBG scan 804D measurement device. A custom-built software has been developed in-house for Ubuntu operating system in order to communicate with the hardware. Two experiments are conducted to determine the accuracy and validate the use of an optical fiber for spatial reconstruction. The fiber is placed in slots with a known configuration, and the spatial information is derived based on the measurements from the fiber. Next, this information is compared to the known configuration. In the first experiment, the fiber is placed on a calibration board that has slots with fixed curvature. There are 6 slots with radius of curvature ranging from 400 mm to 175mm. In total, 3658 samples were collected. In the second experiment, the fiber is placed on a calibration board with 4 slots that have a varying curvature and 2807 samples were collected. Each slot is an Euler curve and the curvature linearly changes over the arc length of the curve.

Results

In the first experiment, the radius of curvature detected by the sensors is evaluated. Since the slots have a fixed curvature the radius of curvature is expected to be constant and to match the radius of curvature of the slot. The average error is found to be 13.7 mm with the standard deviation of 15.2mm. In the second experiment, the fiber is reconstructed in 3D space, thus 3D co-ordinates of the fiber along its arc length are known. The 3D reconstruction is compared to the ground truth curve of the calibration board slots. The mean error between the ground truth and the reconstructed points is 2.62 mm and the standard deviation is 1.74 mm.

Conclusion

The tests show that the multicore optical fibers have the potential to be used for acquiring spatial information of flexible medical instruments. Next, we plan to use the data from the optical fibers in conjunction with ultrasound to acquire robust spatial information of flexible medical instrument at a higher temporal resolution than the ultrasound resolution. This work will be conducted in collaboration with Technical University of Munich.

There are numerous applications that can benefit from these fibers. They can be used for controlling the position of flexible medical devices; to acquire high resolution spatial information by fusing optical fiber data with data from another imaging modality. In general, there are potentially many medical procedures that can benefit from multicore optical fibers.

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