# ROBUST SHAPE SENSING FOR FLEXIBLE MEDICAL INSTRUMENTS

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## Introduction

Medical procedures that utilize flexible instruments such as catheters, require the spatial information of the instrument in order to navigate to the procedure site. In current practice, this information is acquired using imaging modalities such as ultrasound or fluoroscopy. However, there are certain drawbacks; the instrument can be invisible in ultrasound and fluoroscopy exposes the patient to harmful radiation. These drawbacks can potentially be mitigated by utilizing optical sensors for spatial information. Shape reconstruction with a single fiber containing FBG sensors has been demonstrated to be accurate within a couple of millimeters. In this study, we show that robust and accurate sensing can be achieved by utilizing redundant number of fibers. The advantage of using redundant fibers is that they render the sensing system robust to singular sensor failures, however the challenge lies in the algorithm for merging the data from the fibers.

## Methods and Results

The reconstruction algorithm first calculates the curvature and torsion at the sensing points on all the fibers. Then, using the mean of the calculated curvature and torsion at the various sensing points, it reconstructs the catheter shape using Frenet-Serret equations. The algorithm is validated empirically by placing a catheter with 4 fibers in 8 different known shapes that were 2 and 3 dimensional. The 2 dimensional shapes are created by laser cutting Plexi glass and the 3 dimensional shapes are 3-D printed. The shapes contain slots that hold the catheter in place. The accuracy of the reconstruction algorithm is determined by comparing the reconstruction of the catheter with the ground truth, which is the reconstruction of the slots that hold the catheter. Two error measures are used to evaluate accuracy of the algorithm; one is the maximum error and the other is the maximum normalized error. Error is defined to be the difference between corresponding points in the reconstruction and the ground truth. In this study 118 corresponding points are considered for the error calculation. The error is also normalized over the length of the fibers in order to have a measure that can be used to compare reconstruction results from fibers of varying lengths. The maximum error observed in the reconstruction in this study is 1.05 mm and the maximum normalized error is 0.9%.

## Conclusion

The results show that shape sensing using redundant fibers is feasible. The presence of redundant fibers increase the robustness of the sensing system against singular sensor failure and enables sensing for catheters developed in academic research such as the catheter in [1]. The algorithm will be further developed for improved accuracy and will be tested in dynamic experiments such as in catheters actuated using a mechanical system.

## Reference

[1] A. Leibinge, M. J. Oldfield, and F. B. Rodriguez, “Minimally disruptive needle insertion: a biologically inspired solution,” INTERFACE FOCUS, vol. 6, no. 3, 2016.

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