University of Basel
Department of Biomedical Engineering

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Master of Science – Biomedical Engineering
Thesis Proposal

Investigating the impact of fiber sensing density on the performance of eFBG shape sensors

In minimally invasive surgeries, it is often required to use non-rigid instruments in order to maximize accessible regions. However, using flexible tools will raise some safety concerns as there are uncertainties about their shape and tip position. Consequently, an accurate tracking system is desirable to provide positioning feedback for the surgeon. Shape sensors based on Fiber Bragg Gratings (FBG) are suitable for this task as they are small, biocompatible, immune to electromagnetic interference, and require no line of sight.

One of the most recent types of fiber shape sensors is based on eccentric FBGs (eFBG), where the Bragg gratings are inscribed on the edge of the core in a single-mode optical fiber. External perturbations such as mechanical strain and temperature cause changes in the amplitude of the Bragg peaks. The main challenge in these sensors is to accurately model their behavior, as the main signal is often affected by other undesired bending-induced phenomena. Preliminary results show that the complicated relationship between the amplitude of eFBGs and the sensor's shape can be described using deep-learning techniques such as convolutional neural networks (CNN). The trained CNN model can predict the sensor's 3D shape based on the eFBGs spectrum and even detect deformations outside the sensing planes where no eFBG is present.

This master thesis aims to investigate the impact of sensing density, that is, the number of sensing plans per unit length of the eFBG sensor, by comparing the shape prediction accuracy of their CNN models. The following steps describe the work packages:

- The student should prepare a setup to record the signal of eFBG sensors with different sensing densities at random shape deformations.
- A discriminative deep-learning model should be designed and trained for each sensor to investigate the differences in shape predictions.

Nature of the Thesis
Experimental: 50%
Programming: 40%
Documentation: 10%

Specific Requirements
Programming experience using Python, basic knowledge of machine learning techniques, MATLAB, and fiber sensors.

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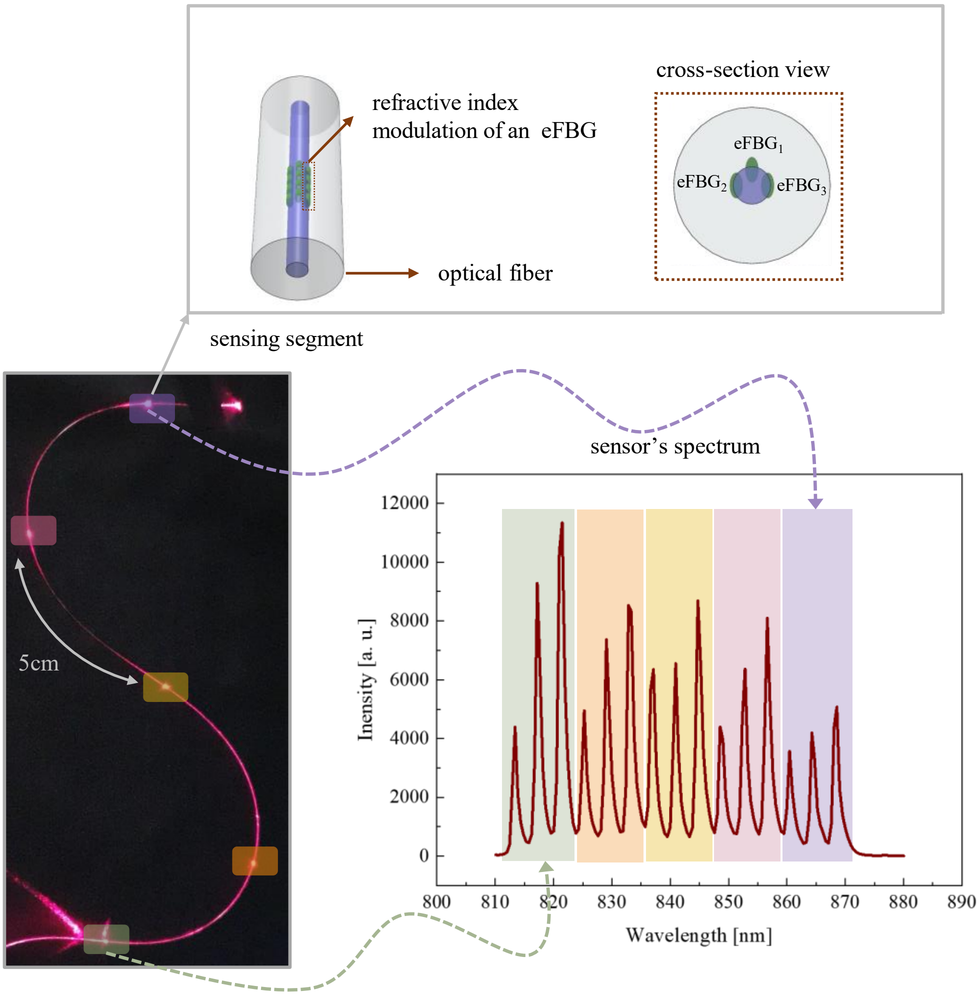

Figure 1. Eccentric FBGs are highly localized FBGs, written off-axis in the core of a single-mode fiber, designed by our collaborators at Fraunhofer HHI in Goslar, Germany. The eFBG shape sensor we used is 30 cm long and features five sensing segments that are 5 cm apart. Each sensing segment has three eFBGs with ~90˚ angular separation. The sensor's spectrum contains the reflected signal of 15 eFBGs from the five sensing segments. During this master's project, two other eFBG sensors with 3 cm and 7 cm distances between their sensing segments will be studied.

More information

[1] SM Roodsari, et al., "The secret role of undesired physical effects in accurate shape sensing with eccentric FBGs", arXiv preprint arXiv:2210.16316, 2022, https://doi.org/10.48550/arXiv.2210.16316

[2] SM Roodsari, et al., "Using Supervised Deep-Learning to Model Edge-FBG Shape Sensors", arXiv preprint arXiv:2210.16068, 2022, https://doi.org/10.48550/arXiv.2210.16068