FBG-based Shape Sensor for Tracking a Fully Flexible Endoscope
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Introduction:

- One of the main challenges in the MIRACLE project is to track the fully flexible endoscope once it enters the patient’s body.
- Because of line-of-sight limitations and electromagnetic interference, the common tracking technologies can’t be used.
- **FBG-based** sensors can provide 3D shape information with less than 1mm accuracy.

1. Fiber Bragg Grating:

- Bragg Gratings are periodical patterns in the core refractive index.
- They have high reflectivity in certain wavelengths called Bragg wavelength, which depends on the period length and the effective refractive index in the core area.

   ![Bragg Grating Structure](image)

- Strain-optic, thermal expansion and thermo-optic effects make these structures sensitive to environmental perturbation (strain and temperature).

   ![Typical Wavelength-Shift Response](image)

2. Shape Sensing:

Having at least two FBG sensor at each z-position, makes it possible to detect compression and expansion caused by bending.

**Sensor assembly methods:**

- Single mode fibers (SMF)
- Multi-core fibers
- Bragg grating waveguides in cladding area

Experimental Setup:

**Fibers:**

- Two arrays of 5 FBGs in SMFs
- Wavelength range: 1515 - 1585 nm
- FBGs 5cm apart

**Substrate:**

- Wire braided Polyimide
- 30 cm long
- 1.5 mm OD and 0.75 mm ID

**Calibration:**

- Curvature template (radius from 1 m to 0.2 m)
- Special fiber holders for orientation control

Preliminary Results:

- There is a linear relationship between bending radius and Bragg wavelength shift.
- The sensor is sensitive to the bending direction.

![Bragg Wavelength Shift vs. Curvature](image)

- Max positioning error @270° is around 0.1mm after each joint.

Shape Reconstruction:

Using the measured wavelength shift from 10 FBGs and some geometrical information, the radius of curvature and its direction can be calculated.

The 3D shape is reconstructed using the moving coordinate system.

References:

[1] Wikipedia.org