Calibration of a 3D Fiber Optic Flexible Attitude Sensing System

Article Overview

Calibration of 3D fiber optic flexible attitude sensors involves fitting sensor responses to known deformations, compensating for twist, and modeling curvature-to-position relationships for accurate real-time shape reconstruction.

Overview of Calibration

Calibration is essential for converting raw strain or wavelength data from fiber optic sensors into accurate 3D position and orientation information. The process typically involves:

o Establishing reference configurations: The fiber is bent or twisted into known shapes to provide baseline measurements for calibration .
o Fitting sensor models: Polynomial or exponential functions are often used to relate measured strain or wavelength shifts to curvature and torsion along the fiber .
o Error compensation: Twist-compensation methods reduce reconstruction errors caused by torsional deformation, improving 3D accuracy .

Methods for Calibration
o Polynomial-Based Calibration Multi-core FBG fibers can be calibrated using second-order polynomial approximations. Known bend configurations are measured, and polynomial coefficients are fitted to map curvature to tip position. This allows real-time estimation without iterative numerical solutions, achieving sub-millimeter accuracy .
o Twist-Compensation and Self-Calibration For DFBG-based systems, twist-compensation algorithms correct for torsional effects along the fiber. Self-calibration methods iteratively adjust the model to minimize reconstruction errors, reducing 3D shape errors from several percent to below 3% .
o Absolute Nodal Coordinate Formulation (ANCF) ANCF links strain measurements to the full deformation state of flexible 3D structures. This approach captures bending-torsion coupling and allows accurate kinematic monitoring, which is particularly useful for active attitude control and load identification .
o Direct Grating Processing Femtosecond laser inscription of Bragg gratings into a single-core fiber enables 3D shape sensing without additional optics. Calibration involves mapping the grating responses to known bending radii and orientations, leveraging the fiber's mechanical flexibility .

Practical Considerations

o Dense Measurement Points: High spatial resolution along the fiber improves reconstruction accuracy, especially for complex deformations .
o Real-Time Processing: Efficient algorithms allow embedded or edge-computing applications, enabling

real-time attitude monitoring in robotics, aerospace, or medical devices .

o Environmental Compensation: Temperature and strain cross-sensitivity should be accounted for during calibration to maintain accuracy in operational conditions.

Summary

Effective calibration of a 3D fiber optic flexible attitude sensing system combines reference-based model fitting, twist compensation, and dense strain measurement. Polynomial or ANCF-based models, along with self-calibration techniques, allow accurate real-time reconstruction of fiber shape and orientation, supporting applications in robotics, aerospace, structural monitoring, and medical devices .

Aiming at the inability to achieve high-precision real-time magnetic heading angle estimation under single degree of freedom rotation,

Fiber optic gyroscope for application at attitude determination systems Abstract: The ADS is the high performance attitude

Abstract Accurate shape sensing, only achievable through distributed proprioception, is a key requirement for closed

Fiber optic shape sensing has proven to have great potential, especially in medical applications such as catheter

Overall schematic diagram of the all-fiber optical sensor combined with FBG and CFBG-FP. Schematic diagram of

The sensor is cost-effective, lightweight and flexible with a large force and torque measurement range suitable for

In this paper, an all-fiber optical sensor combined with FBG and CFBG-FP is proposed for

We proposed a twist-compensation and self-calibration method for high accuracy DFBG-based shape sensing. The method reduces

Fiber optic sensor technology with high interrogation rate and unbuffered output therefore has the potential to provide

Abstract Using an inertia pendulum comprised of two prisms, flexible beams and an elastic flake, we present a novel

A twist compensated, high accuracy and dynamic fiber optic shape sensing technology based on phase demodulation in

This method provides a new correction method for optical fiber shape sensing, which is more convenient and effective

As the basic application of fiber optic sensing technology, strain measurement accuracy as a key index needs to be further calibrated

The concept of distributed acoustic sensing (DAS) is applicable to a wide range of sensing mediums, such as coaxial

Abstract We proposed a new approach to attitude measurement by an evanescent field-based optical fiber sensing

We demonstrate the process by manufacturing multi-material 3D printed fingers and extensively evaluating the

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