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Optical Fiber-based Force Myography (FMG) Sensor for Joint Angle and Grasping Force Estimation

Chongyoung Chung
Dept. of Mechanical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
Daejeon, South Korea
cy.chung@kaist.ac.kr

Heeju Mun
Dept. of Mechanical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
Daejeon, South Korea
heeju.1234@kaist.ac.kr

Ki-Uk Kyung
Dept. of Mechanical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
Daejeon, South Korea
kyungku@kaist.ac.kr

***Abstract*—Accurate sensing of human movement and force is critical for wearable haptic interfaces and robotic control. We present a novel optical fiber-based wearable force myography (FMG) sensor that enables high-sensitivity detection of muscle activity and finger motions. By utilizing light loss induced at the fiber–polymer interface, the sensor achieves stable and noise-resilient signal transmission without relying on electrical contacts, ensuring robustness against electromagnetic interference and sweating. The flexible, compact sensor is constructed with commercially available materials and supports seamless integration into wearable systems. Experimental validation demonstrates that the sensor detects forces as small as approximately 6.78 mN and exhibits a maximum sensitivity of 2.99 V/N in the low-force regime. The system successfully estimates finger joint angles and grasping forces with high resolution, offering a compact and practical solution for motion capture, gesture recognition, and human–machine interfaces. A live demonstration will showcase real-time tracking of hand motions and grip forces using the proposed wearable sensor system.**

Keywords*—*optical fiber, force sensor, force myography, motion tracking

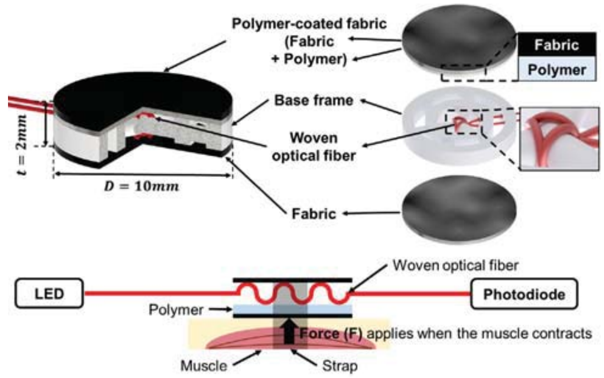

Fig. 2. Design and working principle of the sensor

Fig. 1. Estimating the elbow flexion angle and grasping force

I. Introduction

Accurate and robust sensing of human motion and force is critical for wearable haptic systems, rehabilitation, and robotic control [1]. Traditional force myography (FMG) systems based on electrical sensing often suffer from electromagnetic interference, instability under sweating conditions, and mechanical degradation over time [2]. To overcome these limitations, we propose a wearable FMG system based on optical fiber sensing, which enables stable, noise-resilient, and highly sensitive detection of muscle activity. The proposed system facilitates fine-grained motion tracking, including finger joint angle estimation and grasping force monitoring, demonstrating its potential for enhancing human–machine interfaces.

II. Optical Fiber-based FMG Sensor

A. *Design and Force Sensing Principle*

The proposed sensor detects muscle activity by monitoring light loss in a bent optical fiber embedded within a soft, flexible structure. A plastic optical fiber was woven into a thermoplastic polyurethane base frame arranged in a circular pattern to introduce controlled bending points while maintaining a compact form factor. A soft polymer-coated fabric was placed over the fiber network to form the contact interface as shown in Fig. 1.

When underlying muscles contract, they generate outward pressure against the skin surface. This deformation is transmitted through the soft wearable layers to the polymer-coated fabric, which presses against the bent optical fiber. Increased pressure enhances the physical contact between the fiber and the polymer, leading to greater light loss due to changes in the optical boundary conditions. By monitoring the intensity of transmitted light, the sensor can continuously and sensitively track changes in muscle tension and applied force without requiring direct mechanical strain on the fiber itself. This mechanism provides a stable, noise-resistant signal even under dynamic and biologically variable conditions such as sweating or prolonged use.

B. *Elbow Flexion Angle and Grasping Force Estimation*

To validate its practical application, the system was integrated into a wearable configuration for real-time estimation of elbow flexion angles and grasping forces as shown in Fig. 2. During elbow flexion-extension tasks, sensor outputs were mapped to joint angles using regression models, demonstrating high correlation with ground-truth measurements. Additionally, grasping forces applied to various lightweight objects were accurately estimated based on the normalized optical signals. The demonstration highlights the capability of the proposed optical FMG sensor to support precise motion tracking and force estimation in wearable haptic interfaces.

References

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