# Development of a Glove-Based Optical Fiber Sensor for Applications in Human-Robot Interaction

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***Abstract*—A glove-based optical fiber sensor for the measurement of finger movements aiming HRI applications was developed. The device presented good response on the detection of angular displacements of finger joints, being suitable for further utilization in teleoperation and gesture-based robot navigation.**

***Index Terms*—Data gloves; optical fiber sensors; user interfaces; teleoperators.**

## I. Introduction

The measurement of user hand movements is an essential feature to the development of human-robot interfaces with a more realistic and intuitive approach. Applications of hand-controlled systems include teleoperation of manipulators, haptic systems, and robot-assisted surgery, rehabilitation and therapy [1]. Although the acquisition of fingers movements can be performed by several technologies, such as external cameras, magnetic tracking, exoskeletons and electromyography [1,2], the use of glove-based sensors presents advantages in terms of cost and portability, being also unaffected by latency and fingers occlusion [1,2]. Nowadays, a variety data gloves has been proposed considering different types of transducers, such as resistance-based flexsensors [3], magnetic induction coils [4], and optical fiber sensors [5-7]. Particularly, fiber optic devices present interesting characteristics like lightweight, flexibility and immunity to EM interference, in addition to their high sensitivity and reliability, being very suitable for implementation in advanced HRI schemes. This research reports recent developments on a glove-based optical fiber sensor system, as well as further proposals for applications of this device in the field of robotics.

## II. Methodology

### *A. Sensor Design*

The sensor (Fig. 1) consists of silica multimode fibers attached to a textile glove, by applying adhesive gel in positions spaced by 5 mm along ~40 mm of fiber length. Since the fixed positions are located adjacent to the hand joints, as the fingers are flexed, stresses are induced onto the waveguides due to the differences on mechanical properties of fiber and substrate, resulting in light attenuation by bending losses.

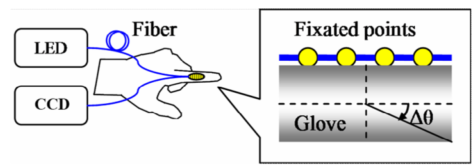


Fig. 1. Experimental setup and transducer design.

Therefore, the intensity of optical signals can be correlated to the angular displacements of finger joints.

### *B. Experimental Setup*

Light emitted by a continuous white LED source is launched into the waveguides, being the sensing fibers adjusted for the measurement of flexion/extension movements of the proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints of index (I) and medium fingers (M), as well as the IP and MP joints of the thumb (T). Then, the optical signals are acquired by a CCD with a 15 Hz sampling rate, and subsequently post-processed in a routine programmed under MATLAB environment. Additionally, the light from the source is directly measured by a reference fiber, being applied on the signal normalization and noise compensation.

## III. Sensor Characterization

Figure 2 illustrates the transducer response to angular displacements performed by the PIP-I joint. The sensibility increases for higher flexion angles, whereas the overall

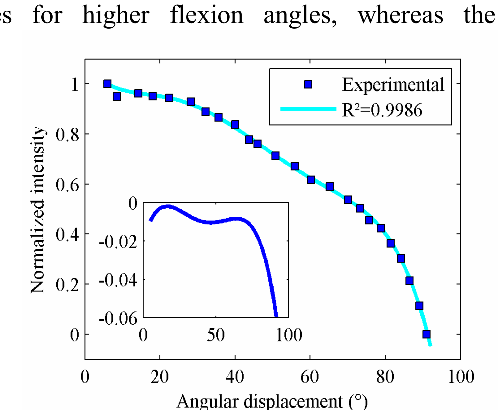


Fig. 2. Effect of angular displacement on light attenuation, fitted by 5th degree polynomial (Inset: first derivative.)

performance is lower for smaller displacement values. It can be explained because in this range the fiber bending characteristics are more influenced by glove wrinkles and slipping effects, yielding to compensations in optical losses.

## IV. Applications in Human-Robot Interaction

### A. Operation of Anthropomorphic Manipulators

The measured hand postures can be utilized on the remote operation of anthropomorphic arms or virtual manipulators in VR systems. In this sense, the angular positions of finger joints are replicated to the various DOFs of the robotic hand, providing the dexterous control of the manipulator on the accomplishment of different tasks. For such kind of application, the system calibration was performed from the correlation of light intensities and nominal joint positions (obtained by external camera method), and using artificial neural networks processing based on backpropagation architecture. After the calibration, the sensor was validated on the real-time operation of a virtual hand designed in MATLAB. Fig. 3 (a) shows the intensity values due to hand opening and closing events, and the results demonstrate that the postures obtained by the simulated model during the hand closing Fig. 3 (c) are compatible to the nominal ones Fig. 3 (b).

### B. Robot Operation by Gesture Recognition

HRI based on gestures is another intuitive way to transmit specific commands from user to the machine, being this approach suitable to the operation of mobile robots. Fig. 4 (a) shows an interface for navigation based on the manipulation of a sphere. Considering the precision grip by the thumb and index fingers, as the user rotates the object about *x* or *z*-axis ($\theta$ or $\phi$, respectively) starting from a neutral condition N, the angular displacements are indirectly measured by the joints angles, since the joints are flexed or extended depending on the hand posture, as illustrated by the preliminary results (Fig. 4 (c)), which correlates the light attenuations due to finger movements to the object rotations. Therefore, the robot movements can be defined according to the sphere orientation (Fig. 4 (b)).

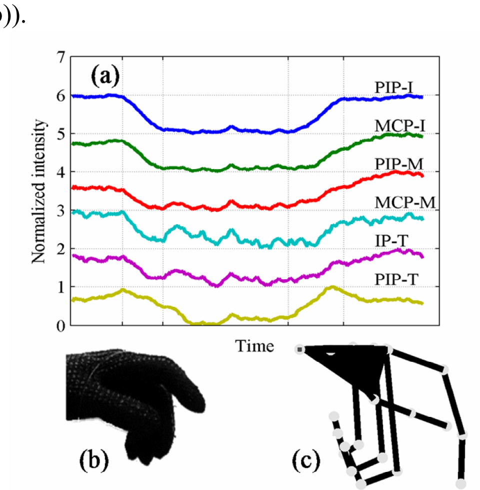


Fig. 3. (a) Transducers response to hand closing: (b) nominal and (c) simulated hand postures.

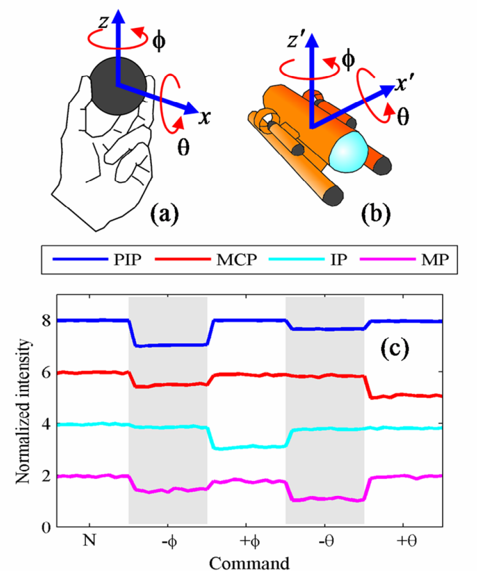


Fig. 4. (a) Hand gestures and (b) robot operation: (c) transducers response to different commands.

## V. Conclusions and Further Developments

The glove-based fiber sensor was successfully demonstrated on the measurement of finger movements, exhibiting good response on the monitoring of angular displacements, and being characterized as a low-cost solution with minimum application of mechanical loads. In this context, the research group is currently working on practical applications in human interfaces for robotic systems.

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