A Smartphone Based Fiber Sensor for Recognizing Walking Patterns

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***Abstract*— This paper shows the development of a prospective portable optical sensor to monitor the human gait. The device is based on an intensity coded fiber optic macro-bend force sensor specially designed to be adapted in insoles. Sensor interrogation is made by the CCD camera of a smartphone, exploiting the functionalities of this kind of device. The sensor device fabrication is described with details. Tests carried out with the sensor have shown its capability of providing information about spatial and temporal parameters of the gait as well as ground reaction forces on heels.**

***Index Terms*— Fiber optic macro-bend, biofeedback tool, gait monitoring, optical fiber sensor.**

I. Introduction

DUE to the complexity of the sensory and motor organization, it can be difficult to keep the upright posture, which is one important orthostatic requirement in the humans' daily life. In this sense, auxiliary devices can be used to provide a useful feedback about the body posture. Biofeedback tools offer help for those people who need to keep an adequate posture control, e.g., impaired people. The obtained information can be used to learn how to control movements and to regulate the posture. This process improves the performance of specific brain areas responsible by the integration of sensory perceptions and movements [1]. Considering the importance of the biofeedback tools, great attention has been given to the development of new equipment and techniques, able not only to detect problems but also to support the rehabilitation [2]–[4]. In this sense, wearable sensing constitutes a promising technology for the real time monitoring of movements [5], allowing medical testing outside clinical laboratory. Real time monitoring of gait in training can contribute, to improve the performance or prevent injuries in athletes [6]. Knees and ankles injuries, e.g., would be avoided by the simple detection of the body weight distribution on the sole of the feet [7], [8]. Some works have shown the influence of the step width in the plantar foot pressure pattern and in the knee abduction moment [9], [10]. In an attempt to propose efficient tools for these purposes, portable devices and wearable sensors have been reported in the literature [5], [11]–[13]. On the other hand, fiber optic sensors have emerged as a powerful technology for applications in biomechanics owing to its unique characteristics. Macro curvatures in optical fibers were used for monitoring respiratory movements. A standard telecommunication fiber containing u-shaped macro curvatures was fixed to an elastic textile to make a belt, highlighting the ability of optical fiber instrumented textile for measuring biological parameters [14]. The analysis of gait with devices based on fiber optic sensors was also proposed in literature [15]–[17]. Insoles with fiber Bragg grating (FBG) sensors were used to monitor plantar pressure during the gait [15], [16]. Both systems rely on specialized FBG interrogation equipment and only suggest the possibility of using smartphone and/or cloud for data processing and storage. Vertical reaction and shear forces related to the body weight were measured with an insole instrumented with five sensing cells [15]. Each cell contains two FBG, one measures the vertical reaction forces whereas the other measures only shear forces. A cork insole with six FBGs for remote gait analysis was proposed [16]. The sensing device allows measuring pressure in six points of interest. In other work, the insole was instrumented with four sensors based on curvature losses in polymeric fiber [17]. The required sensitivity was achieved by removing part of the fiber cladding that could impair the fiber integrity. Data are stored in a SD card and the system uses a commercial LED and photodiode in the interrogation channel. The system was calibrated for force measurements in a quasi-static test. Forces were monitored in one foot during the gait, nevertheless actual forces were not provided.

Among all different configurations of fiber sensors, fiber optic macro-bend force sensor stands out for its simplicity as the interrogation is based on the measurement of losses in the intensity of guided light resulting from fiber curvatures [18]–[20]. Despite being a well-known technology, some difficulties for the sensor implementation, as optical fiber encapsulation and interrogation, must be addressed. In this sense, it is advantageous to exploit not only the computing power of a smartphone but also its connectivity by incorporating this outstanding device in portable sensing systems [21], [22].

In this work a fiber optic macro-bend sensor is proposed as a biofeedback device for monitoring temporal and spatial

Manuscript received June 4, 2019; accepted July 4, 2019. Date of publication July 8, 2019; date of current version October 4, 2019. This work was supported in part by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, in part by Financiadora de Inovação e Pesquisa (FINEP), and in part by the Fundação Araucária. The associate editor coordinating the review of this paper and approving it for publication was Dr. Daniele Tosi. *(Corresponding author: Marcia Muller.)*

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Digital Object Identifier 10.1109/JSEN.2019.2927456