Multiplexing Optical Fiber Macro-Bend Load Sensors

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***Abstract*—This paper shows the multiplexing prospects of a load sensing array composed of six in-series optical fiber macro-bends. These fiber loops were individually embedded in silicone elastomer to constitute six sensor elements. Load configurations combining 0.0, 0.5, 1.0, and 1.5 kg were applied on the sensors to study the device performance. The sensor array, composed of standard fibers for optical communications, is spectrally interrogated in the visible window of the electromagnetic spectrum in a multimodal regime of operation. A simple linear regression model was used to estimate an unknown load configuration applied to the array from its associated transmittance spectrum. A sample space of 411 load configurations was used for training and testing the system. The ability of reconstruction was assessed by comparing the actual and predicted configurations of loads. A mean absolute error of 0.12 kg for the estimate was found under the testing conditions. In order to decrease the dimensionality of the dataset, principal component analysis and a discarding variable method were employed. Under 39% of data reduction, no significant impairment on the sensor array performance was observed.**

***Index Terms*—Data analysis, load sensor array, multiplexing, optical fiber macro-bend sensors.**

I. Introduction

MULTIPLEXING techniques have been extensively studied along the past years accompanying the development experienced by the fiber optic sensing technology [1], [2]. Owing to the ability of recovering information from each sensor of a sensing array, multiplexing techniques may contribute to the feasibility of complex sensing systems. Sensor arrays composed of multiplexed optical fiber sensors have been proposed for the detection of forces in artificial tactile sensing [3], [4]. The flexibility of this kind of sensors can be explored from robotics to applications in medicine and industry. Furthermore, multiplexed sensors can allow a quasi-distributed mapping of measurands by using a reduced number of sensors regarding the number of measuring points, increasing the competitiveness of the fiber optic sensing technology [5].

A variety of schemes have been proposed in order to reduce the number of optical sources, detectors or channels that are usually required in non-multiplexed systems composed of individual sensing elements. Spatial, coherence, time, wavelength or frequency-division multiplexing techniques, each one with its own advantages and drawbacks, are the main multiplexing approaches usually used for those purposes [6], [7]. However, each multiplexing scheme must be designed according to the characteristics of the system, e.g., the number of sensing elements or measurands that must be simultaneously recovered by the system at each position. Besides, the manner as the measurand affects the optical signal is a factor that must be considered. Different methods can also be used to interrogate the sensors depending on the codification of the optical signal. Information can be extracted from the signal by means of intensity-modulation, wavelength and interferometric interrogation methods, among others.

Interrogation of intensity-modulated sensors usually relies only on the characteristics of the optical source and detector that are used, making this class of sensors particularly attractive due to its technological simplicity. Nevertheless, these sensors are subject to unanticipated fluctuations of intensity, an ordinary characteristic of most optical sources. In order to solve this drawback and guarantee the successful operation of these sensors, a number of self-referencing techniques were reported in literature [8], [9].

One example of intensity-modulated fiber optic sensor is the macro-bend sensor, a simple and low-cost device that consists of a bent fiber. The sensing principle relies on the detection of intensity losses resulting from mode coupling between guided and radiation modes when the fiber is bent [6]. Sensors based on bending losses have been successfully applied, e.g., for sensing temperature [11] and linear displacement [12], as well as have been embedded in textile seeking for the development of wearable sensing systems [13].

The fact that fiber bent devices show wavelength-dependent intensity losses led to the study of applications other than sensing. A device based on a macro-bending single mode fiber filter was proposed as part of a low-cost wavelength measurement system [14].

Bends produced in a single-mode fiber were also used in an alternative method of wavelength demultiplexing that has

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