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An approach to improve the spatial resolution of a force mapping sensing system

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Abstract

This paper proposes a smart sensor system capable of detecting sparse forces applied to different positions of a metal plate. The sensing is performed with strain transducers based on fiber Bragg gratings (FBG) distributed under the plate. Forces actuating in nine squared regions of the plate, resulting from up to three different loads applied simultaneously to the plate, were monitored with seven transducers. The system determines the magnitude of the force/pressure applied on each specific area, even in the absence of a dedicated transducer for that area. The set of strain transducers with coupled responses and a compressive sensing algorithm are employed to solve the underdetermined inverse problem which emerges from mapping the force. In this configuration, experimental results have shown that the system is capable of recovering the value of the load distributed on the plate with a signal-to-noise ratio better than 12 dB, when the plate is submitted to three simultaneous test loads. The proposed method is a practical illustration of compressive sensing algorithms for the reduction of the number of FBG-based transducers used in a quasi-distributed configuration.

Keywords: compressive sensing, optical sensor, force mapping

(Some figures may appear in colour only in the online journal)

1. Introduction

Over the last few decades, the field of optical fiber sensors has witnessed significant advances. Among the many categories of fiber sensors, Bragg gratings have brought several advantages to the implemented applications due to their multiplexing and wavelength encoding capabilities. In addition, the fiber Bragg grating (FBG) sensors have high sensitivity as well as electromagnetic immunity. Recent research has demonstrated that the proper arrangement of FBG sensors can provide the mapping of forces when the sensors are embedded into a supporting structure, such as a framework or plate. Such distributed mapping of forces applied to a structure with embedded sensors is of great interest for the monitoring of the integrity of bridges [1], the sensing of structural changes in aircraft wings [2], or in biomedical applications using tactile sensing [3].

A possible approach for designing a force mapping system is to employ independent transducers over a useful area of the framework or plate, each one associated with a specific section of the framework, as reported in the work by Heo *et al* [3] and, to a larger extent, by the system proposed by Childers *et al* [2]. The FBG array proposed by Song *et al* [4] is another example of such an approach, where the authors suggest that the coupled response of the transducers could be used to enhance the resolution.

One potential limitation of such construction models occurs when the sensed area needs to be enlarged, causing the number of transducers to be proportionately incremented while keeping the same spatial resolution. Attempting to overcome this drawback, other authors have proposed a system using FBG sensors properly affixed to a metal plate [5], where the detection of the position of a load on the sensed plate was

