Smartphone-Based Portable Intensity-Modulated Force Sensor

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ABSTRACT

This work proposes a low-cost force sensor, based on intensity modulation in an optical fibre. The transducer element is composed of a knot in a single mode fibre embedded to a silicone adhesive cuboid, and can be easily fabricated. A simple sensing scheme is devised by using a visible light source and a CCD camera of a smartphone, allowing implementation costs to be reduced. Experimental results have shown that the sensor presents a linear response and a standard uncertainty of 1.07 N within the dynamical range from 0 to 30 N.

Keywords: Intensity coded sensor, optical fibre, image processing, force sensor

1. INTRODUCTION

Among a variety of fibre optical sensors, the intensity coded devices are commonly characterized by a less expensive set-up when compared to the otherwise more demanding wavelength-coded sensors. This type of sensor also shares the inherent advantages found in the optical fibre devices as the electromagnetic immunity, biocompatibility and low thermal conduction. In addition, the intensity coded modulation might enable a miniaturized sensor which is adequate for field applications. Several sensing strategies based on intensity modulation have already been reported in literature relying on bending and coupling losses.[1] Force and pressure measurements are of particular interest in sensing applications, including force monitoring during minimally invasive surgeries,[2] anti-squeeze detectors in vehicles[3] and tactile sensing.[4]

Considering that the earliest developments in this fibre sensor area involves the use of light intensity modulation to code the monitored magnitude, this type of sensor can be considered a mature technology. Furthermore, current daily technological and practical innovation with a low cost may be incorporated into the interrogation set-up of such sensors, as the use of high definition CCDs and the computational power of smartphones. As an extension of this idea, this work proposes a low-cost force sensor, based on the intensity modulation caused by the macro-bending of the fibre in a customized transducer operating as an intrinsic sensor. The sensor works in the visible spectrum range, employing a smartphone CCD camera and image processing algorithms to monitor the transmittance of the optical fibre. A linear response sensor with 0.24 N resolution and 1.07 N combined uncertainty for a 68.27 % confidence level was demonstrated.

2. METHODOLOGY

2.1 Transducer Fabrication

The transducer consists of a standard single mode fibre (SSMF, at 1550 nm, G-652 from Draktel) embedded in a silicone cuboid. Figure 1 presents a diagram with the steps to fabricate the transducer. To produce the cuboid, a cast of polystyrene foam was filled with silicone adhesive. After the curing time, the silicone cuboid was removed from the cast and cut in two nearly equal parts, Figure 1(a). A knot was tied in the optical fibre,

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