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Wearable Vital Sign Sensing Technology based on FBG Sensor System

Hiroaki Ishizawa[1], Yuuki Haseda[1], and Koh Johguchi[2]

[1] Institute for Fiber Engineering, Shinshu Univ.
3-15-1 Tokida, Ueda-shi
Nagano 386-8567, Japan
Phone: +81-268-21-5400 E-mail: zawa@shinshu-u.ac.jp
[2] Faculty of Engineering, Shinshu Univ.
4-17-1, Wakasato, Nagano-shi
Nagano 380-8553, Japan
Phone: +81-26-269-5489, E-mail: johguchi@cs.shinshu-u.ac.jp

Abstract

People's concerns about their health has created a demand for a sensor system for vital sign measurement. This paper describes a wearable vital sign sensing system based on the fiber Bragg grating sensor system for the field of healthcare clothing environment and gives an overview from a practical viewpoint.

1. Introduction

A wearable health monitoring system or a smart clothing system for health monitoring is one of the solutions to meet peoples' health management needs. Vital signs have been measured by a several methods, such as volumetric pulse wave metrics, intact pressure measurement, and strain measurement of blood vessels. Previous research has revealed that the fiber Bragg grating (FBG) sensor can detect pulse waves with high sensitivity [1]. Therefore, heart rate, respiratory rate [2], blood pressure [3], and blood glucose [4] as well as mental stress states [5] can be measured using the feature extraction of pulse waves measured by the FBG sensor. This sensor can detect the strain from a pulsation point; therefore, it can measure the pulse waves that contain information on pulse rates, respiration rates, blood pressure, and blood glucose level simultaneously. This paper describes the FBG sensor system and its application to smart clothing for health monitoring. Furthermore, it proposes a closely-packed system for the practical application.

2. General Instructions

FBG sensor systems and pulse wave measurements

FBG sensors have grating in their core along with optical fibers in the longitudinal direction. Grating works as the strain sensor. FBG is an optical filer that reflects the specified Bragg wavelength. The grating period deviations change according to the pressure of the blood vessel beneath the pulsation point. The rapid optical wavelength interrogator detects the wavelength shift. Typical wavelength resolution, sampling period, and strain resolution are 0.1 pm, 1 ms, and 80 nm, respectively.

Vital sign measurement

The subject is in a supine position, and his wrist is kept as high as his heart, as shown in Fig.1. The radial artery is located beneath the measuring point. A typical measurement takes 20 s, which is as long as one cycle of the automatic sphygmomanometer to measure blood pressure and heart rate. Fig. 2 shows the pulse waves. Each raw pulse wave was filtered by a bandpass filter with passband of 0.5–5 Hz. This bandwidth covers the ordinal human heart rate. The FBG-detected waveforms seem to show the heartbeat; therefore, heart rate can be detected by pulse counting for 60 s.

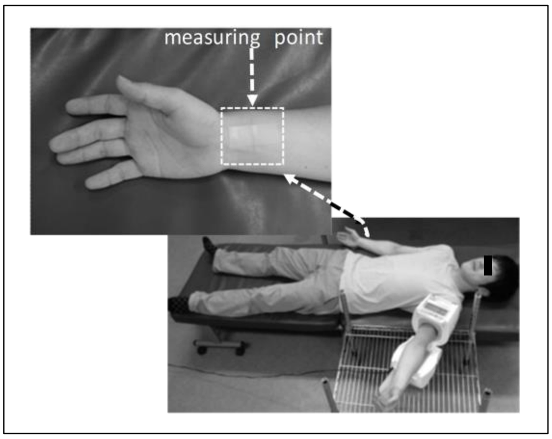

Fig. 1 The appearance of the pulse wave measurement by FBG sensor set on subject's right wrist

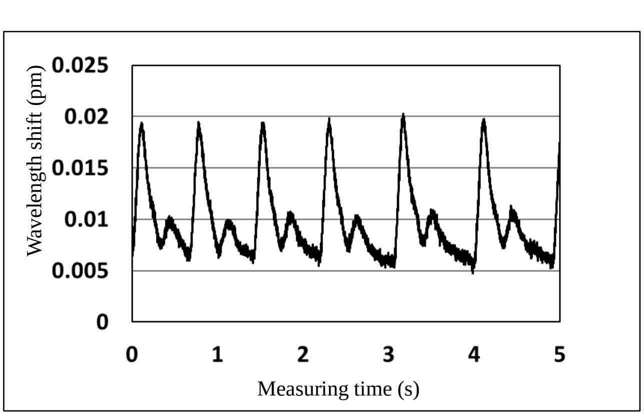

Fig. 2 Typical pulse waves measured by FBG sensor.

Pattern extraction of pulse waves to calibrate vital signs

When we inhale, our pulse rate increases, and when we exhale, it decreases. Therefore, by monitoring the pulse waves and detecting the pulse periods simultaneously, the real-time respiratory could be easily detected. Blood pressure or blood glucose concentration measurement by using the pulse waves and partial least squares regression analysis (PLSR) could be applied to get an accurate calibration model. Fig. 3 shows an example of the blood pressure calibration model (black circles) and its validation results (white squares). The correlation coefficient and standard error of calibration are 0.67 and 5 mmHg, respectively, which is an acceptable level of accuracy. Similarly, the blood glucose measurement calibration model can be extracted by the PLSR with measurement error of approximately ±20 mg/dl. Therefore, multi-vital sign measurement is possible using the FBG sensor.

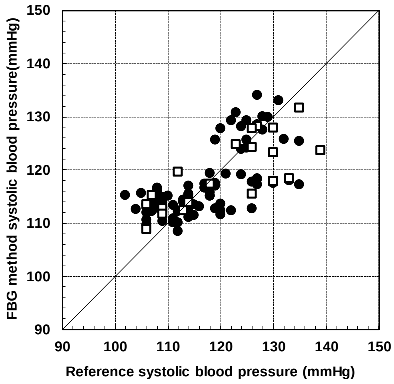

Fig. 3 Blood pressure measurement calibration and its validation.

Application to healthcare clothing wearable system

From a practical point of view, wearable textiles with embedded sensors are the main problem. Typical pulse waves are measured by the FBG sensor. In order to embed the FBG sensor in textiles, a cover for the sensor made of silk yarn was designed/developed by Sakaguchi et al [6].

FBG sensor system for the practical application

In this work, the trial production of the compact and portable interrogator was carried out using a passive edge filter, as shown in Fig. 4. Promote design, trial manufacturing, and evaluation experiments are ongoing. Currently, the wavelength tilt-type prototype system (Fig. 4) has dimensions of 97 mm × 74 mm × 57 mm, and weighs 175 g. However, for digital circuits, commercially-available devices are used. For this reason, it is necessary to reduce these electronic components to further miniaturize the measurement system.

3. Conclusions

.Vital signs could be monitored by detecting the pulse waves. The FBG sensor system has been introduced, and it can measure pulse rates, respiration rates, blood pressure, and Blood glucose, simultaneously. A practical FBG sensor system using a passive edge filter has been proposed.

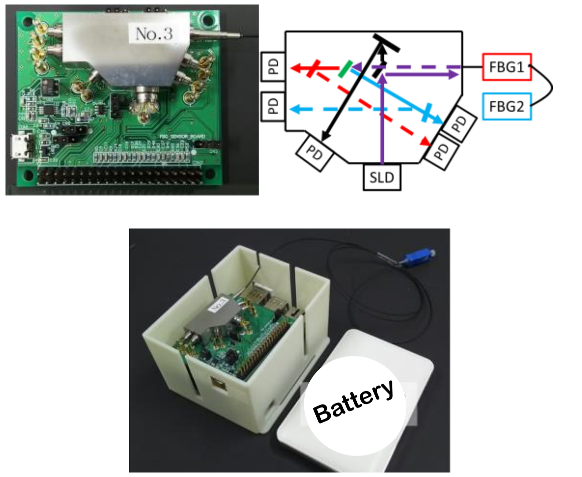

Fig. 4 Passive edge filter in the optical system (top) and compact, portable interrogator.

Acknowledgements

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