COMPUTATIONAL OPTIMIZATION OF A SENSORIZED 3D-PRINTED SMART PATCH FOR CARDIORESPIRATORY MONITORING

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Introduction

The monitoring of cardiorespiratory activity offers crucial information for preventing critical health conditions, thus promoting the early diagnosis and treatment of cardiovascular and respiratory diseases (CVRDs) [1]. Wearables are valuable solutions for monitoring a variety of physiological parameters. A skin-interfaced biosensor based on fiber optics (i.e., the smart patch) is presented. The smart patch is capable of estimating heart rate and respiratory rate by detecting local ribcage strain caused by breathing and heart beating.

Methods

An in silico computational model was developed to prove the effectiveness of the patc design. The model geometry consists of the CAD structure matching the sensor design. Once patched to the skin surface, the sensor geometry was prescribed with bending and stretching boundary conditions. Deformations and vibrations were applied to the skin to model the simultaneous activity of the heart and lungs. The finite element mechanical analysis was carried out by employing the software COMSOL Multiphysics: the computational domain comprehends the patch, composed of silicone matrix and the fabric liners, attached to the human skin modeled as a layer with a constant thickness of 5 mm. A radial function is defined to model the shape of the chest and the cardiac activities. Model geometry and the boundary conditions are depicted in Figure 1.

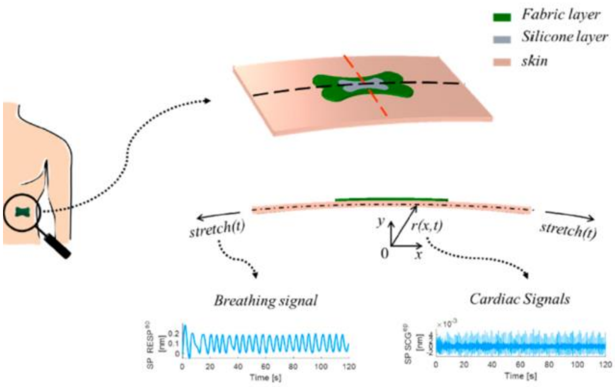

Figure 1: Schematic view of the computational model: on the left, the position of the sensor on the body; on the right,the boundary conditions in the numerical analysis.

Results

The FEM based numerical analysis addresses the stretch and the bending of the skin during the breath, accounting for cardiac activities. Aiming to check the soundness of the patch design, the results are shown in terms of ε in the fiber direction (Figure 2).

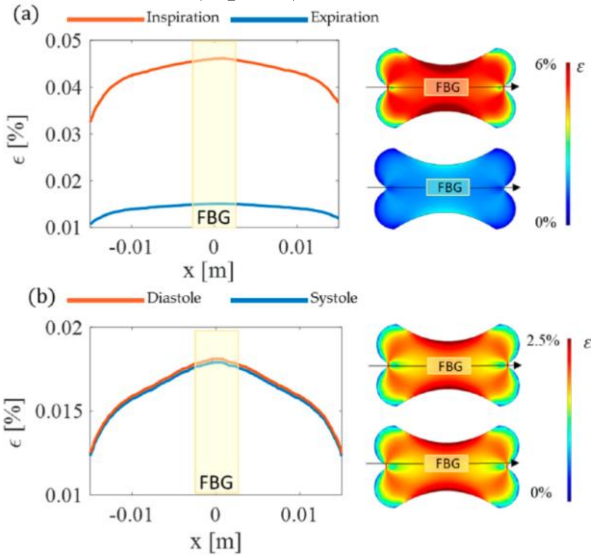

Figure 2: Summary of computational studies highlighting (a) the effects of breathing (blue line refers to inspiration and orange line to expiration) and (b) the effects of heart beating (blue line refers to systole and orange line to diastole) on the FBG sensor.

Discussion

The model findings proved the effectiveness of the proposed design in concentrating ε along the longitudinal axis of the optical fiber. The smart patch presented in this study introduces a highly miniaturized and stretchable biosensor, which can be readily applied for cardiorespiratory monitoring in both clinical (such as on bedridden or wheeled patients and during MR examination) and real-life scenarios (e.g., while watching TV, reading a book, working at the desk, and sleeping).

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