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Abstract

Available Kinetic Energy Sources on the Human Body during Sports Activities: An Optimization Investigation Using Cantilevered Piezoelectric Harvester Model †

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Abstract: Previous work has shown that the impacts induced by human sport activities are one of the most relevant features to operating a cantilevered piezoelectric harvester. In addition, the optimal orientations of the simulated harvester according to body parts were investigated. In this contribution, we study the influence of the harvester dimensions on the simulated harvested energy. The results show that for a defined mass of active material and the optimal harvester orientation, a low-frequency harvester is preferred. Thus, the harvester operating frequencies, orientation, and location on the human body are explored.

Keywords: kinetic energy; physical activity; IMU; wearable electronics; simulation; piezoelectric harvester; signal processing; optimization

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1. Introduction

Harvesting energy on the human body can limit the use of batteries that are cumbersome, uncomfortable, and polluting. Applications and architectures of piezoelectric harvesters are presented in the literature [1]. Nevertheless, many parameters such as the harvester structure or location and orientation on the human body must be considered. A previous study has proposed a method to determine the optimal position and orientation of a cantilevered piezoelectric harvester on the human body [2]. To go further, the present contribution explores the influences of harvester dimension.

2. Materials and Methods

Based on a distributed parameter electromechanical model [3], the simulated energy was obtained by using real acceleration data extracted from performed sport activities on the whole human body. In total, 17 sensor locations were evaluated, and acceleration data were sampled at 240 Hz. Variations of ±95% of a preselected harvester length (L) and width (b) were performed with the following constraint:

$$L \geq 20\sqrt{b.h} \tag{1}$$

$$L.b.h = K \tag{2}$$

where h is the harvester thickness and K the volume of active material which is considered constant. The constraint from (1) ensured the validity of the used beam model. In this study, the volume of active material was constant. According to a defined dimension, the optimal orientation for harvesting energy on different body locations was performed by a particular swarm optimization (PSO). The first and second vibrational mode of the harvester were used for simulations, and higher modes were not considered as they are superior to the Nyquist frequency of the acceleration signals (120 Hz).

3. Results and Discussion

During the performed sport activities, the body parts were moving in different way, and, thus, the measured accelerations are different. Figure 1 presents the simulated normalized energy of a cantilevered harvester on different parts of the human body with the best orientation (obtained with PSO) with respect to its first vibrational mode.

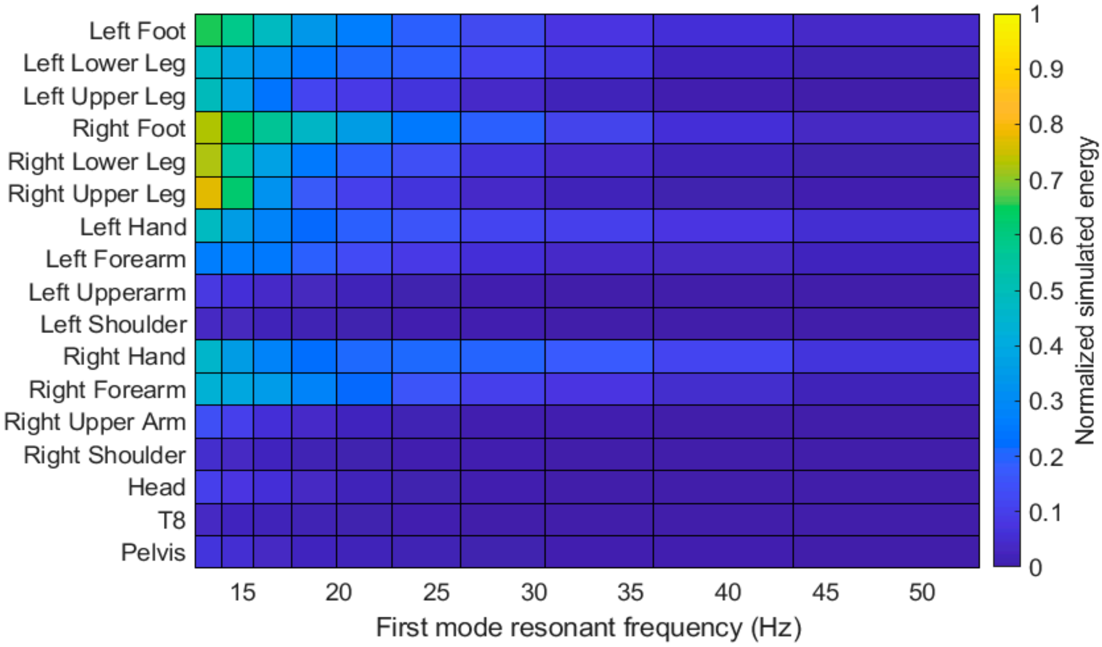

Figure 1. Normalized harvested energy on different body locations for a constant active material volume. Longer lengths and narrower widths correspond to lower resonance frequencies.

Changing the length or width of a cantilevered piezoelectric harvester directly impacts its resonant frequency. The results show that the right leg is the most suitable to harvest energy when the harvester operates at a low frequency (<15 Hz). In addition, depending on the feasibility of a low-frequency harvester, the energy optimum can be determined accordingly to the body location.

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