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RESEARCH ARTICLE

SMARTSOCK: A WIRELESS GAIT MEASUREMENT DEVICE

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Abstract

In this paper we present SmartSock, a physical activity and gait measuring system integrated inside a sock. To achieve its goal, it uses force and acceleration sensors that track the wearer's movements. The device is fitted with a radio transceiver in order to convey measured information to listening computers or mobiles. Contrary to previous works which integrate electronic modules into custom shoes, all sensors, control, power and wireless components are integrated on the same sock. Therefore, the user is not restricted to wear a customized pair of shoes. A power saving mechanism has been developed in order to improve the longevity of the integrated rechargeable battery.

Index Terms— Gait, movement tracking, pressure sensors, accelerometers, shoe-based device.

Introduction

Monitoring human displacement and gait has been the subject of many recent research works [1-8]. Such exercise can render information regarding the pattern, amount and speed of human movement. Attaching sensors to feet, shoes or insole has been the method of choice to achieve such purpose [1-8]. In this paper, we present a movement measuring system called "SmartSock". In contrast to the existing works [1-8], we have integrated all the sensors necessary for gait and movement measurements into the insole and thus creating a highly portable system that can be used with any shoes. The insole is also equipped with a radio transceiver in order to convey information to nearby computing devices. Such device can be used in exercise tracking and gait assessment. Perhaps, the most common approach to monitor gait and movement is to attach sensors to shoes. For example, Sazonov et al [1], [2] and [3] presented a foot wearable system called "SmartShoe" that achieves such purpose. The shoe is equipped with a Bluetooth unit, a clip on accelerometer and several force-sensitive resistors (FSR) to sense motion and forces applied to the feet. The authors present different applications for the SmartShoe such us weight and physical activity management, recognition of postural allocations and identification of steps for people suffering from a stroke.
Another work that shares common functionalities with the previous one is the "Nike+ basketball and training shoes [9]. Nike+ is a commercial footwear item that keeps track of the wearer's movements. As in the previous work, pressure sensors are built into the shoes. Collected data is transmitted wirelessly to an application on accompanying smart phone through which the user can see his/her performance level. In [8], Salpavaara et al presented a custom-made pair of capacitive sensor insoles for measuring the force between the foot and insole. The system can be exploited to monitor the timing and movement of the leg. Although some of the above works integrated some sensors inside the insoles, additional devices have been added in order to collect and transfer sensorial data to nearby computing modules. This resulted in the customization of the shoe. In our proposed system, we managed to integrate all sensors, power module, microcontroller and Bluetooth transceiver into the insole. This gives users the flexibility to wear the shoes of their choice as long as they fit them with the SmartSock. Also, in order to increase the life of the rechargeable battery powering the module, a power saving mechanism has been developed.

The remainder of the paper is organized as follows:
Section 2 presents the proposed system design, Section 3 discusses the device's architecture and implementation, Section 4 showcases the data measured by the device and Section 5 draws the conclusion and our future work.

2. PROPOSED SYSTEM DESIGN

In this section, we elaborate on the SmartSock system design by illustrating in details the hardware and software components involved. The SmartSock aims to measure the wearer's movements. Figure 1 shows the architecture of the overall system that includes the different hardware components.

2.1 Sensory Data Module

Two kinds of sensors are used in our system, pressure sensors and an XYZ accelerometer. The pressure sensors are FSRs and therefore their resistance changes according to the amount of force pressure applied on them. We deployed five pressure sensors positioned under important contact points identified in [3]. This allows us to measure the forces being applied on these points. The accelerometer is used to measure the dynamic acceleration resulting from motion.

2.2. Processing and control unit

In this unit, the analogue sensor values are converted into digital data. The digitized raw data are then analyzed. From these values, the unit decides whether there is an activity or not. If a movement is detected, the sensory data is conveyed wirelessly to any listening computing device. If there is no activity, the control module deactivates the power module.

2.3. Power module

This module is responsible for controlling the power supply to the system. It behaves according to the logic provided in the flow chart of Figure 3. The key characteristic of this module lies in its reliance on readings from the pressure sensors. When all the sensors values are zeros for more than a specified period of time (set to 5 minutes), the module assumes that the SmartSock is inactive (the user is either no longer wearing the shoe containing the insole or not performing any activity). In this case, the system is set into power saving mode. In this mode, most of the hardware components (Bluetooth module, accelerometer and all FSRs except that of the heel) are turned off in order to preserve the integrated battery life. The power saving mode continues until the heel pressure sensor reads value more than zero. In this case, the system runs back into normal power mode and consequently all the hardware components supplied with power.

2.4. The communication unit

This module provides Bluetooth wireless communication between the sensors and a paired computing device (typically a PC, tablet or smart phone).

IMPLEMENTATION

For the prototype, we used a commercial gel insole and attached to it the following components:

- 5 FSRs of 0.5" sensing area diameter located on key contact points
- An ADXL372 XYZ accelerometer located in the heel area
- An ATMEL AVR microcontroller integrated with an ADC unit located on the side
- A BlueSMIRF Silver Bluetooth modem with more than 9600 baud rate located on the side
- 3.3 V power supply from a rechargeable Cell battery located underneath the heel
- Two charging inlets located on the side (used to recharge the cell battery)

All sensors are connected to the microcontroller which reads their analog signal and converts it to digital information. A software application executing on the microcontroller runs the power module logic and orders the sending of relevant data on the wireless link.

4. MEASUREMENTS

In order to validate the functionality of the SmartSock, samples of sensor measurements have been collected during movement. We fitted the SmartSock into the shoe of users and asked them to perform a walking exercise for 2 minutes. Figure 4 shows a Z acceleration measurement during a subject's walking, figure 5 shows a heel pressure measurement and figure 6 shows a forward acceleration measurement during biking. All figures show the amplitude (ADC output) of the signal plotted against the number of measurements. The experiment was replicated successfully with 3 subjects (results not shown due to the similarity of the graphs).

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5. CONLUSION AND FUTURE WORK

A SmartSock has been designed and developed by integrating all the required sensors, control, power, and communication link on the same insole. A power saving mode has been developed in order to preserve the rechargeable battery life. We are currently working on using the SmartSock for fitness and gaming applications.

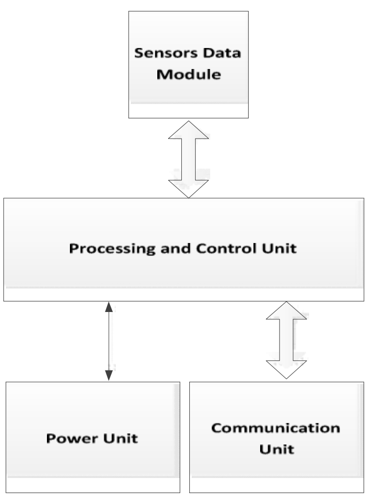

Fig. 1. SmartSock System Architecture.

Fig. 2. Cloud Service

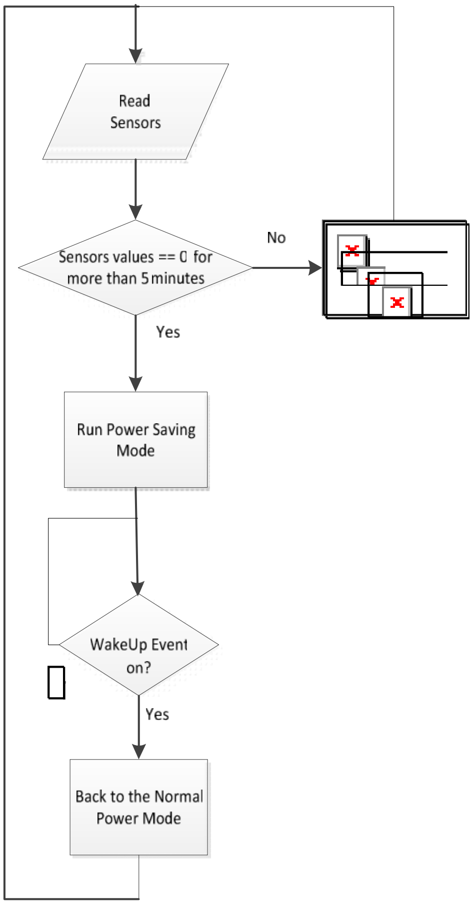

Fig. 3. The Power module flow diagram.

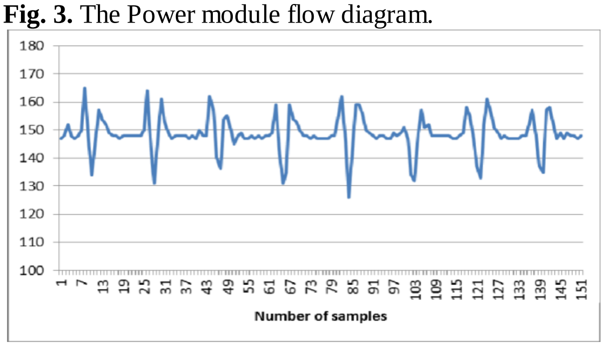

Fig. 4. The Z acceleration during walking.

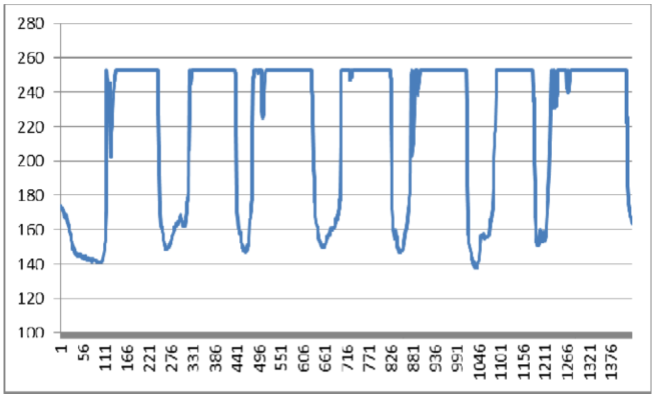

Fig. 5. The heel pressure sensor output during walking.

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