2008 International Conference on Information Processing in Sensor Networks

Locomotion Monitoring using Body Sensor Networks

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ABSTRACT: *Body sensor networks (BSNs) create an enormous opportunity to revolutionalize the way we learn, work, entertain and live today. A particularly promising application of BSNs is in health monitoring. Research indicates that various disorders in aging ranging from mild cognitive impairment to dementia and Alzheimer's could be diagnosed early based on the study of locomotion. Sensor platforms integrated into clothing provide the possibility of reliable locomotion monitoring. In this work, we demonstrate a real-time wireless sensor system that quantitatively measures some of the factors involved in locomotion.*

1. Introduction

Over the past decade, the miniaturization and cost reduction brought about by the semiconductor industry have made it possible to create smaller and more powerful computers. Similarly, advances in wireless communication, sensor design, and energy storage technologies have enabled the concept of a truly pervasive wireless Body Sensor Network (BSN) is rapidly becoming a reality.

Locomotion monitoring is study of the biomechanics involved in human locomotion and gait development. This study is useful in gait analysis, early diagnosis of cognitive impairments like dementia and Alzheimer's, detection of autistic disorders in infants, etc. We will demonstrate a platform with motion sensors that enable locomotion monitoring. Section 2 describes our system architecture. Section 3 presents the locomotion monitoring application and preliminary study reports. We conclude the paper by explaining the demo setup.

2. System Architecture

Our system consists of several Telos motes, each one mounted with a custom-designed sensor board. The sensor board has a triaxial accelerometer and two biaxial gyroscopes as shown in Figure 1.

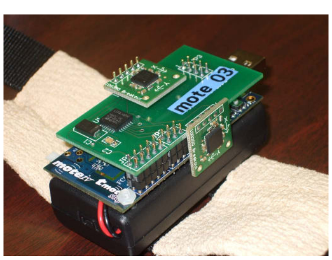

Figure 1. Mote with inertial sensors

The system operates on the TinyOS operating system. The processing unit of each mote samples sensor readings and transmits the data wirelessly to a base station at a particular sampling rate. The base station is a mote without sensor board that receives the sensor readings and forwards the data to laptop via USB. More detailed information on the system architecture and the details of node coordination techniques is reported in [1].

3. Locomotion Monitoring

In the literature focusing on geriatrics, greater attention has been brought to the relationship between gait and cognition. A review by the authors of [2] indicates that various disorders in aging ranging from mild cognitive impairment to dementia and Alzheimer's could be diagnosed early based on mild deviations in gross motor skills. Also, the study of gait development and cognitive abilities in children indicates that various developmental disorders may be marked by differences in gait or motor development.

Our focus is to develop a system for quantitative measurement and assessment of motor function in children and adults. Quantitative measurements of motor function will allow for more complete, reliable and interpretable assessments of function for individual subjects. Some of the quantitative measures that we consider include, 'consistency', 'balance', and 'coordination'. Experiments are conducted to collect sensor data with children and adults as our subjects to determine the normal range of consistency, balance, and coordination. The data is then analyzed to check for deviations in locomotion and gait development using signal processing techniques which include segmentation, feature extraction and classification. More information on the signal processing techniques used is reported in [3].

Figure 2. Adult subject walking on an elevated stick with sensors

978-0-7695-3157-1/08 $25.00 © 2008 IEEE
DOI 10.1109/IPSN.2008.53

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3.1 Preliminary studies

In our pilot study, experiments were performed with twelve sensors on the body of the subject. The subjects performed different locomotive movements such as walking on the floor and on an elevated stick, walking with shoes on, and walking without shoes. Figure 2 shows a subject walking on an elevated stick along with sensor locations indicated. The objective was to investigate the consistency of movements from one step to another, the coordination between joints, and the balance of the subjects. To characterize consistency, the persistence of the spectrum of the movements across time was analyzed. Naturally, the local spectra were calculated using finite windows in time. The following formula is used to generate the results shown in Figure 3.

$$D(\tau) = \iint [S(t,w) - S(t+\tau,w)]^2 \, dwdt$$

where $S\ (w,\ t)$ is the spectrogram of the signal at time t and angular frequency w. The graph is roughly periodic (consistent) for a subject walking on the floor and is aperiodic (inconsistent) for a subject walking on an elevated stick.

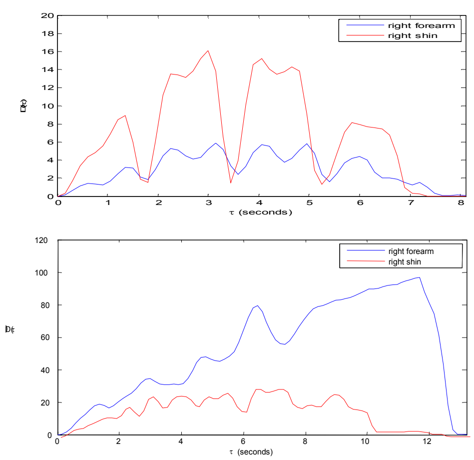

Figure 3. Consistency measure for walking on the floor (top diagram - consistent) and on an elevated stick (bottom diagram - inconsistent) for an adult subject

The balance measurement is done by calculating the change in the position of the center of gravity over time. The orientation change is tracked by observing the effect of gravity on the z-axis of the accelerometer sensor placed on the waist of the subject.

Coordination is identified by comparing the phase and frequency of the data collected from the sensors that are placed on the different parts of the body. In case of normal walking for an adult subject, the phase difference between the right ankle and the left ankle should remain constant, and the frequency response inparticular, should remain consistent as shown in Figure 5a. For a child subject, the frequency response is inconsistent as shown in Figure 5b.

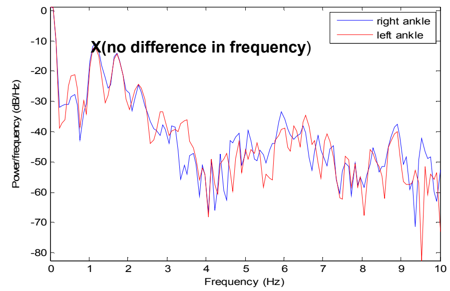

Figure 5a. Frequency response between left ankle and right ankle for an adult (normal walking)

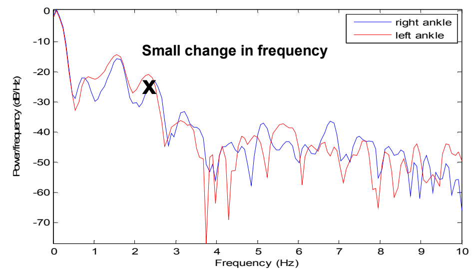

Figure 5b. Frequency response between left ankle and right ankle for child (normal walking)

4. Demo Setup

For the demo, twelve motion sensors will be placed on the volunteer. The sensors are attached to the volunteer with Velcro sports bands or gauze bandages. The sensors are then calibrated to ensure correct orientation. The participant will have to perform the movements as described in section 3.1. The corresponding movements will be tracked, and the aforementioned parameters will be reported by the Java application running on the laptop. Each participant will receive a report with their quantified measurements and the comparisons with baseline.

5. Acknowledgement

The authors would like to acknowledge Drs. Aria Nosratinia and Mandy Maguire for their valuable comments.

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