Wearable Wellness Monitoring Using ECG and Accelerometer Data

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Abstract

This paper presents a prototype wearable wellness monitoring system capable of recording, transmitting and analyzing continuous ECG and accelerometer data. The system also provides an application for recording activities, events and potentially important medical symptoms. The hardware allows data to be transmitted wirelessly from on-body sensors to a handheld device using Bluetooth. Data is then transmitted to a back-end server for analysis using either a wireless internet connection, if available, or a cellular phone service. We conducted experiments using the system for activity monitoring, exercise monitoring and medical screening tests and present preliminary data and results.

1. Introduction

Wellness monitoring is a growing area that will benefit from the use of wearable computing systems. Wearable systems can unobtrusively collect physiological data and human annotations to monitor health and predict susceptibility to disease. These systems may enable elderly people and those suffering from chronic illness to live independently longer and receive early warnings of and treatments for changes in their health. In countries with aging populations, this could reduce health care budgets and improve quality of life for many people.

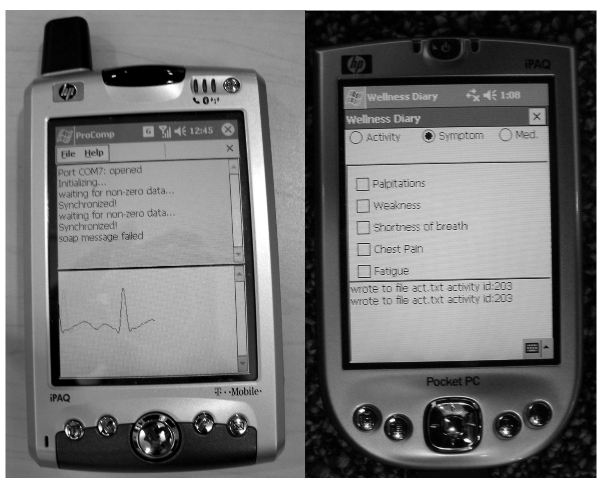

Figure 1. The system showing wireless real-time ECG capture (left) and the wellness checklist (right). The Wellness Checklist allows you to select from three menus "Activity", "Symptoms," and "Medications." The menu shown is "Medications" where users can select from a customized checklist. The checklist shown includes "Palpitations, " "Weakness," "Shortness of Breath," "Chest Pain," and "Fatigue."

We developed a prototype wearable system for wellness and activity monitoring using ECG and accelerometer sensors. Accelerometer-based activity monitoring can be used to assess exercise compliance and determine the amount of energy the wearer uses in a day [1-2] to help plan dietary needs. An increase in activity can indicate an improvement in health, due to successful medicinal or lifestyle changes. Conversely, a decrease in activity can serve as a warning sign for the worsening of diseases such as congestive heart failure (CHF) and depression. ECG monitoring provides a detailed record of cardiac health, allowing doctors to track hour by hour heart rate changes, the number of ectopic beats and the occurrence of arrhythmias such as atrial fibrillation, which can often be asymptomatic.

Combining the data from both the ECG and the accelerometer allows us to interpret the ECG in context. For example, the arrhythmia tachycardia is defined as a heart rate greater than 100 beats per minute (bpm). In a resting wearer, this would be cause for concern, but in an exercising person this would be normal. Finally, the accelerometer data can be used to estimate the quality of the signal data and give a confidence rating on the results of the analysis algorithms.

The system hardware consists of off-the-shelf components: an ECG monitor, a two-axis accelerometer and two iPaq units. The iPaq units provide local processing and storage, but are mainly intended to be used a link between the user and a back-end system[2] with far greater resources. The iPaq allows the wearer to see sensor signals as they are collected and to annotate the record with specific activities, symptoms and medications using: a checklist based Wellness Diary as shown in Figure 1; voice messages or digital pictures.

2. Data collection

Data was collected from users performing a variety of everyday tasks to test the quality of the signal, the robustness of the system, and to determine if the user's activity level would be reflected in the accelerometer data. We found that the quality of the ECG data varied for different activity levels. During low activity states, signal quality was excellent, however during high activity such as running, signal quality deteriorated and analysis algorithms failed. Figure 2 shows ECG data from a low activity state where the algorithm correctly marks R-wave peaks, reporting a heart rate of 66 bpm; and a high activity state where the algorithm reports an inaccurate heart rate of 182 bpm. The clinical concern of this high heart rate can be mitigated the low confidence in the signal quality, since we know the wearer is in a high state of activity.t

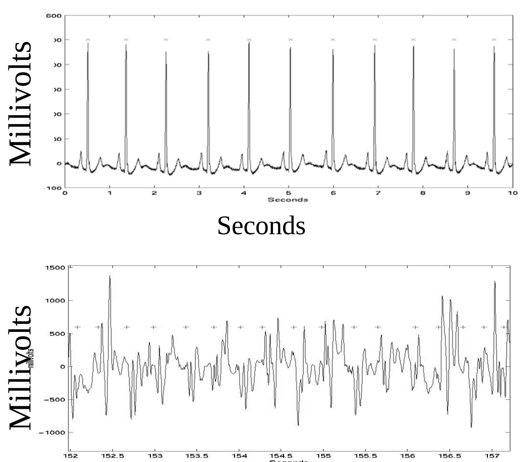

Figure 2. Ambulatory ECG data collected while resting (top) and while running (bottom).

The main activities recorded in the office environment were sitting and walking as shown in Figure 3. Using either the integral of the RMS signal [4] or the signal variance and a simple threshold we were able to distinguish between higher (walking) and lower (sitting and standing) states of activity.

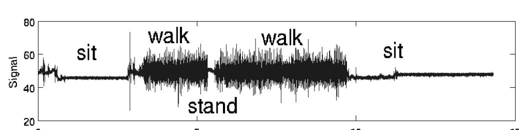

Figure 3. Accelerometer data showing 15 minutes of sitting, walking and standing activities

Additional experiments looked at the accelerometer effects of riding in vehicles as shown in Figure 4. Preliminary analysis shows that both sitting in a car and standing in a subway cause confounding activity level results, reporting higher activity. This is mainly due to baseline shifts that occur either when the car turns or the subway lurches at starts and stops. Eliminating these shifts will reduce this error.

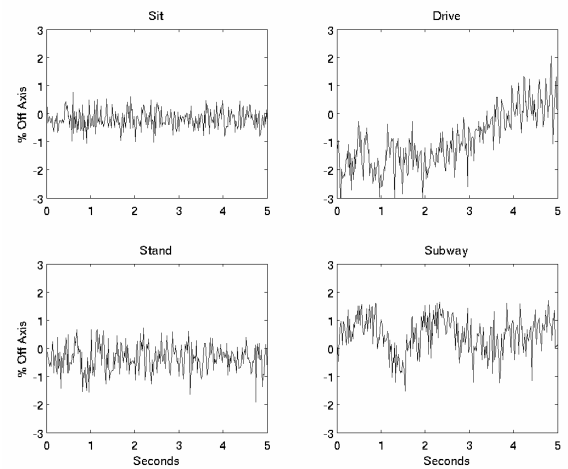

Figure 4. Accelerometer data from sitting and sitting in a car (top) and standing and standing in a subway train (bottom).

3. Results

These preliminary results show a good quality ECG signal, except in cases of highest activity. Algorithms on the back end server were able to accurately identify the R-wave complexes in most of the ambulatory data, which is the basis for the arrhythmia and ectopic beat analysis programs. The accelerometer analysis shows good differentiation between periods of high and low activity and can distinguish stationary activities from similar activities in moving vehicles

12**. References**

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