Physical Activity Recognition Using a Single Tri-Axis Accelerometer

Mi-hee Lee, Jungchae Kim, Kwangsoo Kim, Inho Lee, Sun Ha Jee, Sun Kook Yoo*

***Abstract*—Main objective of this pilot study was to present a method to convenient monitoring of detailed ambulatory movements in daily life, by use of a portable measurement device employing single tri-axial accelerometer. In particular, we implemented a small-size wearable data storing system in real time that we used Micro SD-Memory card for convenient and long period habitual physical activity monitoring during daily life. Mean & standard deviation of acceleration and correlation features were extracted from acceleration data. Activity recognition on these features was performed using Fuzzy c means classification algorithm recognized standing, sitting, lying, walking and running with 99.5% accuracy.**

This study was pilot test for our developed system's feasibilities. Further application of the present technique may be helpful in the health promotion of both young and elderly, and in the management of obese, diabetic, hyperlipidemic and cardiac patients

***Index Terms*— Physical Activity, Accelerometer, Micro SD-Memory**

I. Introduction

Over the past two decades, a striking increase in the number of people with the metabolic syndrome worldwide has taken place. This increase is associated with the global epidemic of obesity and diabetes. With the elevated risk not only of diabetes but also of cardiovascular disease from the metabolic syndrome, there is urgent need for strategies to prevent the emerging global epidemic [1,2].

Although the metabolic syndrome appears to be more common in people who are genetically susceptible, acquired underlying risk factors-being overweight or obese, physical inactivity, and an atherogenic diet-commonly elicit clinical manifestations [3].

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Current guidelines recommend practical, regular, and moderate regimens of physical activity (eq, 30 min moderate-intensity exercise daily)[4]. Regular and sustained physical activity will improve all risk factors of the metabolic syndrome. Sedentary activities in leisure time should be replaced by more active behavior such as brisk walking, jogging, swimming, biking, golfing, and team sports. Combination of weight loss and exercise to reduce the incidence of type 2 diabetes in patients with glucose intolerance should not be dismissed [5].

A practical and reliable method to investigate individual's daily physical activity allows better assessment such as of outcomes of medical interventions. Information such as intensity of exercise, types of activities is also necessary to appropriately formulate safe and beneficial exercise program on individual basis [6]. Ambulatory movement is the most accessible type of exercise easy to perform that does not require any special equipment. Therefore, a reliable assessment of ambulatory movements in daily life, such as standing, walking, ascending stairs (Up), descending stairs (Down) and running, is essential for exercise prescription in the clinics as well as in health promotion programs.

A variety of methods exist to quantify levels of habitual physical activity during daily life, including objective measures such as heart rate, one-and three dimensional accelerometer, and pedometer, as well as subjective recall questionnaires like the International Physical Activity Questionnaire and physical activity logbooks [7,8]. Yet all possess some important limitations. Heart rate monitors have been widely used to quantify physiological stress, but their efficacy at low intensities has been questioned due to the potential interference of environmental conditions and emotional stress [9]. A wide range of self-report activity questionnaires exist that are well suited to large surveillance studies but are limited due to their reliance on subjective recall. Pedometers are an inexpensive form of body motion sensor, yet many fail to measure slow walking speeds or upper body movements, and most are unable to log data to determine changes in exercise intensity [10]. The most common accelerometers used in human activity research measure accelerations either in a vertical plane (uni-axial), or in three planes (tri-axial), with excellent data-logging abilities [1, 10].

Main objective of this study was to present a method to convenient monitoring of detailed ambulatory movements in daily life, by use of a portable measurement device employing single tri-axial accelerometer. Specially, we implemented a small-size wearable data store system in real time that we used Micro SD-Memory card (Secure Digital memory card) for convenient and long period habitual physical activity monitoring during daily life.

In this work, the performance of activity recognition algorithms under conditions akin to those found in real-world settings is assessed. Activity recognition results are based on acceleration data collected from single tri-axial accelerometer placed on subjects' waist under semi-naturalistic conditions for pilot test.

II. Material and Method

A. Wearable measurement device

Our long-term aim in developing an accelerometry monitoring system was to develop a practical system that could be used to monitor and assess physical activities in free-living subjects. Therefore, we developed a wearable device consisted of Micro SD-Memory card connector (AUTF-08WP01, AUSTONE Electronics, Inc., USA) with mini USB socket (5P, SMT type, SHIH HAN CO., LTD., Russia). Measured acceleration signal was stored on micro SD-Memory card or transmitted wirelessly using Zigbee-compatible 2.4G bandwidth for wireless communication, and CC2420 (Chipcon Co. Ltd., Norway) with a simple interface circuit around the chip. In addition, a ceramic chip antenna TI-AN048 (SMD type, Texas Instruments Co. USA) was applied for stable wireless transmission.

For this we used ADXL330 (Analog Devices, Inc., USA), an acceleration sensor that is composed of a single chip and can detect tri-axis acceleration information, and measured acceleration information of axis X, Y and Z according to the subject's posture and activity. Using the implemented system, we measured change in acceleration signal according to the change of activity pattern. Li-Ionic batteries, micro processor units and micro SD memory card, as shown in Figure 1. This equipment was small (60 x 40 x 20 [mm]) and light enough to carry without and restriction. Sampling frequency was 100Hz. Data was downloaded via USB, and processed offline by a PC. The equipment was designed to be attached on the waist (see figure 1).

B. Activity Data Collection

The data for these experiments were gathered in an unsupervised pilot study in which healthy young (age 24-33) subjects performed a variety of activities in the three times on outdoor conditions. Characteristics of the participants are presented in Table 1.

We put the acceleration measuring sensor system on the left waist of the subjects, and measured change in acceleration signal according to change in ambulatory movement and physical activities. In the experiment performed in this research, the change of acceleration was measured while the subject was repeating postures such as standing, sitting, lying, walking and running. A representatives set of routine data is shown in figure 2.

While the movements and postures contained within the routine are by no means a complete set of all possible activities that a given person might perform, they do form a basic set of simple activities which form an underlying structure to a person's daily life, and are likely to provide a great deal of information in terms of the person's balance, gait and activity levels if they can be accurately identified.

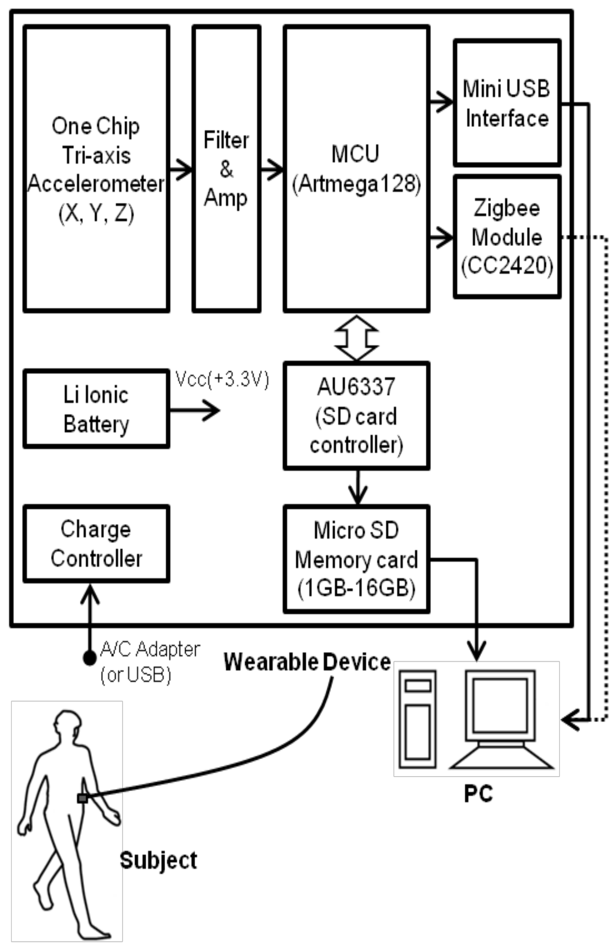

Fig. 1 Architecture of the wearable measurement device

Table 1. Participant characteristics.

Case	Gender (M/F)	Age (yr)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)
A	M	26	182	76	22.9
B	M	28	179	85	26.5
C	M	28	177	69	22.0
D	F	24	167	55	19.7
E	F	33	160	55	21.5

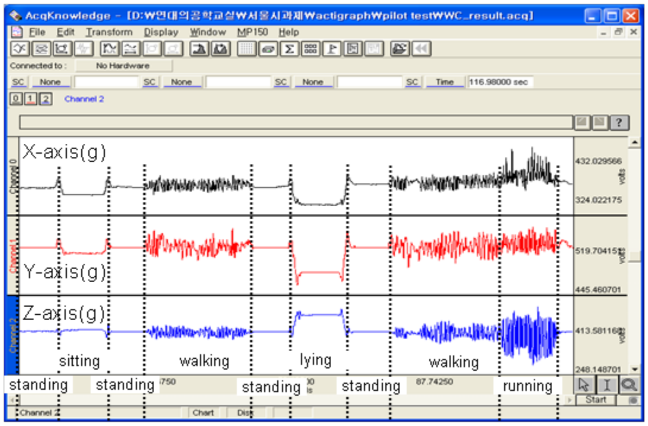

Fig. 2 Representative data from the daily routine for each of the three axes of the tri-axial device

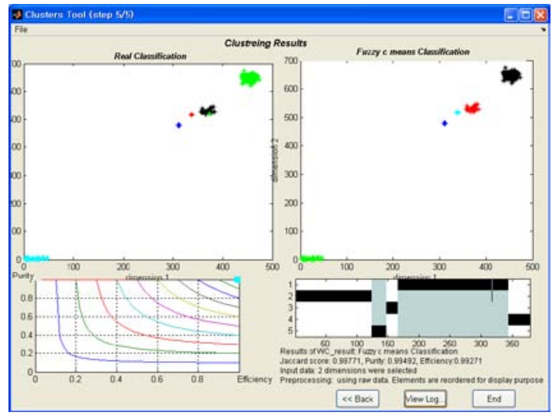

Fig. 3 Activity recognition result using Fuzzy c means classification algorithm

C. Feature Extraction

Features were computed on 512 sample windows of acceleration data with 256 samples overlapping between consecutive windows. At a sampling frequency of 100Hz, each window represents 5.2seconds. Maximum acceleration, mean and standard deviation of acceleration channels were computed over sliding windows with 50% overlap has demonstrated success in past works. The 512 sample window size enabled fast computation of FFTs used for some of the features. The DC feature for normalization is the mean acceleration value of the signal over the window. Use of mean of maximum acceleration features has been shown to result in accurate recognition of certain postures and activities

III. Results

This section describes the experiments and experimental results of the human posture recognition system. In the pilot test, a subject continuous posture change including standing, sitting, lying, walking and running. In the experiment, each posture was recognized third.

Mean & standard deviation of acceleration and correlation features were extracted from acceleration data. Activity recognition on these features was performed using Fuzzy c means classification algorithm recognized standing, sitting, lying, walking and running with 99.5% accuracy as shown Table 2 and Figure 3

Table 2. Clustering results of different posture in a continuous motion

Parameters & Real posture	Jaccard score	Purity	Efficiency
Standing	0.99	0.99	1
Sitting	1	1	1
Lying	1	1	1
Walking	0.99	1	0.99
Running	1	1	1
Average	0.98	0.99	0.99

IV. Discussion & Conclusion

This paper proposes an ambulatory movement's recognition system in daily life. A portable acceleration sensor module has been designed and implemented to measure human body motion. A small portable device utilizing single tri-axis accelerometer was developed, which detects features of ambulatory movements including vertical position shifts. The classification method based on Fuzzy c means classification algorithm, recognition accuracy of over 99% on a five activities (standing, sitting, lying, walking and running). These results are competitive with prior activity recognition results that only used laboratory data.

However, several limitations are also observed for the system. Firstly, collected data was from younger (age 24-33) subjects. Secondly, single accelerometer of placed on body waist typically do not measure ascending and descending stairs walking.

Accelerometers are preferable to detect frequency and intensity of vibrational human motion. [11] Many studies have demonstrated the usefulness of accelerometer for the evaluation of physical activity, mostly focusing on the detection of level walking or active/rest discrimination. [12-14]

This study was pilot test for our developed system's feasibilities. Further application of the present technique may be helpful in the health promotion of both young and elderly, and in the management of obese, diabetic, hyperlipidemic and cardiac patients. Efforts are being directed to make the device smaller and allow data collection for longer time periods. Implementation of real-time processing firmware and encapsulation of the hardware are our future studies.

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