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Automatic fall detection using Wearable Biomedical Signal Measurement Terminal

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Abstract— **In our study, we developed a mobile waist-mounted device which can monitor the subject's acceleration signal and detect the fall events in real-time with high accuracy and automatically send an emergency message to a remote server via CDMA module. When fall event happens, the system also generates an alarm sound at 50Hz to alarm other people until a subject can sit up or stand up. A Kionix KXM52-1050 tri-axial accelerometer and a Bellwave BSM856 CDMA standalone modem were used to detect and manage fall events. We used not only a simple threshold algorithm but also some supporting methods to increase an accuracy of our system (nearly 100% in laboratory environment). Timely fall detection can prevent regrettable death due to long-lie effect; therefore increase the independence of elderly people in an unsupervised living environment.**

Keywords: Fall detection, CDMA module, Accelerometer, Wearable Biomedical System...

I. Introduction

POPULATION aging is a highly generalized process. It is most advanced in the most highly developed countries. Among the countries currently classified by the United Nations as more developed (with a population of 1.2 billion in 2005), the median age of the population rose from 29.0 in 1950 to 37.3 in 2000, and is forecasted to rise to 45.5 by 2050 [1].

Population aging brings about many problems. Hospitals are overcharged and expenditure of healthcare increases. Therefore, e-Health which can improve the independence of elderly people in unsupervised living environments becomes new tendency.

One of the most important topics of e-Health is fall detection. Approximately 30 percent of people over 65 years and living in the community fall each year; the number is higher in institutions. In 1997, 67% of accidental deaths in females aged over 65 were due to falls. Each year in Britain a third of the population aged over 65 has a fall, and half of these people fall at least twice [2].

For these reasons, fall sensor was classed as the first object in the independent living activity hub [3].

Recently, many methods have been proposed to detect fall events such as using accelerometers [4], using gyro sensors [5], using vision sensor [6], using a Micro Inertial Measurement Unit [7]... Analyzing acceleration information to detect fall events is one of the most convenient and simple methods. However, a required range of accelerometer is over ±5 g.

In this study, we combined some methods that helped our system to have a fall detection function but the range of our accelerometer was just ±2 g.

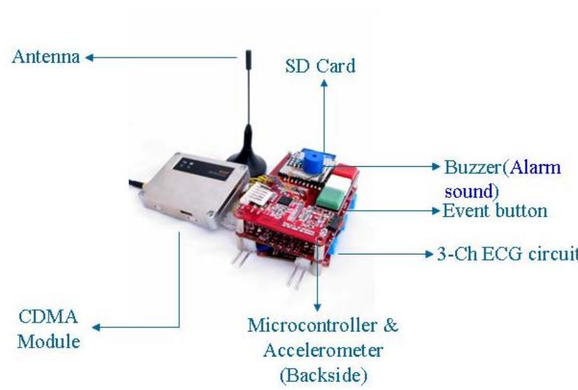

Fig. 1. Wearable Biomedical Signal Measurement Terminal.

Automatic fall detection function was added to WBSMT (Wearable Biomedical Signal Measurement Terminal - see Fig. 1) which developed by Ubiquitous Biomedical Systems Development Center. Without battery, size of WBSMT is 4 x 7 x 8cm and weight is 178 g (see Fig. 2). This system can use Holter function (24 hour ECG monitoring function), an event-recorder function and motion monitoring function simultaneously. When emergency events (electrode separation, heart rate > 150 bpm or <40 bpm, event button press and fall event), the system sends 48 kb data of 3 channel ECG, 3 axial acceleration and an emergency message to remote server.

Because data are transmitted through CDMA module, our device can send and receive data and instruction messages normally in any place where has mobile wireless network. With 3 AA batteries, the device can also operate for 24 hours without changing battery.

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Fig. 2. Wearable Biomedical Signal Measurement Terminal (Package).

In the experiment, we performed activities of daily living such as sitting, standing, lying, going upstairs, going downstairs, sitting to standing, standing to sitting, standing to lying, lying to standing to determine sensitivity and specificity of our fall detection method.

At present, we succeeded in detecting fall events in laboratory environment. Because fall is very dangerous, we can not use elderly people in our experiment.

II. MATERIALS AND METHODS

A. Materials

Kionix KXM52-1050 tri-axial accelerometer was used to acquire tri-axial acceleration with 20 Hz sampling frequency. The size of this sensor is 5.0 x 5.0 x 1.8 mm^3.

TABLE I
KIONIX KXM52-1050 TRI-AXIAL ACCELEROMETER FEATURES

Product	KXM52-1050
Axis(es) of Sensitivity	Tri X, Y &Z
Range	±2 g (1 g – 6 g available)
Offset	1.65 V
Operating Voltage (V)	3.3
Temp. (C)	-40 to +85
Package	5.0 x 5.0 x 1.8 mm DFN
Output	Analog

The measurement range is ± 2 g and the sensitivity is 660 mV/g at the operating voltage is 3.3 V (see TABLE I for more detail). Acceleration analog signals were processed by hardware (filtered) before converting to digital signal by 10 bit ADC of ATmega128 micro-controller (Atmel), then recorded to 128 Mb SD card (Transcend). The memory of microcontroller is 128Kbyte, 4Kb EEPROM and 4Kbyte internal SRAM. When emergency event happens, 48 kb data (ECG and acceleration data) will be sent to remote server via Bellwave CDMA module (see Fig.3). Size of this CDMA module is 46 x 60 x10 mm and weight is 45.5g.

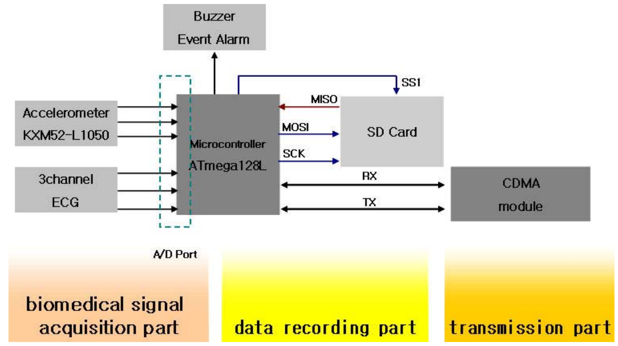

Fig. 3. WBSMT Configuration.

When subject stands still, the values of tri-axial acceleration are shown in Fig. 4.

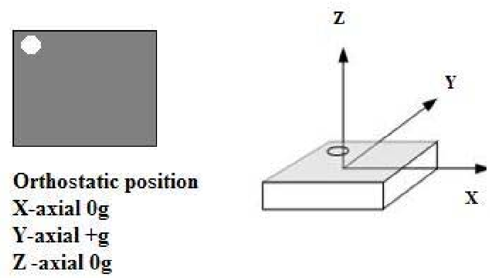

Fig. 4. The values of tri-axial acceleration when subjects stand still.

B. Methods and Experiments

To recognize fall events from other activities we used several thresholds as shown in Fig. 5.

Fall Lower Threshold T_{low}.

Fall Upper Threshold T_{up}.

Lying Lower Threshold T_{lying1}.

Lying Upper Threshold T_{lying2}.

After 10 seconds from fall event, if subject can not stand up or sit up, the system generates an alarm sound at 50 Hz and sends data to remote server (Emergency Event).

Our system generates sound until the subject sits up or stands up (using threshold T_{lying1}, T_{lying2}).

To verify sensitivity and specificity of our system, we tested during ADL(activities of daily living), such as, sitting, standing, lying, walking (slow and fast), going upstairs, going downstairs, sitting to standing, standing to sitting, standing to lying, lying to standing and falling.

For each trial, after the system is turned on, subject should keep still for 30 seconds and then start doing activity. Due to a kind of activity, the activity duration is long or short. Before turning off our system, subjects should keep still for 30 seconds again.

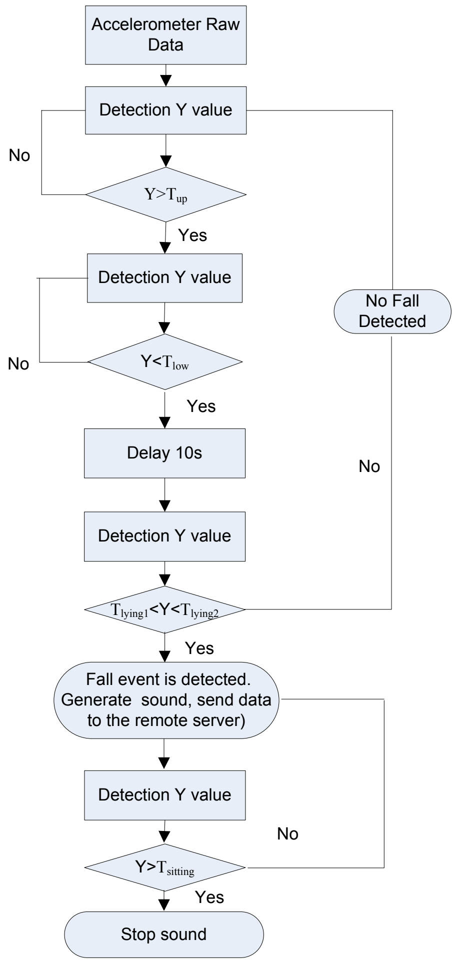

Fig. 5. Algorithm to detect fall events.

III. Results

The thresholds were obtained by analyzing accelerometer signals from 40 falls and 110 ADL's.

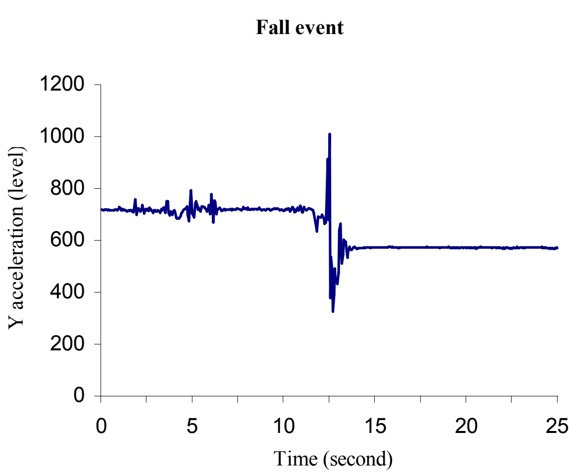

Fig. 6. Y-acceleration of fall event.

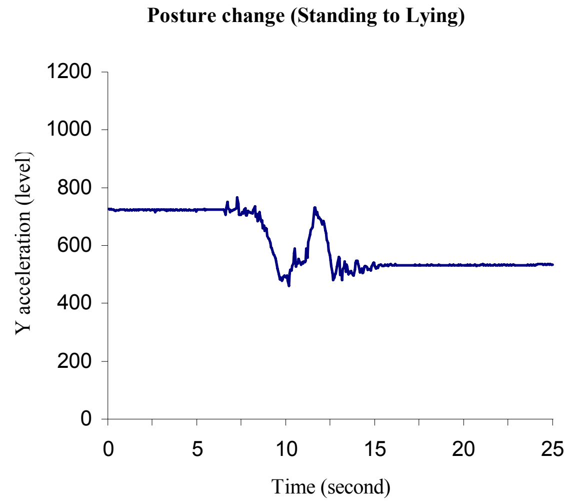

Fig. 7. Y-acceleration of posture change (standing to lying).

If we use only fall upper threshold or fall lower threshold, some walking activities were misrecognized as fall.

In most case, after fall event, position of subject is lying. Therefore, lying lower threshold and lying upper threshold were used to support for fall upper threshold and fall lower threshold.

Using these four thresholds, no error was recognized in laboratory environment.

When fall event happened, 48 Kb data were sent to remote server via CDMA module and were displayed as in Fig. 8.

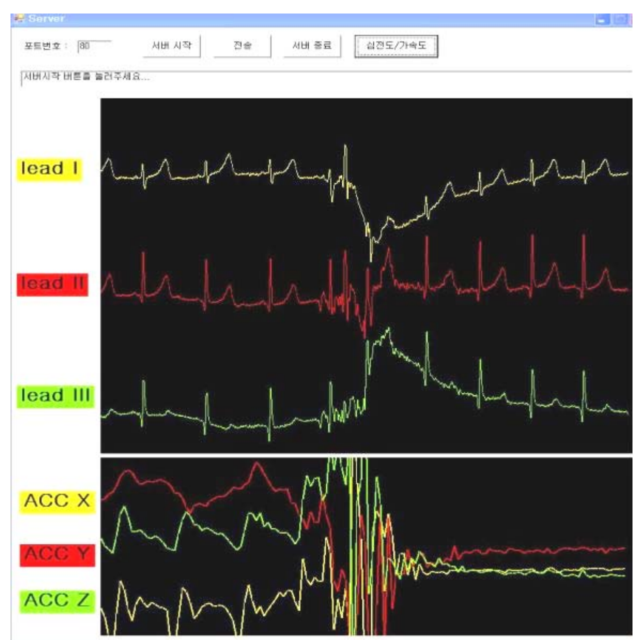

Fig. 8. Remote server screen (fall event).

IV. CONCLUSION

In this study, we built a simple method to recognize fall events accurately.

Although it has some limitations that the generated sound was not very loud, they can be improved with ease.

In future research, we will integrate not only accelerometer but gyro-sensor and magnetometer to recognize fall events and the other human motion types.

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