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Elder Fall Detection and Reporting Using Smart Phones

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ABSTRACT

With the rapid growth of the population of the elderly in the world, many countries in the world have been in the aging society. Falls are a major public health concern and one of the greatest obstacles to independent living for elder adults in terms of social services. In this paper, we present a fall detection system derived from some motion sensor via an android-based smart phone in which we utilize adaptive threshold algorithm for fall detection. Furthermore, we implement this system called E-FallD on the HTC G8 mobile phone. As demonstrated by the experimental results, E-FallD has a good detection performance and it is an efficient and smart application. In the mean time, using adaptive threshold algorithm could increase sensitivity dramatically. In a word ,our system provides a realizable, effective and portal solution to fall detection for users.

Keywords-fall detection; Android; realtime processing; adaptive threshold algorithm;

I. INTRODUCTION

21 century is the time of the population aging. At present, all developed countries in the world have been in the aging society, many developing countries are or will be entering the aging society. With the rapid growth of the population of the elderly in the world, the demand for the healthcare systems is increased accordingly. Meanwhile, falls are a major public health concern and one of the greatest obstacles to independent living for adults. A report shows that: more than one third of the population over the age of 65 falls at least once a year in the USA [1]. according to the report, It is a common phenomenon that the older adults who lives alone can't be able to get help after fall as soon as possible.

In view of the problems mentioned above, more and more fall detection system are designed available to detect fallen elderly and attempt to reduce the pain they get. At present, these fall detection systems are commonly divided three main categories in according to the different acquisition data methods. Ambience-device-based system commonly use pressure sensor to detect the user whether fall or not. The principle is that when the user is falling down at a place where the pressure sensor at that place, the sensors will sense a higher pressure than normal because of the impact of the fall, then the system will identify fall. For instance, M. Alwan, et al. [2] used the vibration sensors on the floor. The processor recognizes fall through analyzing these data. The advantage of this approach is its cheap device and non-intrusive. cannot discern if pressure is from the user's weight, so that it suffers low accuracy. Camera-based system is increasingly used in in-home assistive system because they have multiple advantages over sensor approaches and the price of cameras decreases rapidly. First, camera-based system is able to be used to detect multiple events simultaneously. Secondly, they are less intrusive because they are installed on building not worn by users. Lastly, the recorded video can be used for remote and post verification and analysis. For example, R. Cucchiara, et al.[3] used 3D shape of body in fall detection. 3D body shape is obtained multiple cameras that are calibrated in prior. However there are also some disadvantages in camera-based system.

It can't guarantee the users' privacy and security, and the it is not able to detect if users fall happened in where not install cameras or at night. In addition based-on 3D image system usually have certain delay. Because of wearable and cheap, the wearable-device-based system is the most commonly used for fall detection. The wearable-device-based system is that users wear some devices with imbedded sensors to get available data like acceleration ,then the system process data by algorisms to recognize the user if fall or not. Clifford, et al.[4] designed a system for fall detection. The system includes a monitoring unit, including accelerometers ,a processor and a wireless transmitter.

At present, this system is used most commonly for fall detection because of its many advantages. Firstly, the device is portable so it is convenience to users. Secondly, the devices are cheap. Thirdly, wearable devices for fall detection are easy to be set up and operated. However, this system is prone to have a high rate of false alarm. Another big disadvantage of the system is that it is intrusive.

In this paper, we propose a fall detection application which is developed on a HTC smart phone running the Android 2.2 operating system. It is also a wearable-device-based system. We mainly based on the below considerations: With the improvements in mobile technology, the cost of smart phones decreased and in the same time their computational capabilities increased. In addition, the key point it that many of these smart phones have integrated accelerometers that are used for fall detection. In most of these systems, it is also possible to access acceleration signals provided by the integrated accelerometer.

So we can only use the smart phone and don't have to use special acceleration sensors to collect data. Such a system is ideal for fall detection that can automatically detect falls and provide a warning mechanism.

We summarize key contributions and findings of our work as follows:

The rest of the paper is organized as follows. In section II, we presents an overview of related work. Section III presents the system design and implementation and experimental results in Section IV. Section V draws a conclusion of the paper.

II. RELATED WORK

In section I, we introduce three major fall detection system, which are ambience-device-based system, camera-based system and wearable-device-based system. And we proposed based on android smart phone fall detection system which belongs to wearable-device-based system. This system is mainly composed by three key modules which are the accelerometer, microprocessor and wireless communication module. The accelerometer provide acceleration measurements to the microprocessor. The microprocessor receives acceleration measurements and determine if the user is currently experiencing a fall event. The processor generates a signal in response to the detection of a fall event and wireless communication module transmits the signal to a remote signal receiver[5]. And the appearance of the smart phone that integrate the three important module together, makes smart phones-based system for fall detection portable, convenient and high efficiency.

Almeida, et al.[6] designed that detectors are installed in a crutch to dynamically detect fall and measuring pace, which uses gyroscope chip to measure angular velocity of the crutch. When the equipment get a larger angular velocity it infers that the crutch is lying down and infers that the holder of the crutch has a fall.

J. Chen, et al.[7] propose a fall detector based on a wearable sensors. In their work, they assume that a large acceleration impulse will occur upon when the user is falling on the ground who wears the detector. When such an impulse is observed on the acceleration signal, they can calculate orientation of the sensor before and after the impact, and check if there has been a change in the orientation. If both conditions are satisfied, they detect a fall.

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In the pioneering work, there are several similar systems to our work. These systems are all designed based on Android smart phone.

F. Sposaro and G. Tyson[8] present an alert system for fall detection using common commercially available electronic devices to both detect the fall and alert users. They use a common Android-based smart phone with an integrated tri- axial accelerometer. Data from the accelerometer is evaluated with several threshold based algorithms and position data to determine a fall. If a fall is suspected a notification is raised requiring the user's response. If the user does not respond, the system alerts, social contacts with an informational message via SMS. However iFall generates a large number of false alarms; therefore this method still suffers from the similarities in the acceleration signals generated by different actions.

D. Jiangpeng, et al. [9] proposed utilizing mobile phones as the platform for pervasive fall detection system development which is called PerfallD, as they combine the accelerometers and communication components. Again, it used the threshold fall detection algorithm , yet its threshold is adjusted using data collected from real users. However, the disadvantage of PerFallD is lacking warning alarm. Therefore in case of a fall, it is unable to inform caregivers or the medical personnel about the fall event immediately.

Our system E-FallD is designed to directly address some of these issues and yield better detection result. E-FallD uses the threshold algorithm for fall detection, and the threshold is adaptive based on user's message such as: height, weight, sex and level of age. It provide personalized service in order to better distinguish falls from non-fall actions. In case of a detected fall, our system can inform guardian by sending text message . And if it detected a false result, the user can cancel it by press an button , so E-FallD design which is a mechanism for prevent false alarm.

III. SYSTEM DESIGN AND IMPLEMENTATION

A. Hardware

The system is designed for the HTC G8, wildfire A3366. The CPU of the phone is MSM7225 ARM running at 528MHz. Its dimensions are 106.75 mm × 60.4 mm × 12.19 mm and weighs 118 grams. The touch screen has a 240 x 320 resolution. It has 384 MB RAM and 512 MB ROM memory.

B. Software

We design our application on the Android 2.2 Platform. Android is an open source framework designed for mobile devices and it has a powerful Software Development Kit (SDK) based on Java Framework. The Android SDK provides libraries needed to interface with the hardware and deploy an Android application.

And Android applications are written in Java and run on the Dalvik virtual machine. Of course, we need install eclipse on the computers. In the mean time, we must download a Openlntents SensorSimulator for Android which currently supports accelerometer, compass, orientation, temperature, light, proximity, pressure, gravity, linear acceleration, rotation vector and gyroscope sensors, where the behavior can be customized through various settings. The Openlntents SensorSimulator lets us simulate sensor data with the mouse in real time. So we could get the acceleration data on the Dalvik virtual machine.

C. Equations

This paper mainly concerned about the designing and realization of the fall detection system, so the algorithm we choose is threshold algorithm which is most classical in fall detection. The accuracy of threshold algorithm is high, although it is relatively novel to other algorithms. And our contribution to the algorithm is that it could dynamically adjust threshold value and time window according to user information, such as the ratio of height and weight, sex and age. Compared to other fall detection, such as in[10] C.Doukas, et al. proposed SVM, threshold algorithm can deal with real-time data better and more convenient.

Our algorithm is based on three axis accelerations . Accelerations in X-axis, Y-axis and Z-axis are represented by Ax , Ay and Az . And the resultant acceleration Asum can be obtained by equation（1）

$$Asum = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

There are some threshold value should be fixed. The window time is represented by Twin where Twin=1.5s, and the two acceleration threshold are represented by Thmax and Thmin, where

Thmax =1.75g and Thmin =0.75g [11]. In this paper, Twin and Thmax are adaptive based on user's message, such as the ratio of height and weight, sex and age. In[12], the body mass index (BMI), or Quetelet index, is a heuristic proxy for human body fat based on an individual's weight and height. And BMI can be obtained by equation (2)

$$\textbf{BMI = mass(kg) / height}^2\textbf{(m)}$$

For these individuals, the current value settings are as follows: a BMI of 20 to 25 may indicate optimal weight; a BMI lower than 20 suggests the person is underweight while a number above 25 may indicate the person is overweight; a number above 30 suggests the person is obese (over 40, morbidly obese . So we can adjust the thresholds in table 1:while a number above 25 may indicate the person is overweight; a number above 30 suggests the person is obese (over 40, morbidly obese. So we can adjust the thresholds in table 1:

TABLE I. THRESHOLDS ADAPT BY DIFFERENT USER'S MESSAGE

	age		sex	
	=>60	*<60*	*M*	*F*
Th_{max}		+0.05g		-0.05g
T_{win}		+0.1s	+0.1s	
	BMI			
	<20	*20-25*	*25-30*	*>30*
Th_{max}	-0.05g		+0.05g	+0.1g
T_{win}	-0.1s		+0.1s	+0.2s

The fall detection algorithm is implemented as follows:

- The resultant acceleration signal is partitioned using Twin with 50% overlap(s).
- For a segment, the maximum value and the minimum value are represented by Amax and Amin, the time is represented Tmax when Amax and the time is represented Tmin when Amin.
- The activity is classified as a fall if Amax > Thmax and Amin< Thmin and Tmin<Tmax .

Otherwise, the activity is classified as an ADL (Activity of Daily Living).

D. System Implementation

We can see the framework of the system in"Fig. 1".There are two judgments which are fall and cancel or not.

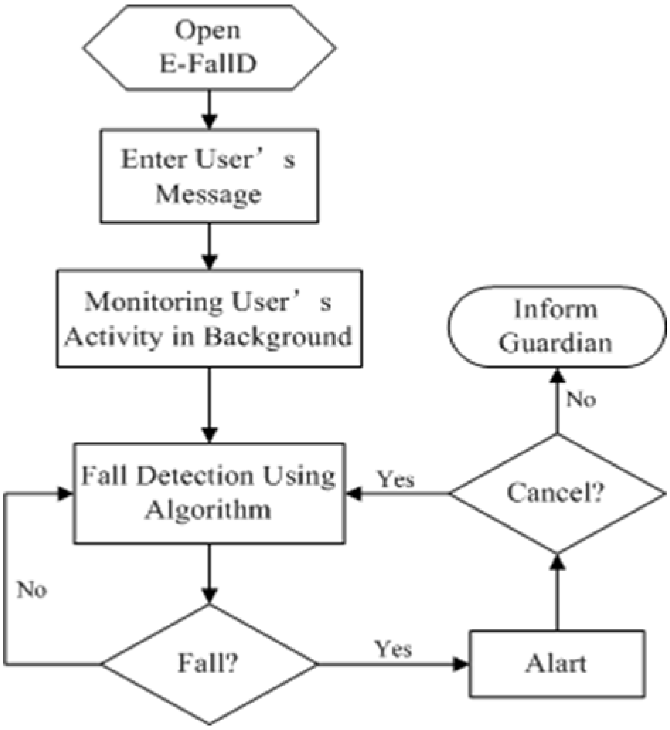

Figure 1. The framework of E-FallD

The biggest advantage of our application is simple, smart and efficient. There are three large main screen in the application is showed in "Fig.2" "Fig.3" "Fig.4".

Figure 2. The implementation of E-FallD (a)

Figure 3. The implementation of E-FallD (b)

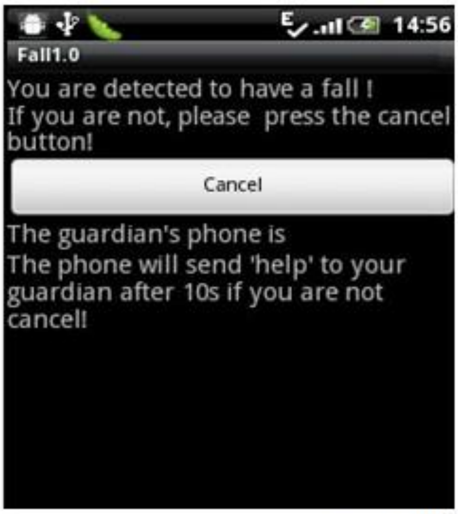

Figure 4. The implementation of E-FallD (c)

The first screen is to register user's message, we can see in "Fig.2", there are user's name, sex, age, height, weight and guardian's phone which is the most important. The use of these message we have explained on above. When have finished the user's message, you can press the "finish" button and the application will change to the second screen, we can see it in "Fig.3". The "fall detection" button is used for starting the activity. The activity corresponding to the screen is to obtain acceleration, process the data by threshold algorithm, and then judge the user have a fall or not. All these operations run in background and automatically. In the meantime, we can see the curve of the acceleration in the screen. It makes us more convenient to see the change of acceleration. If the user is detected to have a fall, the screen will change the third one, we can see it in “Fig.4”. It is used to prevent the false alarm. If the user is not fall, he could press the “cancel “button to cancel sending help message. If the user has a fall accident indeed, he will not press the “cancel” button, and then the help message will be sent to his guardian after 10s automatically, whose telephone number is registered at first.

In our experiments, we used the smart phone HTC A3366 with Android 2.2 operating system installed on it. In the tests, We conduct the experiments with a group of real persons. Obviously, we cannot test falls with real elderly people. We asked the subjects to repeat both falls and ADL which includes normal actions such as walking, sitting down and jumping.

TABLE II. THE PERFORMANCE OF E-FALLED WITH TWO DIFFERENT ALGORITHMS

	FN	FP		
	Fall	*Walk*	*Sit*	*Jump*
Classical	53	6	57	111
Adaptive	29	5	52	102
	Sensitivity(%)		*Specificity(%)*	
Classical	86.75		85.5	
Adaptive	92.75		86.75	

In table 2, we can see that we have got a satisfied result in the experiment. It showed that E-FallD is an efficient application for fall detection and adaptive threshold algorithm is useful for improving the sensitivity. Although the specificity is lower, but E-FallD owned a perfect mechanism for preventing false alarm. So if the system had an perfect alarm mechanism, the most important is to improve sensitivity for fall detection.

IV. CONCLUSION

In this paper, we presented fall detection system using smart phone based on Android, in which we use adaptive threshold algorithm by user’s message for fall detection. And we implement this system called E-FallD on the HTC G8 mobile phone. As demonstrated by the experimental results, E-FallD has a good detection performance and it is an efficient and smart application. In the mean time, using adaptive threshold algorithm could increase sensitivity drastically.

In future, we are planning to add some more machine leaning methods into the system in order to improve fall detection accuracy. We are also planning to conduct more experiments in which the people are in each age group including some elderly, and build a database for research to fall detection

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