A Simply Fall-Detection Algorithm Using Accelerometers on a Smartphone

Ekachai Thammasat
Engineering Department
Thailand Institute of Scientific and Technological Research
Pathumthani, Thailand

Jarree Chaicharn
Department of Electrical and Computer Engineering
Thammasat University
Pathumthani, Thailand

Abstract—**Every year, several thousands of elderly people experience with falling accident. Falling is then a main problem about healthiness of elders. This paper tries to find out a simple algorithm to detect a fall. With less calculation, the device can quickly distinguish between a fall and a normal activity of daily living (ADL). As the smartphone technology is currently in very advance, it includes several sensors to come along. The sensors building in the smartphone are very useful in every field of measurements even in medical engineering. The tri-axial accelerometer is one sensor available on the smartphone and one application is to use for fall detection. From the study, the simple algorithm can be applied for fall detection by observing any change of x-, y-, or z-acceleration 10g within time limited obtaining from ADLs in terms of lying down. The advantages of using the smartphone as a fall detector are that it can alarm or call out for help. It is also getting cheap, widely used, and comfortable to use or mount.**

***Index Terms*—Fall detection, accelerometer**

I. Introduction

Falling is a main problem about healthiness of elders. Willems and others [1] stated that several thousands of elderly people experience with falling accident each year. Particularly, one over third of aging people who are about over 75 years old has a falling experience. This record indicates that falling is one over fifth of the main causes of death for aging population. In the same population, falling is also the main cause of injuries like crack of hip and impacts awareness of fear to fall in acting activities of daily life (ADL). Therefore, there are several developments relative to algorithms utilizing in portable fall-detection devices based on accelerometers.

Lindemann and others [2] developed an algorithm for a fall detector based on accelerometers to distinguish between ADL and falls, and recommended to place at head level. The threshold in terms of acceleration in all x-, y-, and z-direction was >6g. Bourke and others [3] also developed a fall-detection algorithm based on tri-axial accelerometer, suggested to mount on the trunk or thigh. Using simultaneously both upper and lower thresholds, the fall-detection thresholds of the algorithm were >3.52g for the upper threshold and <0.36g for the lower threshold. In addition, Jantaraprim and others [4], [5] improved the accuracy of a fall-detection algorithm based on a tri-axial accelerometer mounted on the user's truck obtaining ≥1.75g and ≤0.75g for the upper and lower thresholds, respectively.

The developments mentioned earlier developed their own devices based on tri-axial accelerometers. Users have to mount or attach the device to their body for utilization. Possibly, the users, particularly elders, may forget to mount or feel uncomfortable. However, the new technology of current smartphones mostly includes special sensors for measurements such as accelerometer, gyroscope, compass, magnetic field, proximity, light, and pressure. Therefore, the developed algorithms can also be applied using accelerometers on any smartphone. There are several advantages for using a smartphone for fall detection. It is comfortably and widely used and the cost is affordable.

In this paper, we present a simply fall-detection algorithm using accelerometers on a smartphone based on the algorithms mentioned as previous. This algorithm does not define a threshold to apply with general users, but it will learn ADLs of a specific user and define the appropriate threshold for that user. Therefore, this algorithm will work sensitively and accurately for the user.

II. Methods

A smartphone applied in this experience is Samsung GALAXY S III (Model: GT-I9300T) which already builds in all sensors mentioned as previous particularly including the accelerometer sensor. The operating system (OS) is Android version 4.0.4. An application to record accelerations is Accelerometer Monitor which is an open-source software available on the android market.

From the literature reviews [1]-[6], most papers suggested to mount or attach the device to the upper part of the user's body or above the waist. The reason is because the upper part of body changes in x-, y-, and z-planes of the body less than the lower part when performing in ADL's like walking or sitting. Therefore, we assigned to put the smartphone in the pocket of the shirt as for convenience of the user and turn the front side of the phone to the body. Another idea is the user

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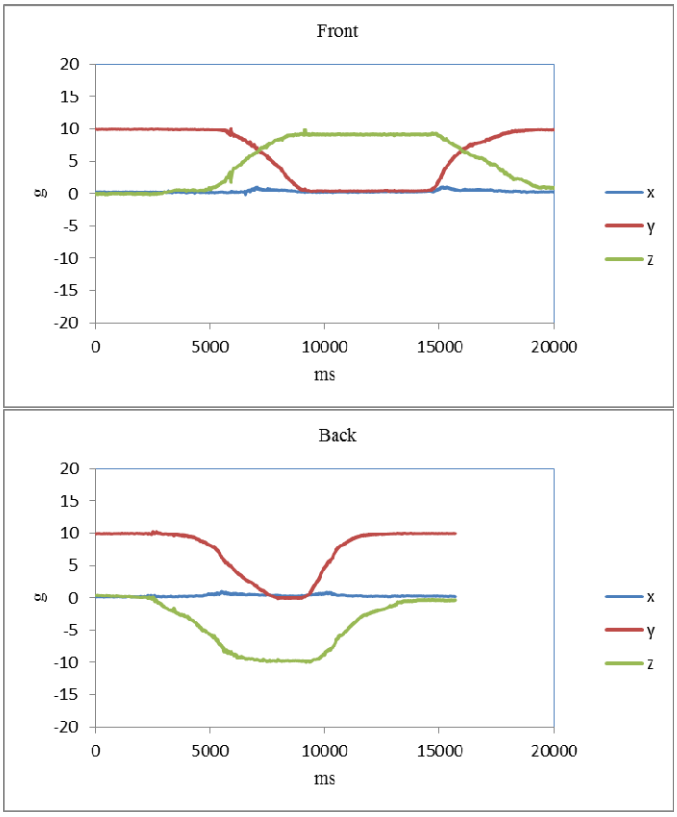
may hang the phone as a necklace, but the user has to take care of its sway.

A result of a fall should lie down in one direction; for example, falling to the front side, falling to the back side, falling to the left side, or falling to the right side. When the user puts the smartphone as assigned, Figure 1 illustrates the level of tri-axial acceleration. If falling to the front side occurs, the acceleration of the z-plane will change from approximately 0g to 10g and the acceleration of the y-plane will change from approximately 10g to 0g. If falling to the back side occurs, the acceleration of the z-plane will change from approximately 0g to -10g and the acceleration of the y-plane will change from approximately 10g to 0g. If falling to the left side occurs, the acceleration of the x-plane will change from approximately 0g to 10g and the acceleration of the y-plane will change from approximately 10g to 0g. If falling to the right side occurs, the acceleration of the y-plane will change from approximately 0g to -10g and the acceleration of the y-plane will change from approximately 10g to 0g.



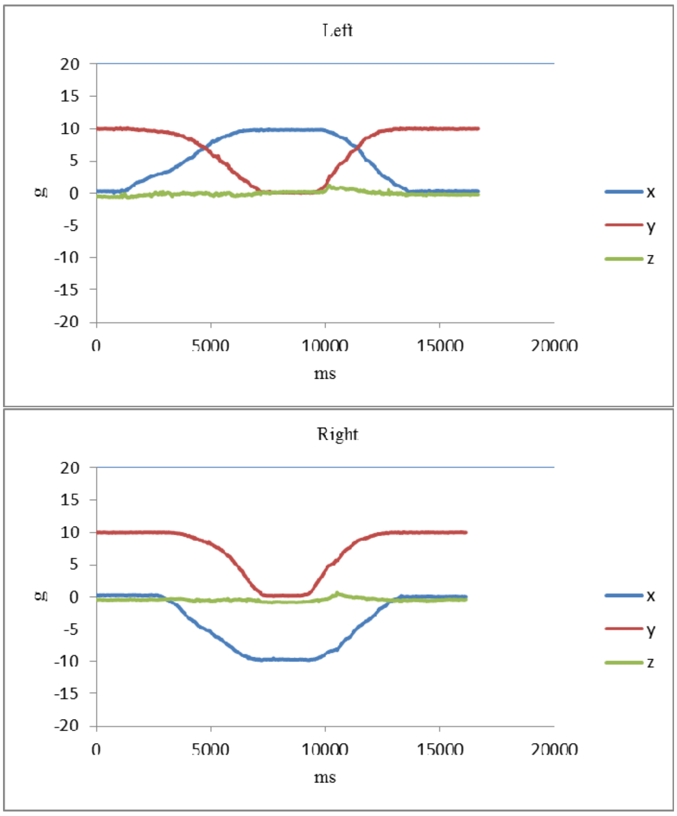


Figure 1. Illustrates the results of tri-axial acceleration for falling to the front side, back side, left side, and right side.

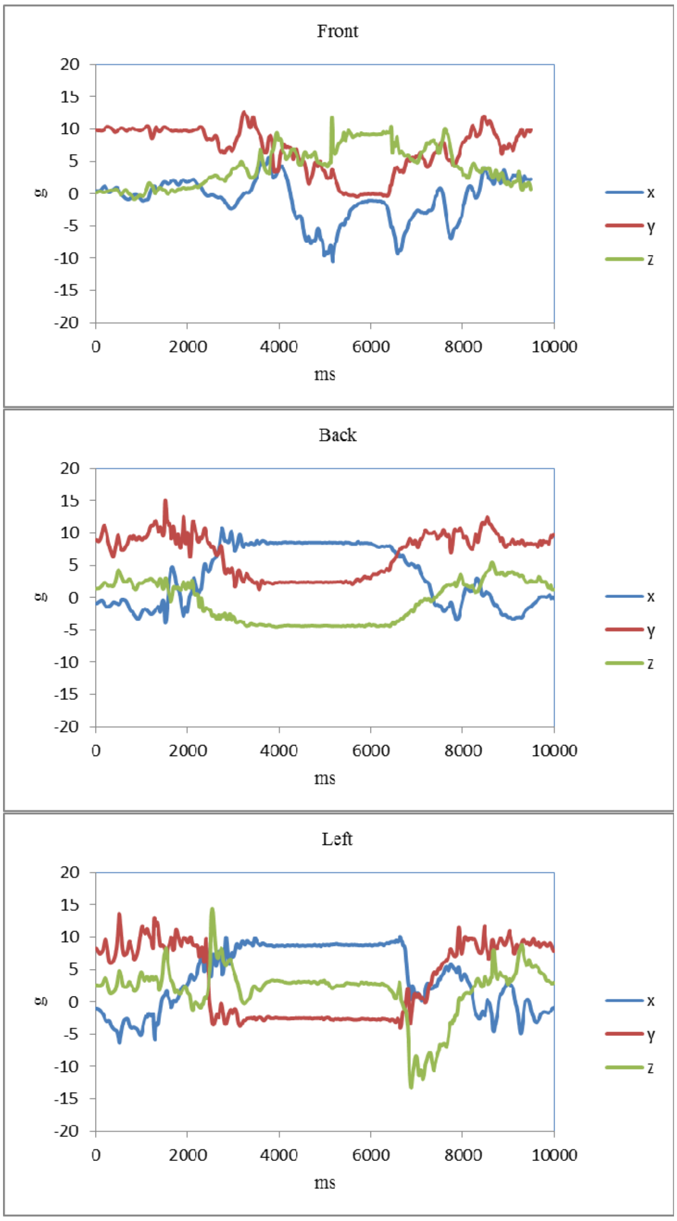
For fall detection, the algorithm developed in this paper is emphasized on time to change the acceleration of any plane; for example, the duration of z-axial acceleration from 0g to 10g. If the duration is less than the time spent to perform normal ADLs, the algorithm will decide as a fall. In other words, if any x-, y-, or z-axial accelerometer changes approximately 10g within a short period of time learning from the user's ADLs, a fall incident is detected.

III. Results

The appropriate time duration to detect a fall can be obtained from a simulation of ADLs in terms of lying down regularly. Then, the algorithm will announce as a fall if any axis change approximately 10g within time limited which is less than time to spend for regular ADLs. From the experiments with a subject who is male and 33 years old, the subject put the smartphone in the pocket of the shirt and acted normally to perform ADLs in terms of lying down to obtain the time duration for fall detection.

While he was lying down to the front side, he took time 1,912 milliseconds to change the y-plane form 10g to 0g. Then, while he was lying down to the back side, he took time 1,168 milliseconds to change the y-plane form 10g to 0g. After that, while he was lying down to the left side, he took time 427 milliseconds to change the y-plane form 10g to 0g. Finally, while he was lying down to the right side, he took time 885 milliseconds to change the y-plane form 10g to 0g.

Obviously, the activity that the subject spent the minimum time which is 427 milliseconds is lying down to the left side. Therefore, this time value is appropriate to apply in the algorithm to detect any fall of the subject. In this case, the smartphone will announce as a fall whenever any x-, y-, or z-plane changes 10g within 427 milliseconds.



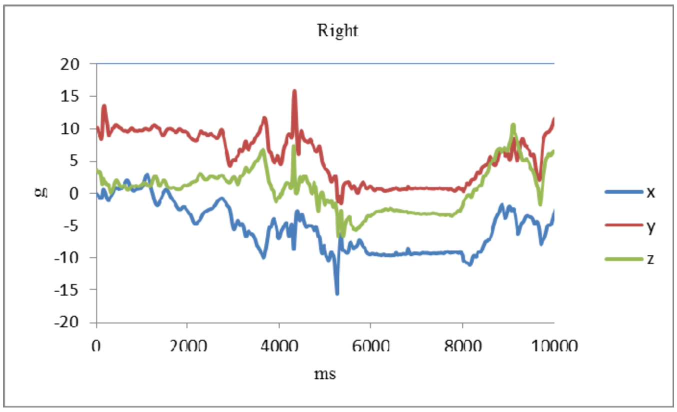


Figure 2. Illustrates the experiment results of lying down to the front side, back side, left side, and right side by a subject.

IV. Conclusion

In this paper, we seek a simple algorithm to detect a fall. With less calculation, the device can quickly distinguish between a fall and a normal ADL. Also, as the smartphone technology is currently in very advance, it includes several sensors to come along. The sensors building in the smartphone are very useful in every field of measurements even in medical engineering. The tri-axial accelerometer is one sensor available on the smartphone and one application is to use for fall detection. From the study, the simple algorithm can be applied for fall detection by observing any change of x-, y-, or z-acceleration 10g within time limited obtaining from ADLs in terms of lying down. The advantages of using the smartphone as a fall detector are that it can alarm or call out for help. It is also getting cheap and comfortable to use or mount.

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