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Development of Fall Risk Detector for Elderly

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Abstract

In Malaysia, falls has become the most common injuries for elderly. Therefore, a wearable fall detector device is created to decrease the risk of serious injury among elderly. The device consists of an accelerometer (ADXL345) as a sensor, an Arduino Nano as a microcontroller, and a Global System for Mobile Communications (GSM) as a notifier. A group of 15 young people participated in performing several sets of different falls and ADL (daily life activities) to determine the ability of the device. The result shows a good functioning performance by 92.6% sensitivity to detect fall and 89.3% specificity in discriminate fall from daily life activity.

Keywords: *Fall; Accelerometer; Daily life activity*

1. Introduction

Falls are conspicuous traits among the causes of unintentional injury. It can happen in several ways. A fall can be intrinsic, where some actions or conditions affects the body posture, or can be extrinsic, where the factors of environment acts as main contributor of the falls, or by the combination of both of it [1]. Falls also can be classified as injurious and non-injurious where the risk factors for these two types can be diverse [2, 3].

One of the most important risk factors involving falls is the weakening of the muscle [5], especially in the legs. This often happens to the older people who has weak muscle strength, flexibility and as well as their weak endurance. Poor balances of the body is the other key factors to these falls. Blood pressure that drops too much when getting up from lying down or sitting [4] can also increase the incident of accidental falling. In addition, reflexes that have slower reaction can also contribute to falls. This is due to the longer the reaction time taken before falling, leading to the increase in difficulty to balance the body.

Fortunately, the advancement of technology has made the fall detection system to be achievable. The technology today have made detection for falling event by monitoring the people and consequently provides emergency support to the people in need to be achievable. Rapid growth of the population of the elderly has given rise to the development of the fall detection technology for them. The use of advance sensors, communication and computer technologies have made the fall detection system to be more viable [5].

2. Literature Review

2.1. Existing Fall Detection Research and Development

Due to the fall incidents that arise from among elderly have resulted in an increase in the cost of medical services, serious injuries and sometimes can lead to fatalities, there are many researchers that have conducted a number of research and development on the fall risk detection as well as the prevention of the fall.

The previous researches can be categorized into three types of approach which are through, ambience device, camera-based and wearable device. Each of it has its own advantages and disadvantages. The Table 1 shows on the summary of the three types of approaches for fall detectors that have been introduced.

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Table 1. A summary of three types of approaches for fall detector [6].

	Defination	Advantages	Disadvantages
Wearable Device	The user wears device with installed sensor	Cheap: Easy to set up	The sensor is intrusive to user; User tends to forget to wear the device
Camera-based	Visualization with camera	Monitor multiple events simultaneously; non-intrusive; recorded video available for post verification	Very sensitive to lighting condition; only applicable for indoor; residents feels like being watch.
Ambience Device	Use multiple installed pressure sensors to collect data	Cheap and non-invasive	Cannot differentiate if the pressure from the user or object; Cannot visually verified; Expensive

3. MEMS Accelerometer Technology

Based on the article written by Ning Jia, he stated that the technological advances in microelectromechanical-system(MEMS) accelerati -on sensors have made it feasible to design a fall detector placed in the three-axis integrated MEMS(iMEMS) accelerometer [7]. The iMEMS accelerometers can sense the acceleration on one, two or three axis by combining the micromechanical structures and electrical circuit into a single silicon chip. The accelerometer offers wide settable ranges of acceleration gravity (g), depending on the applications. It can be presented in analog or digital outputs. This feature offers convenient and flexible solutions to the user. The iMEMS accelerometers technology can be used to detect the changes in acceleration that occur in free falls. Figure 1 (a-d) below shows on the accelerometer responses for different types of motions which are walking downstairs, walking upstairs, sitting down and standing up from a chair.

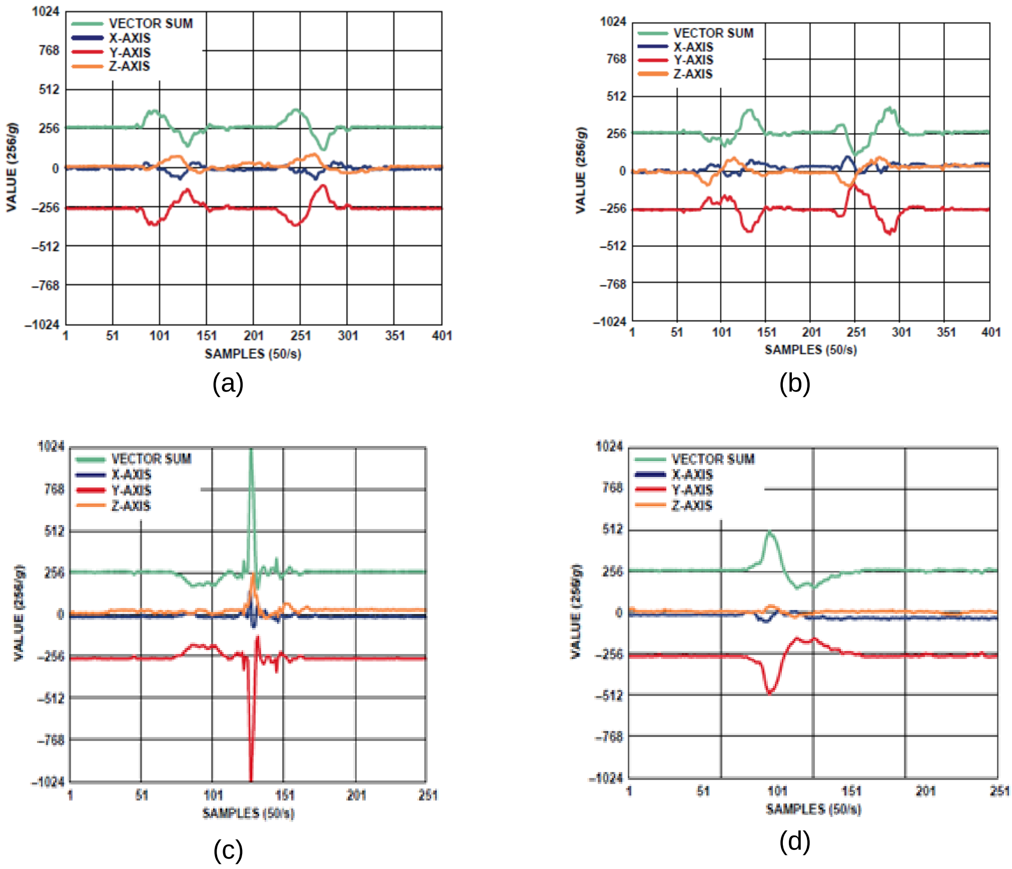

Figure 1. Accelerometer responses to different types of motion [8] (a) walking downstairs (b) walking upstairs (c) sitting down (d) standing up.

The accelerations during free falls are completely different from the accelerations happened that are shown in Figure 1.0 (a-d). Figure 2 illustrates the acceleration changes curves during an incident of free fall. Four critical differences in terms of the characteristic for free falls can be seen as the criteria for fall detections are, explained in details in the following [8]:

a. Start of fall: The incidence of weightlessness phenomenon will always happen at the start of the fall. The vector sum of accelerations will tend toward to 0 g and less than 1 g. The duration of the free fall will be depending on the height.
b. Impact: Human body will bump the ground or other object after experiencing weightlessness. A large shock can be seen in the acceleration curve graph.
c. Aftermath: After falling and having a bump, the human body cannot rise instantly. The human body will remain in a motionless position for a short period of time. This shown as an interval of a flat line on the acceleration curve graph.
d. Initial status: The individual’s body will be on a different posture after a fall. The static acceleration in three axis will be different from the initial status before and after the fall.

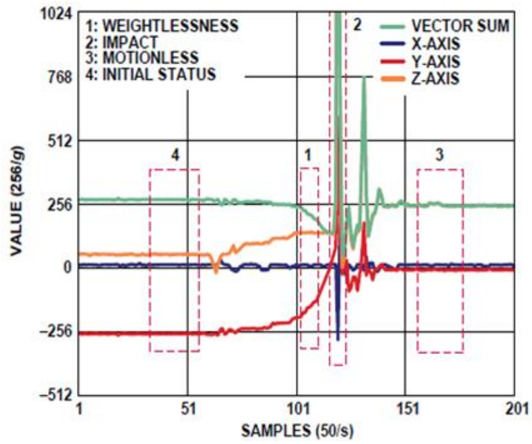

Figure 2. Acceleration curves during process of falling.

4. Methodology

The system is controlled by the Arduino Nano microcontroller, an open source electronics prototyping platform which is commonly used in designing interactive devices. The accelerometer ADXL345 is used as the sensor in the device for the purpose of fall detection. The threshold value for the sensor is 0.75 g was used in this experiment [8]. Figure 3 shows the sensor and the placement of the sensor. The subjects wore the wearable sensors at the waist dorsally and performed the test. To avoid the motion artefacts, the sensor was tightly attached to the waist. Accordingly, the sensor was slotted in a belt that was attached to the waist as shown in Figure 3(b).

The buzzer will act as an alarm to notify the people around and act as a benchmark for the seriousness of the falls. Within 1 minutes, if the alarm is not switched off by the user, the system will classify it as a heavy fall and assume that the user is unconscious. The push button is used to switch off the alarm sound if false fall is detected. The GSM (Global System for Mobile Communications) will be communicating with the caregiver/guardian if a heavy fall is detected. It will send a notification message to the caregiver to inform them. Fifteen (aged 20-25) young adult from Universiti Teknologi Malaysia, participated in the experiment. Each subject performed 3 time for each of the activities to determine test the device. Although there are no elderly were participate for this experiment, for a safety reason, young adult sample were used as a control before the real elderly sample will be test in our next experiment. The system overview is shown in the Figure 4, while the flow charts of this project is shown in Figure 5 presents the flow of the wearable fall detector among the elderly.

(a) (b)

Figure 3. (a) The wearable sensor. (b) The sensor placement

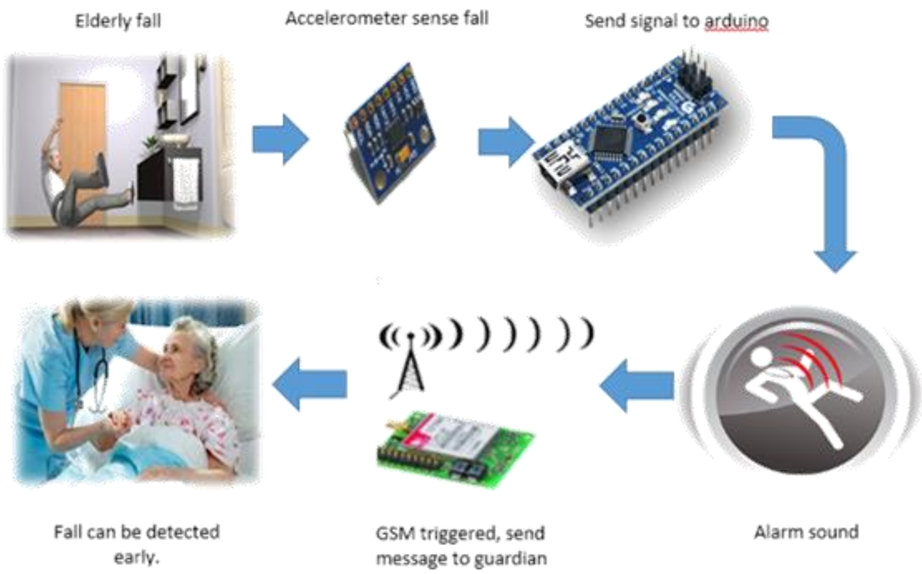

Figure 4. System Overview

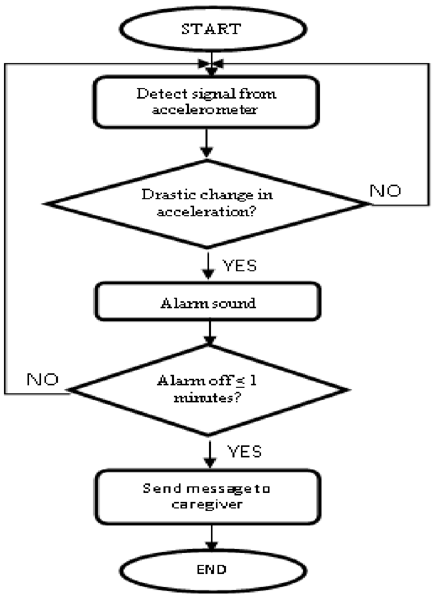

Figure 5. Flowchart of the device

5. Analysis

This study consists of two sets of tests involving 15 young adult with the age range between 20-25 years old to determine the ability of the device. The statistical analysis to evaluate the fall detection are as follows [9]:

a. True positive (TP): A fall is detected
b. False negative (FN): A fall occurs, but the device does not detect it.
c. True negative (TN): A daily life activity (ADL) is performed, the device does not declare a fall.
d. False positive (FP): The device detects fall, but it does not occur.

5.1. Test for Sensitivity

The test for sensitivity is to correctly detect a falls. Each of the subject required to perform three types of falls which are forward falls, backward falls, and lateral falls either left or right falls. Each of the falls will be repeated three times. The result is recorded in the table to show the sensitivity percentage of the device which can be determined by using the equation provided in (1).

$$Sensitivity = \frac{TP}{TP+FN} \times 100\% \quad (1)$$

5.2. Test for Specificity

The test is for specificity is to determine if the device detects a fall even though the particular activity was a non-fall activities or known as daily life activities (ADL).The subject needs to perform three times for each ADL task. The tasks include sitting down and standing up from a chair, lying down, walking and bending down to take something from the floor. The result is recorded in the table and the specificity percentage can be calculated by using the equation provided in (2).

$$Specificity = \frac{TN}{TN+FP} \times 100\% \quad (2)$$

6. Result and Discussion

Based on the result in Table 2 it shows that the device has achieved average sensitivity percentage of 92.6%. The sensitivity of the device is relatively acceptable for a single accelerometer sensor. Moreover, the reliability of the results is constrained with the actions performed. These activities were performed with protections which results in a much less impact than the real life scenarios. The real fall might show a better performance result.

Based on the results shows in the Table 3, the device has achieved an average specificity percentage of 89.3%. The percentage for the specificity is quite low. It is maybe due to the similarity in terms of posture of some activities to the posture of falling down. False alarm is a common issue faced by many of the fall detectors. Therefore to overcome this issue, the device has a cancel button located on the wearable device to prevent any false alarm.

Table 2. Result of sensitivity test

Types of falls	Sensitivity Percentage (%)
Forward falls	91.1 %
Backward Falls	100 %
Lateral Falls	86.7 %
TOTAL	92.6 %

Table 3. Result of specificity test

Types of ADL	Specificity Percentage (%)
Sit down	93.3 %
Standing up	95.6 %
Walking	95.6 %
Lying down	75.6 %
Bending down	86.7 %
TOTAL	**89.3 %**

7. Conclusion and Future Work

The result of this wearable fall detector device shows that it can detect fall with 92.6% sensitivity and discriminate falls from ADL with 89.3% specificity. Based on the result, the device has shown a good functioning performance. The false alarm that is produced by the device can be reduced by a cancel alarm that has been provided on the device.

The further development that can be done to improve the wearable device is by providing a global positioning system (GPS) to the wearable device. It will help the caregiver or any person that receives the message of the fall to easily identify the location of the critical falls that has happened to the elderly. It will also decrease the time respond in giving assistance to the elderly.

Another innovation that can be done to the project is by reducing the entire size of the device by using surface-mount technology (SMT) method which use smaller components and have better mechanical performance under vibration conditions. It will make the device to be even more comfortable to wear. The power supply may also be switched to lithium battery in order to reduce the size of the device.

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