DESIGNING A TECHNOLOGY FOR THE ELDERLY: ELDERBAND AND ELDERALERT

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Abstract

The number of adults aged between 60 and older experiencing fall is alarming. Therefore prevention of fall among elderly assisted by technology is this research priority. There are various fall detection devices and smartphone applications available in the market which all have the same aim, acting as a medium to notify the emergency contacts of the location and time when user falls. The users of those devices and applications are mainly elderly who may have suffered from falls or have difficulties which may lead to more serious injuries. However, there are a number of constraints posed by these available fall detection devices and applications. The fall detection devices are expensive and some require monthly subscription. The devices need to be carried with the user at all times to ensure the fall can be detected. Therefore, this research aims to minimize the mentioned disadvantages with the introduction of ElderBand and ElderAlert. ElderBand is a smart wearable which is lightweight and can be worn by user at all times. ElderAlert is a smartphone application which enables notifications to the emergency contacts in case of a fall. Both ElderBand and ElderAlert are connected via Bluetooth for the fall detection system to work. ElderBand transmit acceleration data continuously to ElderAlert to estimate a fall. It then notifies the emergency contact when a fall is detected. This research provides ideas on how technology could be designed for better quality of life for the elderly.

Keywords: Fall detection, elderly, smart wearable, smartphone application.

1.0 INTRODUCTION

When human reached a certain age group, they are considered as old people or the elderly. To define the specific age group for the elderly is quite abstract as it differs from a number of factors such as opinions, culture, country development and such. However, the age of 65 are widely accepted by most developed countries to categorize a person as elderly [1]. In medical term, elderly is defined as *"the normal aging process is characterized by a progression of physiologic events that occur throughout the life cycle"* [2].

When a person grows older in age, the physiological condition of the body declines and this is where the term 'frailty' begins. Frailty is a clinical term which addresses the decline of physical reserve and function of a person due to aging process which causes increase in vulnerability to medical problems. Gerontologists who are doctors specialized in treating the elderly suggest that a person is considered as frail when he or she has the following symptoms that include: loss in weight, general exhaustion, weakness in strength, slow walking speed and low physical activity levels [3]. The occurrence of fall among elderly is highly associated with frailty. A few factors which lead to falling among elderly include decline in muscle tone, balance and flexibility, diseases such as Alzheimer, stroke and arthritis, surgery and environmental hazards [4]. Elderly who experience fall may not be able to bear with the consequences that may be serious such as fractures and traumatic brain injuries. In some cases, fall could lead to death and other impairment.

Due to the above reasons, fear of falling may be developed among the elderly. It will then cause reduction in doing physical and social activities such as exercising, walking, going out with families and friends and such. When a person become less active, the motor skills of the body will decline, further increases the likeliness of falling [6].

There are one among three adults over the age of 65 in United States of America fall each year which results in more than 20,000 death tolls, 2.4 million emergency visits and more than $30 billion in medical costs. In United Kingdom, it is estimated that there are 3 million falls annually. It is also mentioned that half of the people who had fallen before will fall again within a year while around a quarter of those who fall suffers from serious injuries [5].

From the studies mentioned before, it is obvious that fall is one of the risks that are faced by the elderly and the consequences are considerably serious. Of course, it is non-arguable that prevention is better than cure, in which, treatments can be done once frailty is detected. As for a start, the elderly could be helped with a secured living environment and fall preventive measures such as installing handles, anti-slip mats, sturdy furniture and such at home. However, falls may not be totally avoided through preventive measures. On the other note, it is important to note that falls may pose more serious problems if the person could not get up straight away or call for help. Remaining static on the floor or ground after a fall for a few hours may lead to problems such as dehydration, loss of body temperature (hypothermia), lung infection due to bacteria (pneumonia), muscle breakdown which lead to kidney damage (rhabdomylosis) and skin sores [6].

Therefore, due to the above factors, this paper intends to inform a technology solution that could benefit the elderly. The technology solution is known as the "ElderBand & ElderAlert". "ElderBand" is a smart wearable device and is connected to an Android smartphone application, known as "ElderAlert". Thus, the objectives of this paper are twofolds, as stated below:

i. To inform ways technology could be designed to help the elderly when fall is detected. This could be of a great help for a better living condition among the elderly.
ii. To evaluate the accuracy of fall detection rate of the ElderBand and ElderAlert.

This paper is structured as follows. First, in Section 2.0, previous work that has designed various solutions to detect fall among elderly are presented. The techniques adopted for fall detection are also discussed in this section. The methodology followed during development phase is presented in Section 3.0. In Section 4.0, the ways ElderBand and ElderAlert are constructed are explained in great detail. The benefit of this solution is discussed in the conclusion section, followed by future recommendations to a few limitations.

2.0 LITERATURE REVIEW

No doubt that there are a number of fall detection devices and applications available in the market now. It is due to the extensive research and development done by different personnel with different methods to provide solution to the same problem. A few well-known fall detection devices and applications are carefully studied as shown in Table 1.

Referring to Table 1, the first solution is known as the Smart Fall Detection application. This application uses Artificial Neural Network (ANN) to process the acceleration signal from the accelerometer in the smart phone. The ANN was trained with 1000 samples of fall and non-fall patterns to detect the fall among elderly. The application uses three states which are fall-checking state, which is to read the acceleration data and search for fall occurrences and using the ANN. If ANN detects a fall, the application will enter to long-lie state where the application checks for a period of no movements. If there are movements, it goes back to the fall-checking state. If there are no movements for 30 seconds, the application will enter fall-state where the siren is played back and sends text message to specified emergency contact. If there are GPS data available, the application will send a second text message with the GPS location of the fall (Kerdegari, 2011).

The second application shown in Table 1 is known as Fade. This is another free Android application which detects fall using the information collected from the smartphone's accelerometer. It is designed and created for people who are prone to falling when left alone without any supervision. Fade is able to issue alert message to pre-defined contacts after detecting a fall via SMS and email. The alert message contains time and place where the fall occurred. Besides that, Fade can also make a phone call to the contact while automatically activating the smartphone's speaker.

The biggest setback of these two solutions (i.e. Smart Fall Detection and Fade) to elderly is the fact that they have to carry their smartphones installed with the apps anywhere and everywhere. It is quite impossible to demand elderly to carry their smartphones all the times especially to places such as toilets and kitchens.

Further, the third solution shown in Table 1 is a 24/7 Automatic Fall Detection Alert System developed by Bay Alarm Medical. The system consists of a base station and a help button. The base station is required to be plugged into the house landline and also it has a power adapter to be plugged in. The base station acts as a wireless medium for the help button with approximately 180 meters range. The help button acts as an automatic fall detection device for which the user has to carry the help button with them.

Although this system is successful, the Bay Alarm Medical Company claims that no automatic fall detection system will detect every fall but their system is optimized to reduce false alarms. This system is priced from $33.95 per month and additional charges for additional help buttons or similar devices.

Lastly, referring to Table 1, the mobile personal emergency response system, GoSafe is developed by Philips Lifeline. Which can be used either indoors or outdoors provided there is mobile connectivity. This system includes a communicator and help button. The communicator is able to dial the response center when the button is pressed within range. It also acts as a speakerphone for call conversations so that the call can be heard clearly. It needs to be plugged into a power source but has up to 30 hours of backup battery power. This system requires monthly subscription of $54.95 and one time purchase of the GoSafe pendant for $149 (Philips Lifeline).

The Bay Alarm Medical and GoSafe have to be carried all the times. It is quite heavy for elderly people. Thus, it is expected that elderly might not be keen to carry the help button at all times. This will reduce the efficiency of having these devices.

Further, there are a number studies being done to produce the best fall detection devices using different types of sensors. The reason for using sensors for fall detection is mainly to provide acceleration data which is either calculated by meters per second squared or in G Force to application or device to be interpreted into confirming a fall. This is important as the main objective of these studies is to reduce false alarms falls, and to increase fall detection rate to the maximum.

This research mainly uses accelerometer to detect fall. Accelerometer is an electromechanical device that is used to measure acceleration force. The acceleration force is divided into two, static, which is the continuous force of gravity; and dynamic movements or vibrations of the accelerometer [7]. There are mainly two types of accelerometer, those are two-axis and three-axis accelerometers. Two-axis accelerometer is only able to measure acceleration along x-axis which is side-to-side angle and y-axis which is the forward and backward angle [8]. This research uses the three-axis accelerometer that has an additional z-axis, which is to measure the gravity pull in action with the device as shown in Figure 1.

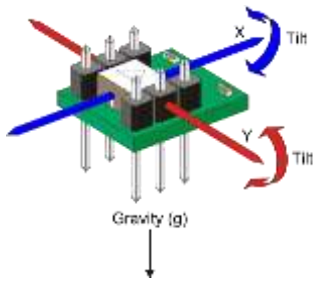

Figure 1 Three-axis accelerometer

In detecting fall, this research uses accelerometer to see the changes in motion and the body position of the user who wears the device when falling. The acceleration data from the accelerometer are continuously analyzed with fall detection algorithms to determine whether a person is falling [9].

On the other hand, there are numerous fall detection algorithms developed by previous researchers with the aim to increase the accuracy of fall detection rate and to decrease the false alarm rate. This research has adopted the fall detection algorithm shown in Figure 2. This fall detection algorithm is chosen as it is proven to be successful in determining falls from the acceleration data gathered from the accelerometer. The thresholds of the readings collected from the sensors (i.e. accelerometer) can determine whether the measurement taken indicates a fall. Referring to Figure 2, when the readings taken spike above or drop below the normal threshold, a fall is indicated [14]. Then, the fall detection devices will take necessary measures after the fall event has occurred.

Table 1 Previous Solutions designed for Detecting Fall

	Smart Fall Detection	Fade	Bay Alarm Medical 24/7 Automatic Fall Detection Alert System	Philips Lifeline GoSafe
Developer	Hamideh Kerdegari (UPM, Malaysia)	Instituto Tecnológico y de Energías Renovables (ITER, Spain)	Bay Alarm Medical (US)	Philips Lifeline (US)
Benefits	Do not need extra devices except own smartphone.	Do not need extra devices except own smartphone.	High range of 180 meters from help button to base station. Help button is waterproof and has 2 years of battery life.	Help button can work separately from the communicator. Able to call response center from the help button. Help button is waterproof and has 7 days of battery life between charges.
Disadvantages	Have to carry the smartphone at all times.	Have to carry the smartphone at all times.	Have to carry the help button at all times which is heavy. Have to be within range with the base station.	Have to carry the help button at all times which is heavy.

Technology used	Smartphone with built-in accelerometer. Artificial Neural Network (ANN) with trained fall and non-fall pattern samples.	Smartphone with built-in accelerometer. Threshold-based fall detection algorithm.	Help button with built-in accelerometer and base station acting as landline communicator Threshold-based fall detection algorithm	Help button with built-in accelerometer, gps sensor and mobile network with communicator acting as a built in speaker and microphone Threshold-based fall detection algorithm
Subscription fee	Free	Free	$33.95 monthly	$54.95 monthly Help Button: $149

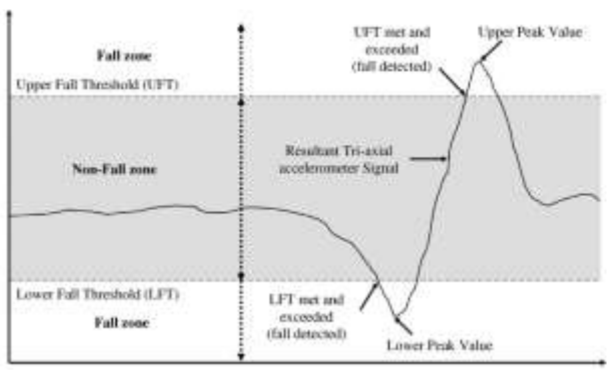

Figure 2 Fall detection thresholds chart

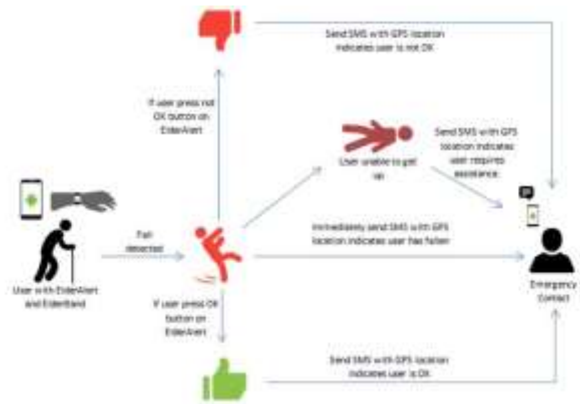

Figure 3 ElderBand and ElderAlert System Process Flow

3.0 METHODOLOGY

In developing the ElderBand and ElderAlert, this research adopts the evolutionary prototyping methodology. Evolutionary prototyping enables the developer to build ElderBand and ElderAlert from scratch and gradually improving it according to what is best for the elderly people. The development evolves in cycles and there are numerous changes and enhancements implemented in each cycle. One of the main benefits of adopting evolutionary prototyping method is the ability to develop the prototype at the early stage. The prototype is gradually improved whenever defects and missing functionality detected. Adopting this method allows development time to be shorter and cost-effective.

During the earlier part of the development stage, specifications and ideas related to ElderBand and ElderAlert were compiled. Details of each specifications and requirements were clearly defined at this stage. After defining the specifications, system process flow and conceptual modelling were designed accordingly. Following the process flow as shown in Figure 3 and the modelling designs, ElderBand and ElderAlert were then developed in stages. Testing did take place at the end of each stage. The prototype was refined several times according to errors found during testing. At some stages, additional features were introduced to make the prototype works better.

In the end, ElderBand and ElderAlert are completed and met the initial requirements and specifications set. Nonetheless, despite the testing and refinement conducted, there were still some rooms for improvements. These limitations are discussed at the end of the next section.

The most important lesson learnt during the project development lifecycle is to design a technology solution that caters the needs of the elderly. Throughout the project, the functions are designed with elderly people in mind. Therefore, it is important to note that companies and designers should pay attention to the needs of the elderly when developing technology intent to them.

4.0 RESULTS AND DISCUSSIONS

As mentioned before, the main significances of this research is to develop technology that could help advancing better living for elders. Therefore, the research aims is always to improve the possibility of the elderly to live longer at home with minimal assistance from anyone but being assisted by means of technology. Thus, the Elderband and ElderAlert was design with the following criteria:

i. **Identify fall of elderly**: When an elderly falls, ElderBand will be able to detect the fall from the reading captured by the accelerometer. ElderBand will then send a signal to the ElderAlert.

ii. **Initiate alert to surrounding**: When ElderBand and ElderAlert detect a fall, ElderAlert will initiate loud sound alert which can be heard by people within the area so that they could react accordingly.

iii. **Send SMS message to emergency contact**: In cases where elderly might fall but are unable to react, ElderAlert will send and automatic SMS message with GPS location to the emergency contact to inform about the fall and for them to react accordingly.

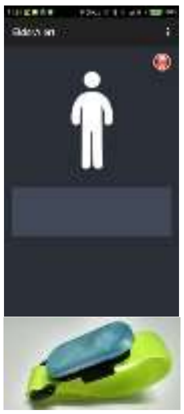

Figure 4a ElderAlert (top) and ElderBand (bottom)

Figure 4b Graph capturing movement data sent by the ElderBand

Figure 4a presents the ElderAlert mobile application main screen and the ElderBand. User needs to tap on the application screen to be connected to ElderBand. If ElderBand and ElderAlert are not connected to each other, the standing stick figure is white in color and the traffic button is red in color. When ElderBand is connected, the stick figure will be changed to a green walking stick figure and the traffic button will turn to green, as shown in Figure 4b. This indicates that there are signal being send from ElderBand to the ElderAlert. The graph in Figure 4b is showing the acceleration movement data captured from the ElderBand. When there are movements captured by ElderBand, signals of movements are send to ElderAlert. ElderAlert marks those movements in graph.

Figure 5a indicates that ElderAlert detects a fall. When ElderBand's movement is unusual and above the threshold value of a normal movement, it sends a signal to ElderAlert, as shown in Figure 5a. If the elderly is able to help him/herself, they shall press the OK button. ElderAlert will then send an SMS message to the emergency contact notifying the user is fine. On the other hand, if the elderly falls badly and in a serious condition, ElderAlert's timer will starts an emergency countdown. Once the emergency countdown is over, which indicates that the elderly fails to perform any action, an automatic alert emergency message with location will be sent to the emergency contacts. A sound emergency alert will also be played continuously to alert any available assistance, as shown in Figure 5b.

Figure 5a ElderAlert detects a fall

Figure 5b Emergency Alert

The ready prototype has gone through lab testing with selected participants. However, since ElderBand and ElderAlert are created specifically for the elderly, it is impossible for them to be part of the testing exercise. Elderly people are too fragile and frail to be asked to mimic falls for testing purposes. Thus, a group of martial art students were selected as test subjects. They are chosen due to the fact that they are well trained on how to fall correctly to ensure a safe landing. The testing has been conducted in martial arts room which is padded with mats to prevent bad injuries when test subjects perform the act of fall.

Figure 6 presents the ways test subjects are required to walk normally and perform different acts of random fall with ElderBand strapped on their wrist. With the various random falls perform, acceleration readings signal when fall occur were sent to ElderAlert. How ElderAlert function when each fall took place were noted. Any unnoticed fall indicates a failure of ElderBand and ElderAlert to function well. Refinement and modifications were then conducted according to the testing logs, as shown in Figure 7.

In Figure 7, the testing logs shows 3 different columns. The first column labeled "*Acc Data*" presents the continuous acceleration reading from ElderBand. The second column labeled "*Low*" logs the acceleration readings below 1g, which is equal to the normal gravity pull. Acceleration reading below 1g means that the person is in a free fall state. Lastly, the third column labeled "*High*" logs the acceleration readings above 2g. Acceleration reading above 2g indicates that the elderly is experiencing some movement that caused acceleration such as a swing of the arm, picking up something, clapping hands and such.

The importance of logging acceleration readings during testing is to know the range of acceleration readings that indicated falls of the test subjects. Besides that, by knowing the range of the acceleration readings that indicates falls, the accuracy of fall detection of ElderBand and ElderAlert is increased.

Figure 6 Recording the acceleration data when fall *occurs*

Figure 7 Acceleration data logged when fall occur

Table 1 Fall Acceleration Sample Data Table

No.	Subject	Age	Height	Weight	Fall Acceleration Sample Data (g)				
1	A	21	160cm	70kg	2.63	2.51	2.52		
2	B	18	162cm	58kg	3.46	3.37	3.46		
3	C	18	165cm	62kg	2.54	3.33	2.86	3.20	3.03
4	D	21	180cm	70kg	2.96	2.86	3.54	2.87	
5	E	18	170cm	51kg	2.57	2.92	2.85	2.83	
					Fall detection threshold : 2.6g to 3.5g				

Sample of data gathered from 5 test subjects are shown in Table 2 and the threshold which indicates fall is determined to be around 2.6g to 3.5g. However, the threshold which indicates fall for this research could not be concluded as 100% accurate. This is due to the fact that there are few other factors that may contribute to the accuracy of a fall, that include:

i. The sensitivity of ElderBand as the built-in accelerometer is only used for prototyping purposes.
ii. The test subjects are healthy young males. The prototype couldn't be tested on frail elderly as it requires the test subjects to fall frequently to log the acceleration data.
iii. The condition of the testing ground is not realistic as the mat may absorb impact to a certain degree that it may not present the actual fall impact in real life situations.

5.0 CONCLUSIONS

In conclusion, this paper presents the ways ElderBand and ElderAlert were designed and constructed as a technology that could help the elderly. Although most of the technology implemented are often not elderly-friendly, this research found ways that could allow elderly to still benefit from technology usage.

First, ElderBand and ElderAlert are designed in such that it does not require the elderly to key in or input any data into the application. This is important as most of the elderly are technology illiterate. They often reject a technology when they do not know how to use it, difficult to use it and fail to make it functioning. Thus, ElderBand and ElderAlert were designed in such that the elderly could use the technology just by switching on their ElderAlert application and putting the ElderBand on their wrist.

Secondly, the technology created is lightweight, waterproof and intact to the wearer. This is important as elderly people often find it annoying to carry heavy equipment with them all the time. They also often forgot to carry gadgets (e.g. phones) and might left it somewhere that is hard to find. Therefore, ElderBand was designed in such that it is strapped to the wrist at all times and very light. On the other hand, ElderAlert could be left anywhere comfortable (e.g. near the bed) as long as it is within 50 meters of the wearer of the ElderBand. Thus, this will make the elderly feel comfortable and not annoyed by something which is heavy and has to be carried at all times.

Finally, ElderBand and ElderAlert do not require any installation in the house. It runs on built-in phone Bluetooth and GPS functions. As long as the Bluetooth and GPS are switched on at all times, the ElderBand and ElderAlert will be fully functioning.

Therefore, it is important to note that technology might be used by the underserved community that includes the elderly people. However, it should be designed in such that it allows them to live independently and safe. It is not going to be the same technology designed for younger people. For older people, technology needs a higher value proposition.

Nonetheless, due to the restrictions of few factors such as time frame, development skills, and such, ElderBand and ElderAlert are not as perfect to be considered as a ready product. There are still rooms for improvements. First, since tri-axis accelerometer is able to measure the tilt angle of the user, an additional tilt angle measurement algorithm can be added on top of the fall detection algorithm which is using acceleration readings to increase the accuracy rate of fall detection. Secondly, since the electronic component of ElderBand is only suitable for prototyping purpose, in future extension of ElderBand's functionality, better electronic components should be used in ElderBand for a longer-lasting time-span.

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