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Research paper

Development of a Fall Detection System for the Elderly

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Abstract:

Fall detection is a major challenge especially for the elderly as the decline of their physical fitness.There are various fall detection devices and smartphone applications available in the market butmany are found pricy and not feasible for elderly usage. Some free or cheap device need to be carried by the user at all times in managing falls incidents and elderly will not religiously follow that requirements. Therefore, this project aims to merge the advantages of both fall detection devices and applications.By applying the evolutionary prototyping methodology, ElderBand and ElderAlert were created to assist the elderly in detecting and managing fall incidents. ElderBand is a smart wearable which is lightweight and can be wear by the user at all times; while ElderAlert is a smartphone application which enables notifications to the emergency contacts in a case of fall incidents. ElderBand and ElderAlert accuracy were successfully tested and should be able to position the usage of smart wearable with mobile application into agrowing healthcare market.

Keywords: Fall detection app, elderly, healthcare, mobile applications, smart wearable

1. Introduction

According to the study done by National Conference of State Legislatures (2015), 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 falled before will fall again within a year while around a quarter of those who fall suffers from serious injuries (Chartered Society of Physiotherapy, 2014). Therefore, it is obvious that fall is one of the risk beared by elderly and the consequences are considerably serious.

Besides that, according to Rubenstein (n.d.), remain 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. With the growing numbers of elderly who living by themselves, unnoticed falls might lead to fatalities.From the literature review, although there are available technologies to detect and report falls, most of it are expensive and complicated for elderly in Malaysian market.

Therefore, this project was initiated with the intention to leverage on the current wearable and phone devices in developing an affordable yet simple solution that could offer quick assistance for elderly when there is a fall. A smart wearable which is known as “ElderBand” and an Android smartphone application which is known as “ElderAlert”were developed achieved the intention. ElderBand contains necessary electronic modules (accelerometer, Bluetooth and microcontroller.) to record data and sent the acceleration data to ElderAlert, to be processed, which can identify a fall, alerting the surrounding and send SMS messages with GPS location to emergency contact immediately.

2. Literature Review

There are number of fall detection devices and applications available in the market now. Table 1 shows few well-known fall detection devices and applications.

Table 1: List of available Fall Detection Devices and Applications.

	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	Bay Alarm Medical (US)	Philips Lifeline (US)

		(ITER, Spain)		
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 Pendant: $149

Referring to Table 1, the drawbacks of the first two solutions are these applications require the elderly 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 specially to places such as toilets and kitchens. Besides that, the Automatic Fall Detection Alert System developed by Bay Alarm Medical has no automatic fall detection system to 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. Lastly, GoSafe by Philip LifeLine requires monthly subscription of $ 54.95 and one-time purchase of GoSafe pendant for $149. In addition, this device needs to be plugged into a power source but has up to 30 hours of backup battery power.

Therefore, ElderBand and ElderAlert aims to merge both the advantage of current fall detection devices and applications while minimizing the aforementioned disadvantage of both.

ElderBand uses accelerometer, an electromechanical device that measure acceleration force. There are mainly two types of accelerometer; 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 (IHS Engineering360, n.d.). This project uses the three-axis accelerometer that has an additional z-axis, which is to measure the gravity pull in action with the device. In detecting fall, this project 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 analysedwith fall detection algorithms (based on Figure 1) to determine whether a person is falling.The thresholds of the readings collected from the sensors (i.e. accelerometer) can determine whether the measurement taken indicates a fall. Referring to Figure 1, when the readings taken spike above or drop below the normal threshold, a fall is indicated. Then, the fall detection devices will take necessary measures after the fall event has occurred (Bourke et al., 2007).

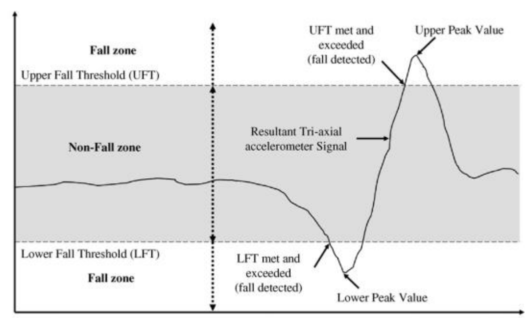

Figure 1:. Fall detection thresholds chart

Bluetooth is used as the connectivity method between the ElderBand and the smartphone with ElderAlert app due to low cost of implementation, low bandwidth and low power consumption to transfer data from the ElderBand to ElderAlert.

3. Methods

In developing the ElderBand and ElderAlert, this research adopts the evolutionary prototyping methodology. The methodology 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. There are numerous changes and enhancements implemented in each cycle. One of the main benefit of adopting evolutionary prototyping method is the ability to develop the prototype at the early stage; and this allows the development time to be shorter and cost-effective.

At 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. Then, system process flow and conceptual modelling were designed accordingly (as in Figure 2). Based on the designs, ElderBand and ElderAlert were then developed in stages.

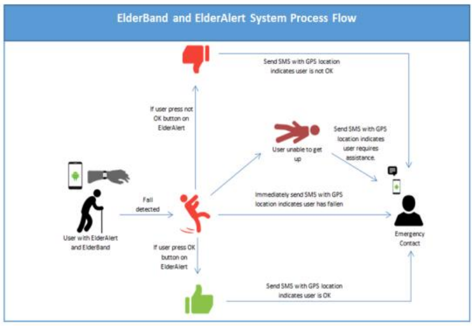

Figure 2:. ElderBand and ElderAlert System Process Flow

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 improve the prototype.In the end, ElderBand and ElderAlert are completed; and met the initial requirements and specifications set.

4. Results

In improving the possibility of the elderly to live longer at home with minimal assistance from anyone, the proposed technology, the Elderband and ElderAlert were designed with the following criteria:

i. **Identify fall of elderly**: When an elderly fall, ElderBand will be able to detect the fall from the reading captured by the accelerometer. It 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**: When an elderly fall, but he/she is unable to react within an allocated time, ElderAlert will send an automatic SMS message with GPS location to the emergency contact to inform about the fall and for them to react accordingly.

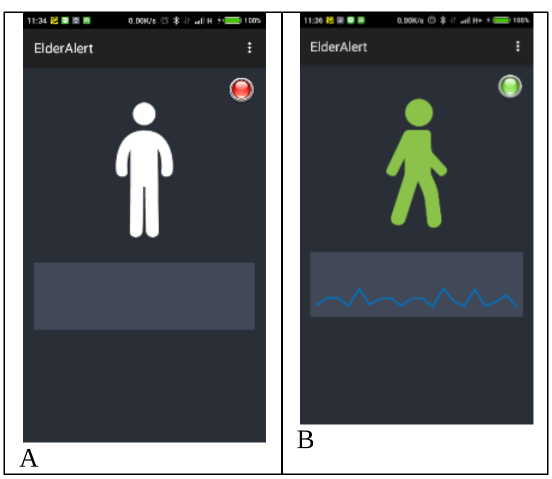

Figure 4: ElderAlert mobile application main screen

Figure 4 presents the ElderAlert mobile application main screen. User needs to tap on the application main 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 (as in Figure 4A). When ElderBand is connected, the stick figure will be changed to a green walking stick figure and the traffic button will also turn to green (as shown in Figure 4B), in indicating 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.

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 falls badly and in a serious condition, Elder Alert'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 (as shown in Figure 5B). A sound emergency alert will also be played continuously to alert any available passer-by /assistance.

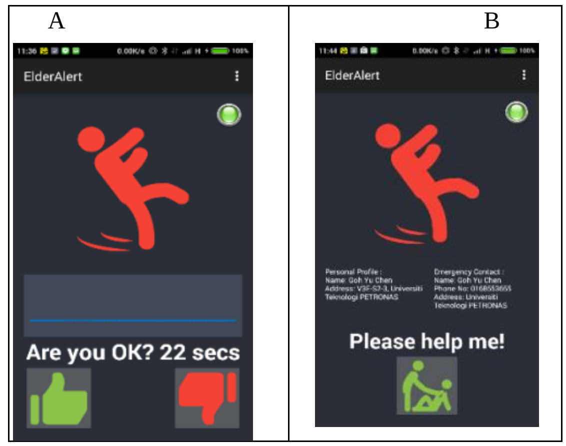

Figure 5: ElderBand screen during fall detection

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.

In Figure 6, the testing logs shows 3 different columns. The first column labelled *"Acc Data"* presents the continuous acceleration reading from ElderBand. The second column labelled *"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 labelled *"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.

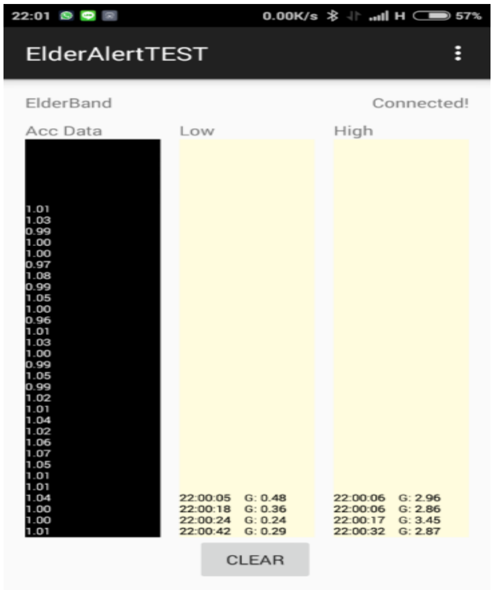

Figure 6:. Acceleration data logged when fall occur

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.

The overall data gathered from test subjects are taken into account and the threshold which indicates fall is determined to be around 2.6g to 3.5g. However, the threshold which indicates fall for this project could not be concluded as 100% accurate. This is due to the fact that there are few other factors that contribute to the accuracy of a fall, that include, the: (1) sensitivity of ElderBand, as the built-in accelerometer is only used for prototyping purposes, (2) test subjects are healthy young males. The prototype could not be tested on frail elderly as it requires the test subjects to fall frequently to log the acceleration data, and (3) 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. Conclusions

This paper aims to focus on the application of computing technology towards monitoring health and wellness among the elderly. It is important to note that technology designed for the elderly need to be different from wearable technology designed for specific area such as fire fighters and rescuers monitoring systems (Magenes, 2010),sensor evaluation for wearable strain gauges in neurological rehabilitation (Giorgino, 2009), and Parkinson's disease 24-hr monitoring (Thielgen, 2004). The enabling technologies are developed yet it is the intention of this study to put a great deal of emphasis on the deployment of these wearable sensors and sensors in an eco-system that focus on monitoring the health and well-being of the elderly. This is aninterestingshift inthe field of wearable technology from the development of sensors to the design of an ecosystemfor a specific purpose (i.e.monitoring the health and well-being of the elderlyas in the case of this project).

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