Wireless Fall Warning System with Real-Time Motion Monitoring

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Abstract

Fall is one of the major causes of serious injury, which include fractures, traumatic brain injury, and death to the elders or people who live alone. A wearable fall detection system is becoming a potential solution thanks to its popular accelerometer sensor and easily implementation. In this study, we proposed a design and implementation of wireless fall warning system with real – time motion monitoring. The wearable motion sensor module received real-time human motion is used in combination with a smartphone through wireless Bluetooth connection. A Fall warning application on smartphone is responsible for wirelessly send fall warning message of subject through GSM service and Google map – based fall location. The implementation of our proposed system shows a great potential solution in supporting elders, decreasing deaths and improve their lives qualities.

Keywords: Fall people, Elders, Fall detection, Real-time motion monitoring

1. Introduction

Fall detection is a major challenge in the field of communal health care, especially for the aged or disabled people or stroke people that require immediate support [1, 2]. Fall people who live alone are found after few hours after fall is very common. Accurate system to identify falls of elders is needed to enable timely support of nearby or remote people. This kind of system will mitigate serious problem to their healths. Human fall process is loosely defined as the sudden change in human orientation from standing position to lying position on the ground or slowly knee down. Recently, there are amount of researchs in the developement and implementation of assistive devices for fall people. Many in-house camera systems are employed as a tool to monitor human movement and detect fall based on image processing technolgy. Howerver camera systems are expensive, limited to the range of one's house and invade to person's privacy [3]. Another approach attempt to detect fall with wearable devices. Such system using accelerometer has the advantage of its cheap price and easily implementing. These methods can provide the user's movement information through the motion sensors placed on the patient. The sensors used in this method include accelerometer, gyroscope, magnetometer, and more. Currently, fixed threshold is most commonly used to detect the onset of fall signal where the first point in time of signal amplitude exceeding a selected value. However to reduce fail alarm, a more complex fall algroithm is needed. Timely alerts and seeking help from remote area play an important role in decreasing dealth rates and serious health problems if waiting time is too long. One research using neck band sensor in combination with smartphone [4]. This kind of connection uses call service which require monthly fee. Besides, fall detection can also be implemented with built-in sensors on smartphones [5]. However, researches by [6, 7] indicated that the accuracy of the sensors in these devices is lower than that of independent sensor when used with the same fall detection algorithm. The interface is designed but complicate for elders use.

The advantage of this system is simple to setup and relatively cheap. But wearing a smartphone seems not realistic for everyday use [8].

The purpose of this study is to propose a design and implementation of a wireless fall alarm system with real-time motion acquisition of subject. This system is combination of high accuracy 6-type of fall detection wearable hardware and application on smartphone to send warning call and message to remote helpers. Besides, all motion data of subject will be stored on cloud system for further investigation and research.

This paper is organized in five sections: Section 2 discusses the fall dectection algorthm. The proposed

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fall detection and warning system is provided in Section 3. Section 4 is about experiments setup and finally the Section 5 is results and discussion.

2. Fall detection algorithm

2.1 Fall detection algorithm

We employ fall detection algorithm that proposed in our recent work [9] to distinguish 6 type of fall. That algorithm has an avarage accuracy of 92%. By using 3 axis data collected from both accelerometer and gyroscope, the system can identify human movement. Then, microprocessor process raw data and extract the accleration and angle of subject. 6 types of fall are loosely defined as follow:

- Straight fall (F_): F_Getup, F_Faint, F_Struggle_Faint;
- Keel over (K_): K_Getup, K_Faint, K_Struggle_Faint.

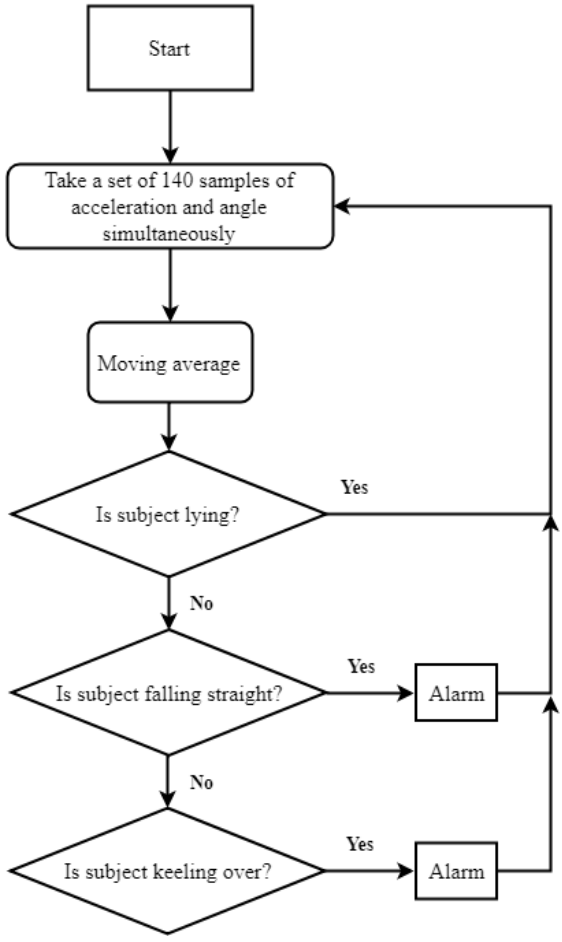

Fig. 1. Fall detection algorithm.

Fall detection algorithm is shown in Fig. 1. Data in 14s (140 samples) is used to calculate and classify the activity. The algorithm extract features from acquired motion data by dividing fall process into three phases. Angle of human orientation and acceleration of each phase are simultaneously calculated and compared with fixed thresholds in order to classify 6 types of fall. It first determines if subject is lying. Then we check straight fall cases and finally keel over cases. The effect of gravitational acceleration or mechanical oscillation can be minimized / eliminated thanks to low pass and high pass filter.

2.2 Real time fall detection algorithm

The system records real time motion data of the subject but only stores 35 samples (equal to the first phase of fall) to recognize sign of fall. If the system detect user orientation (angle value) exceeding 80 degree, the system will continue record 140 samples to the buffer memory. It then applies fall detection algorithm to classify 6 types of fall. Only with real fall, the system triggers alarm system by sound, light and fall message to smartphone application.

3. System design

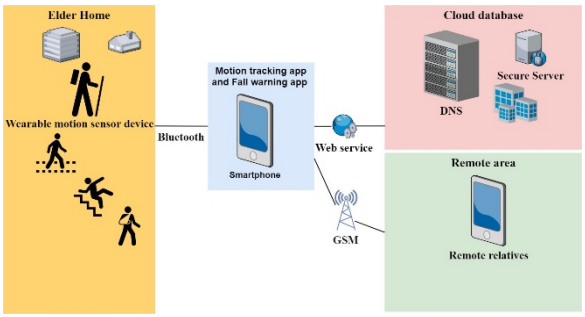

Fig. 2. Architecture of the proposed wireless fall warning system

Our proposed system comprises of 3 modules as shown in Fig. 2: Motion sensor module, fall warning application module and cloud database module.

3.1 Motion sensor module

Motion sensor module are designed to wear on human's waist. This system uses Atmega 328 with accelerometer ADXL 345. Mircrocontroller reads acceleration data from ADXL345 (Use function ADXL345_READ()) every 100 ms (sampling rate is 10 Hz). Magnitude of acceleration along three axis will be recorded (accX, accY, accZ). Calibarion is processed based on the offset value and gain of each axis which is:

$$accX' = \frac{accX - offsetX}{gainX} \quad (1)$$

$$accY' = \frac{accY - offsetY}{gainY} \quad (2)$$

$$accZ' = \frac{accZ - offsetZ}{gainZ} \quad (3)$$

Then we applied following fomulas to calculate general acceleration and angle change (angle) from accleration components.

Acceleration magnitude :

$$accA = \sqrt[2]{accX'^2 + accY'^2 + accZ'^2} \quad (4)$$

$$\text{Angle} : angle = \frac{\cos\frac{accY'}{accA} * 180}{\pi} \quad (5)$$

Motion senso module will continuously send the data of user movement to the Fall warning application on specific smartphone. The motion sensot module uses Bluetooth technology to wirelessly send user status to smartphone. Module bluetooth HC-05 is designed for transparent wireless serial setup. This module is Bluetooth 3Mbps modulation with 2.4GHz radio transceiver and baseband.

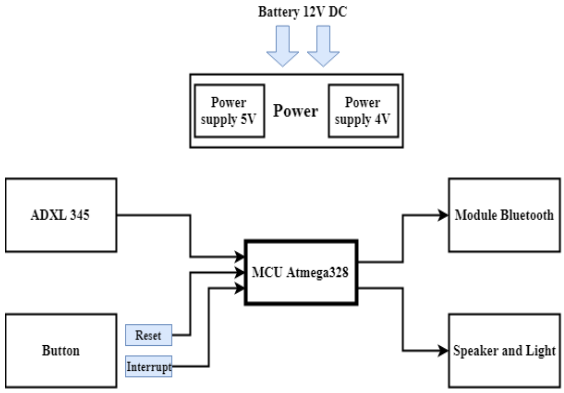

Fig. 3. Block diagram of motion sensor module

3.2 Fall warning application module

Fall warning application module is used as data aquisiton and remote warning system when real fall is detected. The module includes Motion Tracking app and Fall Warning App. The Motion Tracking App continuously updates the data from motion sensor module through bluetooth communication and displays them on the app's main screen. If one type of the fall is detected, the Motion Tracking App will display human symbol on the main screen and continue the loop to get the results.

When the application has read data from the motion sensor module, we create a checked() method to check the characters on the data and filtered out information about the current posture of the subject. The data from the hardware include by a 3-number string encoded. This string will then be separated from the rest of the data by appending a "|" and a newline to its end. So, we filter a 3-number string encoded and save as the input data variable. The application compares the input data with the fix three number string code. we using the compare () method to define the subject's posture. Table 1 shows encoded data from motion sensor: 0xx: Non-fall / Meaningless, 111: Lying, 200: Keel over – stand, 201: Keel over – struggle, 211: Keel over – faint, 300: Straight fall – stand, 301: Straight fall – struggle, 311: Straight fall – faint, 400: Button call.

We defined the fix three number string code: 3xx – fall and 400 – button call. If the input data variable is "3xx" that mean the elderly fall else if the input data variable is "400" that means the elderly needs help. After that the postures are defined by the input data and saved as the postures variable.

Table 1. Input and output of the motion tracking application

Data	Input	Output
Non-fall	0xx: Non-fall / Meaningless 111: Lying 2xx: Keel over include: 200: Keel over – stand 201: Keel over – struggle 211: Keel over – faint	Display posture of the elderly on screen
Fall	3xx: Straight fall include: 300: Straight fall – stand 301: Straight fall – struggle 311: Straight fall – faint	Display alert screen Make alert call Send alert message
Need help	400: Button call	Display alert screen Make alert call Send alert message

As for the real fall that requires warning for help, the motion tracking mode will immediately switch to warning mode.

Fig. 4 shows the flowchart of detecting fall and remote warning process.

1. Aquisiton of motion data and classification of 6 types of fall
2. Offline warning by sound and light
3. Send data to smartphone and trigger notification message with fall location to relatives.

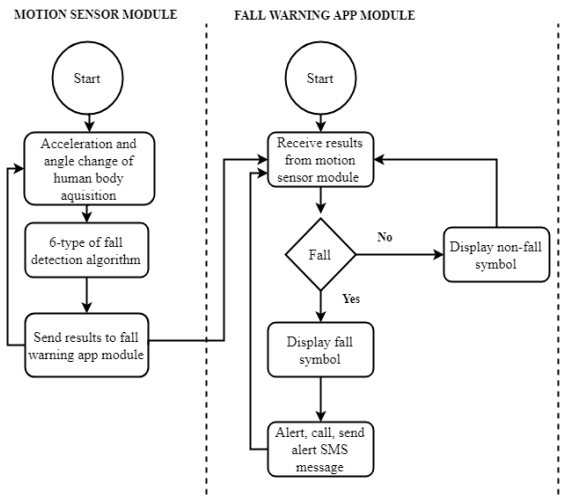

Fig 4. Motion tracking application

The warning mode is developed in two directions: warning to remote relatives and surounding people. Both types of warning mode are triggered simultaneously. The wearable motion sensor device will activate the warning mode itself using sound alert and light to nearby people. This will make people around quickly find the position of the fall people to help. Simultaneouly, the Fall Warning App on smartphone creates a warning call to remote relatives from a preset number to inform the fall case. After the call, immediately, a notification messege is then sent to ask for immediate assistance. The notice message includes information about the location, time and content of the warning.

As sensor module and smartphone devices are in the same location so we use the GPS on smartphone to locate the fall area. Google Play Services provide a tool for common application tasks such as the Maps SDK, etc. With the Maps SDK for Android, we can add maps based on Google Maps data to our application. The API automatically handles access to Google Maps servers, data downloading, map display, and response to map gestures. We also use API calls to add markers, polygons, and overlays to a basic map, and to change the user's view of a map area. These objects provide additional information for map locations and allow user interaction with the map. The API allows us to add these graphics to a map

The alert time is when the application receives the alert data by Calendar.getInstance() method. All of this data will be merged together to form a warning message.

In case of the subject has been helped and people want to turn off the alarm or want to let the person know the warning is false, the listenerOnClick () method will listen if the user presses the fake warning button or off. warning. Immediately warningWrongAlert () will send false alarms to relatives and at the same time turn off lights and sound warning. Fall warning diagram is presented in Figure 5.

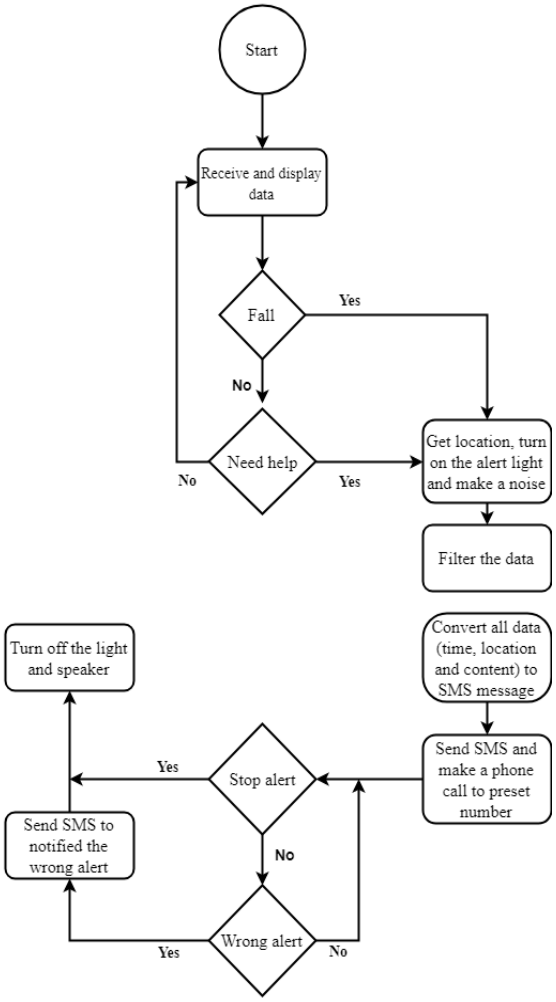

Fig 5. Alert mode diagram in Motion Tracking App

3.3 Cloud database module

Cloud database module is implemented through Fall warning application module to send sampling data from sensor module to cloud database for storage The purpose of storage users'motion data is for futher investigation and research. Statistic function of the system is seperated from fall detection system so it doesn't need to wait for fall detection algorithm end. This program is designed to connect to online server for data storage

4. Experiment Design

We choose 5 subjects, all males from 18 – 22 years old in our experiment to test the response of our system. The volunteers are required to wear motion sensor module device on their waist and perform ADL

and fall activities. Fall warning application is designed on Android – based smartphone to receive motion data and send to cloud database for storage. Fall status will be displayed on main interface of Fall waring app and automatic trigger warning call and message once fall is detected.

5. Test results and discussion

The proposed system in Fig. 6 is set up to evaluate the performance of the system. Sensor module (red box) records motion data of human and motion data are sent to smartphone.

The Fall warning application is installed on the Android - based mobile device. The main screen displays real-time status (Fig. 7a) and has manual warning button in case of emergency. When fall happened, the symbol on the main screen will change and trigger the warning mode (Fig. 7b).

This system performs well as it detects fall. When real fall happened, both wearable motion sensor device and smartphone perform warning to seek for help. Motion Tracking immediately sent notification message including warning content (Fig. 8) and maps link of the place of fall (Fig. 9). The helper only needs to click on the link on their smartphone to open the maps and easily located the address of fall person. To help the user to define easy where the user position is or what the falling position, the falling position is designed with red maker.

To evaluate the accuracy of the position of fall area and timing of the alert, experiments have been set up in lab 419, C9, Hanoi University of Science and Technology from 15:30 to 15:45 on the same day. The outputs are summarized in Table 2.

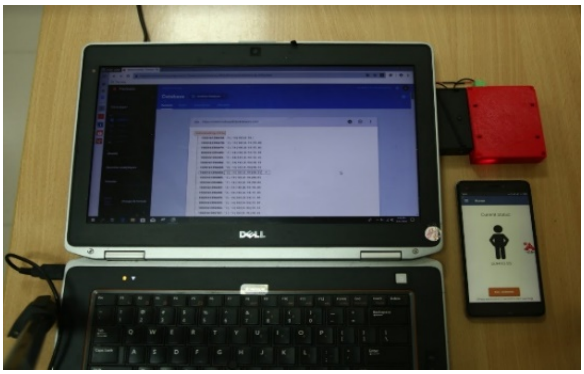

Fig. 6. The proposed system comprises motion sensor module (Redbox), fall warning application on smartphone and online data storage.

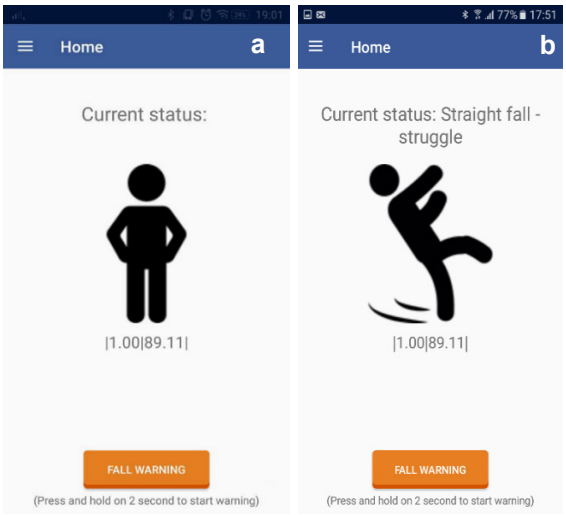

Fig. 7. a. Graphical interface of a smartphone shows status of person in Activities of Daily Living; b. Manual warning button and straight fall – struggle symbol when fall is detected.

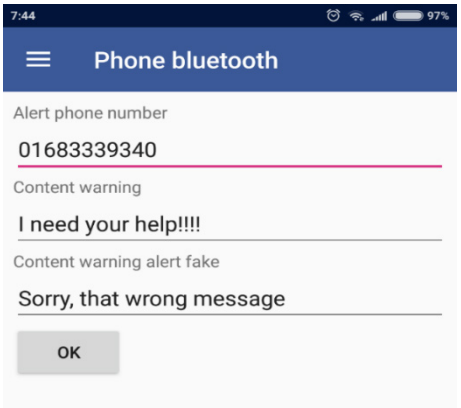

Fig. 8. Preset number and content of notification message in application settings.

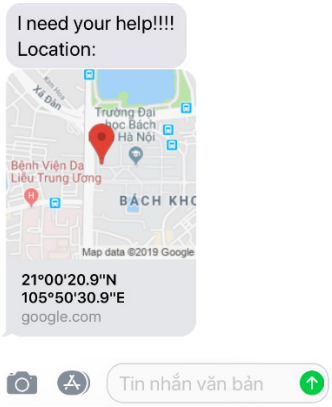

Fig. 9. Warning message includes message, location and time of fall on preset number smartphone.

Table 2. The results of notification message when fall happened

No	Input			Result		
	Content	Time	Position	Content	Time	Position
1	Need help	15 hours 30 mins	21°00'20.7"N 105°50'31.0"E	Need help	15 hours 31 mins	21°00'20.7"N 105°50'31.0"E
2	Need help	15 hours 35 mins	21°00'20.7"N 105°50'31.0"E	Need help	15 hours 35 mins	21°00'20.7"N 105°50'31.0"E
3	Need help	15 hours 37 mins	21°00'20.7"N 105°50'31.1"E	Need help	15 hours 38 mins	21°00'20.7"N 105°50'31.1"E
4	Need help	15 hours 40 mins	21°00'20.7"N 105°50'30.9"E	Need help	15 hours 40 mins	21°00'20.7"N 105°50'30.9"E
5	Need help	15 hours 45 mins	21°00'20.7"N 105°50'31.0"E	Need help	15 hours 45 mins	21°00'20.7"N 105°50'31.0"E

The results are 100% accurate, while time and location information are a bit misleading. Time deviation ranged from 0 to 1 minute due to the transmission.

6. Conclusion

We have described a design and implementation for fall detection and wireless warning system. The Motion sensor module is wearable device with embedded 6 types - fall detection algorithm in combination with a smartphone application to seek help from remote area. Smart phone is necessary device that always stays in people's pocket in everyday life. By combining high accuracy fall detection device with a smartphone to receive motion data and wirelessly send warning notification in case of fall will improve the efficiency of the system and easily to set up. The application is programmed to get location of subject and embedded into notification GSM message to provide location to caregivers, doctors and ambulance. Our system allowed for real-time data storage on cloud-based storage for further investigation. The proposed system in this study show a great potential in supporting elders, decreasing deaths and improving their lives qualities.

Acknowledgments

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