Smart Elderly Home Monitoring System with an Android Phone

Jer-Vui Lee, Yea-Dat Chuah and Kenny T.H. Chieng

Department of Mechatronics and Biomedical Engineering, Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Kuala Lumpur, Malaysia
leejv@utar.edu.my

Abstract

Falls, heart attack and stroke are among the leading causes of hospitalization for the elderly and illness individual. The chances of surviving a fall, heart attack or stroke are much greater if the senior gets help within an hour. In this project, a smart elderly home monitoring system (SEHMS) is designed and developed. An Android-based smart phone with 3-axial accelerometer is used as the telehealth device which could detect a fall of the carrier. The smart phone is then connected to the monitoring system by using the TCP/IP networking method via Wi-Fi. A graphical user interface (GUI) is developed as the monitoring system which exhibits the information gathered from the system. In addition, the concept of a remote panic button has been tested and implemented in this project by using the same android based smart phone. With the developed system, elderly and chronically ill patients could stay independently in their own home with care facilities and secure in the knowledge that they are being monitored.

Keywords: *Fall Detection, Monitor Elderly, Remote Panic Button and Smart Home*

1. Introduction

The elderly or people with disabilities want to remain in their homes even when their health condition has been getting worse [1]. The global population of people over the age of 65 is expected to more than double from 375 million in 1990 to 761 million by 2025” [2]. With this, the telehealth service has been widely implemented and used to help one (refers to elderly or individual with disability) to live independently at home. As the problem of aging and disability are converging, the smart home based health monitoring has become a key research area for ubiquitous and embedded system computing.

The idea of this project is to develop an intelligent and versatile home safety environment that could help the elderly and individual with disability live independently in their own home. This paper presents the design and development of a telehealth system and how it is integrated with its monitoring system in monitoring the elderly at home. Section 2 introduces the background of the project. Section 3 introduces an overview of SEHMS. Section 4 and 5 discusses the telehealth system and monitoring system respectively. Section 6 shows a simple demonstration. Section 7 makes the conclusion.

2. Background

Telehealth devices are used as a tool in monitoring patients and respond promptly to indicators of acute exacerbations [3]. Monitoring the ‘vital signs’ of the patient at home is an important event of the smart home technology. When the preset parameters (physiological indices such as blood pressure, oxygen saturations, pulse, spirometry, temperature, ECG and blood glucose readings) are breached, alerts are sent to the health care professionals (such as community matrons, GPs and hospital consultants) via internet portal. In recent years, mobile phones had been used as tools for encouraging physical activity and healthy diets, for symptom monitoring in diseases, for sending reminders to patients and for a range of other health problems [4-9]. Smartphone was used to address the needs of persons with Alzheimer’s disease [7]. Smartphone was used to monitor vital physiological parameters of patients [8]. Jesús, *et al.*, proposed a system that supports physicians to determine an accurate and centralized elderly frailty diagnosis, by using an Android mobile phone [9]. The accelerometer which embedded in the phone is used to collect data movement from physical activity. A set of measures are calculated which combined with the clinical indicators (from tests and medical instruments) and it provides frailty assessment to facilitate decision-making to the subsequent treatment.

Nourya, *et al.*, had found that the smartphone is a good candidate in monitoring the mobility of the elderly as this technology is already accepted in our daily life [10]. Leijdekkers, *et al.*, [11] developed a remote healthcare monitoring system that to care for the elderly and the chronically ill in their homes with care facilities. This remote healthcare monitoring system includes a smart phone, wireless sensors, web servers and IP webcams. The authors centered the window based smart phone by integrates all the devices with it. The smart phone acts as a receiver that receives all the data sent by the wireless healthcare sensor and further process the data by sending the data the healthcare server or calls an ambulance during emergency. With the remote healthcare monitoring system, patients are free to move about in their own home and secure in the knowledge that they are being monitored.

Various researches had included a smart phone for detecting the fall of the elderly [12-16]. Frank, *et al.*, [12] had designed an android application as alert system for fall detection. The authors evaluated the data from the 3-axial accelerometer with several threshold-based algorithms and position data to determine a fall. Once there is suspected fall, the application will request a respond from the user. If the user does not respond in a within certain period, a notify message will be sent to the social contacts. If the contact person responds with an incoming call, the application will answer the call automatically and the speakerphone will be enabled. The application runs as background service that constantly listen to the accelerometer. The application will only wake up when there is suspected fall. When the application received the response from the user after wake up, it will restore the previous activity and back to the sleep condition. As mentioned above, this application uses both acceleration and position data to determine a fall, thus it could minimize the false alarm triggers by the activities such as dropping of the phone and minor fall that leave the user unharmed. The false alarms are further decreased by allowing the amplitude's upper threshold to be variable. In addition, the personal information such as age, weight, height and level of activity also have been considered and factored into the equation.

The fall detection system developed by Thomas [13] is an intelligent sensor which consists of accelerometers and a processor that capable of analyzing incoming data in real time and classifying motions event such as falls or other normal and abnormal events. The sensors of this system are able to communicate with the nearby camera phones or PC through Bluetooth for further data processing. This system can be mainly separated into three different parts which are the fall detector, wireless connection, and data recording and analysis tools. A camera phone is used in conjunction with a smart fall detector to verify and transmit live data in case of a fall. A fall detection device equipped with 3-axis accelerometers, a GPS receiver and embedded processor for analyzing the data is used to detect falls. If a suspected fall is detected, the fall detection device will connect to a camera phone and the data is then streamed to the phone. When the phone received the data from the fall detection device, it will attempt to make contact with the user via external speakers on the phone and request a vocal or keypad feedback from the user. If there is no response from the user after a certain period, it will automatically call an emergency service and the data from the phone (microphone, camera and fall detector) will be transmitted to the emergency service worker for further analyze of the situation.

FallAlarm had been proposed by Zhao, *et al.*, which a smart phone was used for fall detecting and positioning [14]. The system design consists of a tri-axial accelerometer sensor and a Wi-Fi module that embedded in the phone. Data from the accelerometer is evaluated with a decision tree model to determine a fall. If a fall is suspected, a notification is raised to require the user's response. If the user is injured hardly and cannot respond in time, the system immediately begin to position the occurrence of the fall event by detected surrounding Wi-Fi signals, then automatically send a alarm message to his pre-specified guardian with a message via SMS(Short Message System). Consequently, the victim can be monitored and cared in real time. Tested on a real-world data set, the FallAlarm system can achieve an acceptable accuracy for practical application.

3. System Architecture

The smart elderly home monitoring system (SEHMS) is divided into three different modules which are safety monitoring system, telehealth system and telecare system. Figure 1 shows the block diagram for the overall system architecture. The red single open arrow dotted lines represent the data transmission line to the monitoring system (personal computer). The blue single open arrow dotted lines represent the data transmission line from the monitoring system. The double arrow lines represent parent and child relation within the modules. The yellow dotted line boxes indicate the respective connection method used between the terminals.

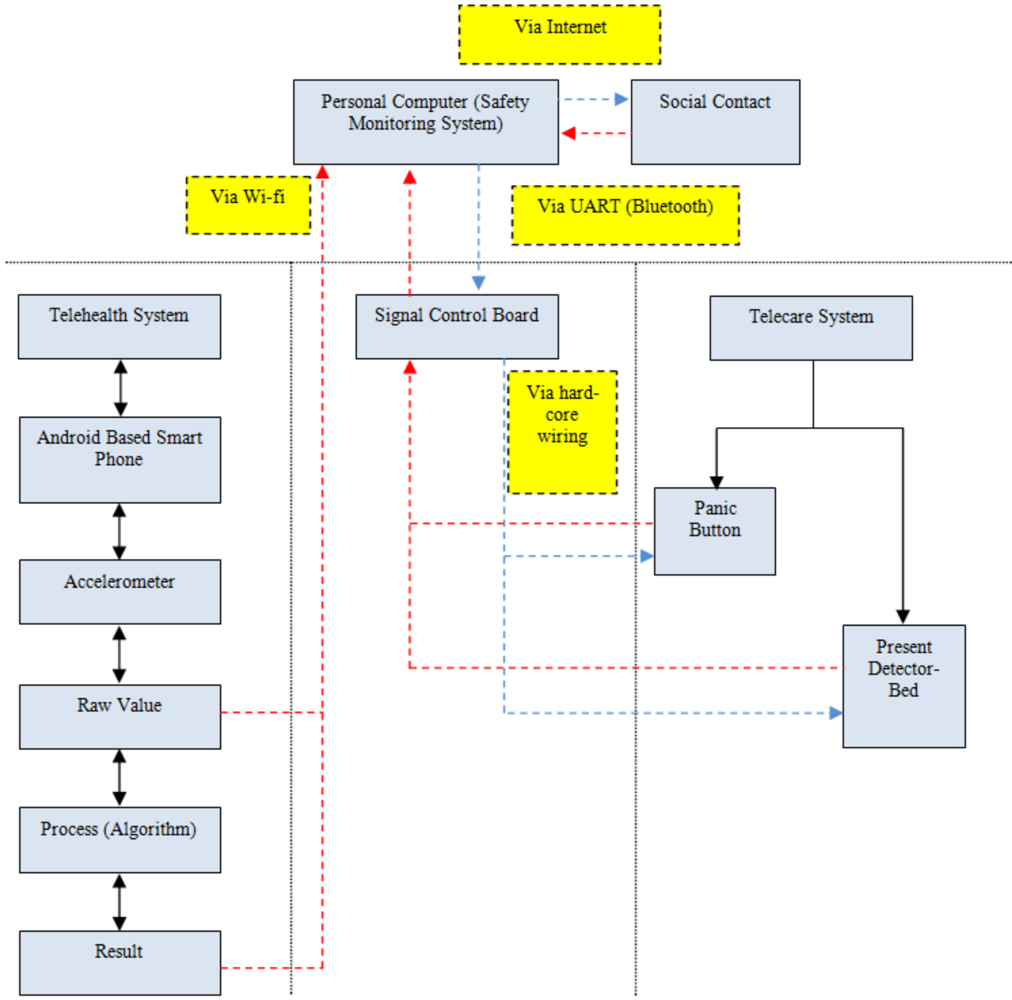


Figure 1. Overall Architecture Block Diagram of SEHMS

4. Tele-health System

An android application is developed to detect fall. When the application is activated, the accelerometer will read the acceleration of the phone in 3 different axes (x-axis, y-axis and z-axis). The data obtained from the acceleration is further processed and compared with a threshold. If the value processed exceeds a predefined threshold, a fall is suspected. This will lead to an activation of the system that opens an option to the user to examine the fall via a graphical user interface (GUI). If the user responds (deny the fall) to the GUI, the suspected fall will be cancelled and the android application will go back to the initial state. If the user doesn't respond to the GUI, a fall will be confirmed and the android phone will send an emergency alarm to the monitoring system via Wi-Fi. Very often that if there is a fall happened to the elderly (or chronically ill patients), they might be unconscious and this will lead to death. With this fall detection system, the possibility of rescuing the elderly (or chronically ill) from death due to falls can be increased. In addition, the concept of a remote panic button has also been tested and implemented in this project by using the same android based smart phone. The difference between the remote panic button and normal panic button is the mobility of the remote panic button. The remote panic button is connected to the monitoring system via Wi-Fi, thus the phone carrier can be monitored within the Wi-Fi coverage area. The remote panic button can be installed on a wrist band, a wheel chair, a walking stick and etc.

4.1. Android Based Smart Phone

An android-Based smart phone (HTC Desire A8181 as shown in Figure 2) is used as a fall detection device. Java Eclipse was used to develop the android program that can be run in any android platform based electronic devices. The idea behind of the fall detection is to extract the data from the accelerometer and further process it. The application was developed in such a way that if the processed value is larger than a certain level, then a suspected fall is detected. The fall can be further examined by user though the GUI on the smart phone where he/she confirms or denies a suspected fell. In the other hand, if there is no reply from the user within one minute, a fall is confirmed automatically and the smart phone will send out a signal or message to the monitoring system via TCP/IP. Figure 3 shows the process flow of the program coding of the android based smart phone which acts as a fall detection device.

Figure 2. HTC Desire A8181

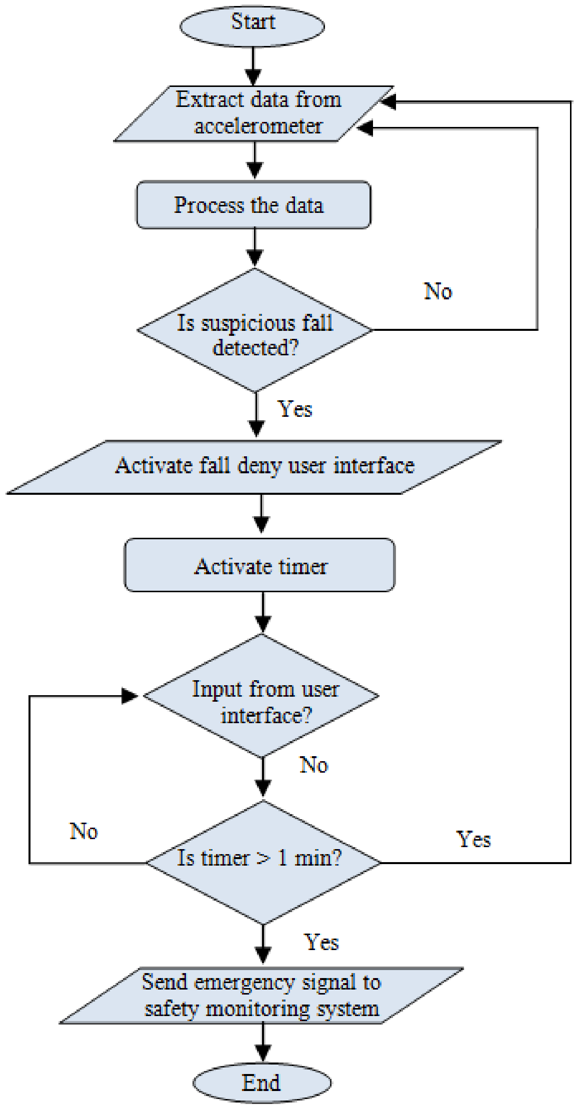


Figure 3. Process Flow for Smart Phone as a Fall Detection Device

4.2. Remote Panic Button

Figure 4 shows the process flow for the remote panic button of the smart phone. The remote panic button works in such a way that, if one press the “Help Button” once, it will sends a emergency triggering signal to the monitoring system, and display a message to notify the user that the remote panic button is being triggered. If the user has activated the remote panic button accidentally, he/she can cancel the alarm by pressing and holding the remote panic button for two seconds. This action will display a message of cancellation and send a false alarm signal to the monitoring system if the cancellation succeeds.

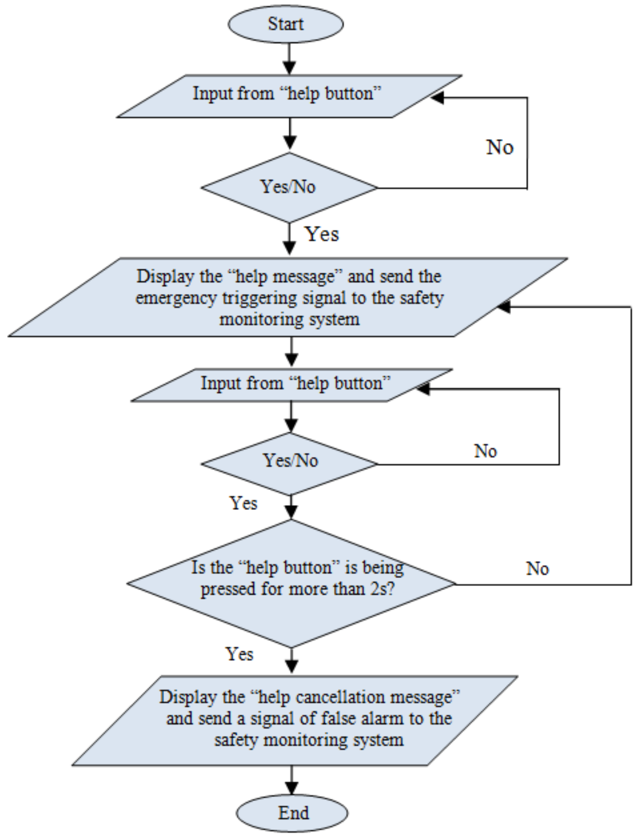


Figure 4. Process Flow for Smart Phone as Remote Panic Button

4.3. The Software Development

4.3.1. Transmission Control Protocol/Internet Protocol (TCP/IP)-Client: TCP/IP is a low level internet protocol that enables one to send data through a wireless connection. The reason of choosing a low level internet protocol is due to its international standardization that enable most of the microchips (*e.g.*, PIC, Intel, Freescale, and *etc.*) connect to the internet via TCP/IP. The ultimate goal is to transmit the data from commercial telehealth devices (*e.g.*, electrocardiography device, weight machine, blood pressure device, and *etc.*) to the monitoring system for telemonitoring purposes. One needs to set the role of the server and clients to establish the connection between them through TCP / IP. In this project, the author set the monitoring system as the server that listens to telehealth devices (clients).

The short code above enable the android based smart phone to send a "string" message to port 4444 of a server (monitoring system) with the specific Internet Protocol Address (IPAddress). The working principle of the code above as stated below:

i. Open a communication link between the telehealth device and monitoring system

ii. Send the "string message to the monitoring system

iii. Close the communication link

The IP address of the safety monitoring system can be changed easily from time to time due to re-establish of the connection. Thus, the input of the monitoring system's IP address on the telehealth device side is designed in such a way that could be changed as required.

4.3.2. Accelerometer: Reading the data from the built-in accelerometer in an android based device is an easy task. But one needs to study and understand the types and functions of the data to perform the task such as data extraction, calibration, calculation, null state, and data sending.

4.3.3 Synchronous Task: The activity of sending the data via TCP/IP is written in a function. If the program runs the instruction function, it will wait the data to be sent out then only it will jump out from the particular function and continue to run other instructions. In this android application, there are a few functions run cooperatively to deliver its functionality. Most of the functions required to run continuously to provide the latest update such as function that acquire the data from the accelerometer, the function to listen to the toggle button (remote panic button), function to update the main GUI of the android based smart phone.

4.3.4 Graphical User Interface (GUI): There are two GUI designed for the Android based smart phone. The first GUI is used to key-in the monitoring system's IP address (as shown in Figure 5) while the second GUI is the main user interface (as shown in Figure 6) where all the interaction between the user and the applications take place. The "Help Button" in Figure 6 indicates the remote panic button where the orange box with the label "1" indicates the area where status of the "Help Button" will appear. Once the toggle button beside the message "Send Data to Server:" in the "ON" state, the application will continuously send the data of the accelerometer (which is built-in in an Android based device) to the monitoring system. The process can be stopped by toggle the particular button to the "OFF" state. The red box with the label "2" indicates the area where valuables of the built-in accelerometer (x-axis, y-axis and z-axis).

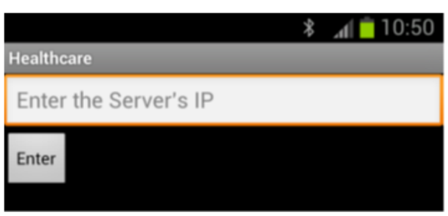


Figure 5. GUI to Input the Server's IP Address on the Client Side

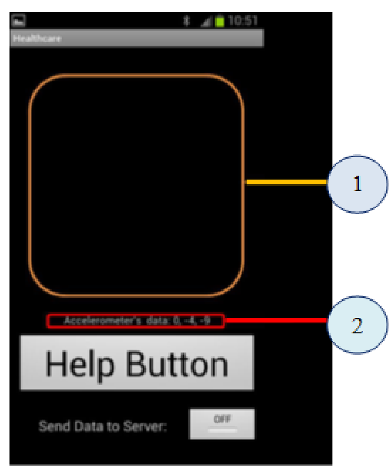


Figure 6. Main GUI for the Android Based Smart Phone

5. The Monitoring System

The monitoring system behaves as the heart of the overall system. It creates an environment that enables the elderly and individual with disability to live independently in their own home. With this system, elderly and chronically ill patients could stay independently in their own home with care facilities and secure in the knowledge that they are being monitored. The monitoring system is developed on a personal computer which is integrated with other modules. Once triggered, the monitoring system will send the information of the alarm (information such as what cause the emergency alarm, where the alarm occur and when is the alarm triggered) with the alarm notification to care giver, social contact and/or emergency respond team via sms, emails or/and phone calls. This will increace the chances the elderly (or chronically ill) to be to rescued after an accident happened. The authorized social contact, care giver and/or emergency respond team can further access to the monitoring system for more information. In addition, the monitoring system can also answer the call automatically after the emergency alarm has started.

5.1. The system flow and development

A personal computer equipped with Bluetooth and Wi-Fi connections is used as the platform for the monitoring system. Visual Studio is used to develop the monitoring system as well as the GUI that monitor the status of the telehealth device. Figure 7 shows the program flow for the monitoring system. Basically, there are two main tasks performed by the monitoring system which are (a) update the status of the telehealth device, (b) and to call for help if it is required.

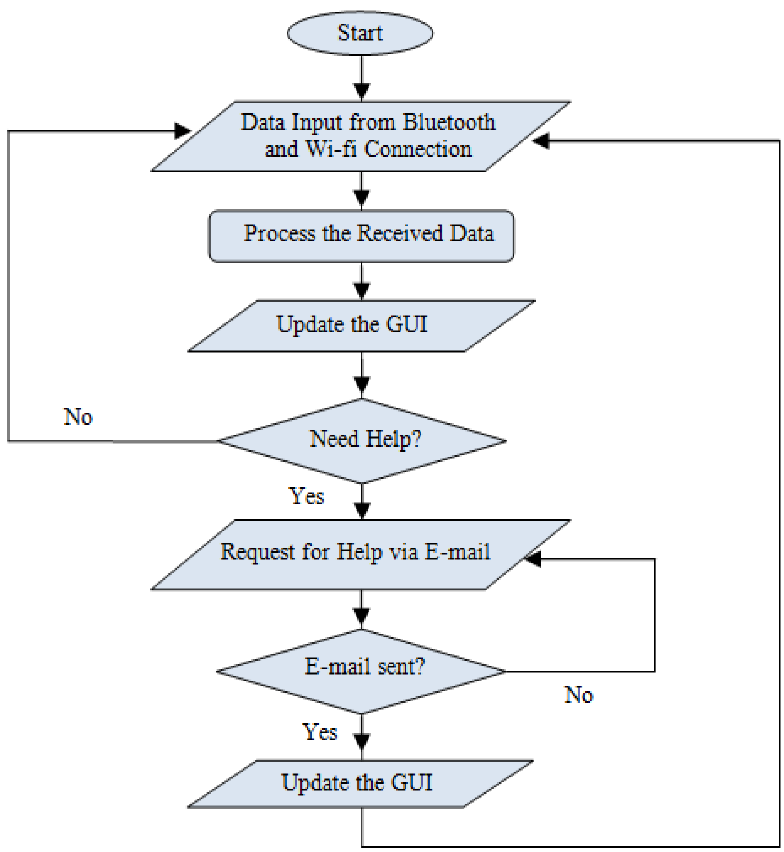


Figure 7. The Process Flow for the Monitoring System

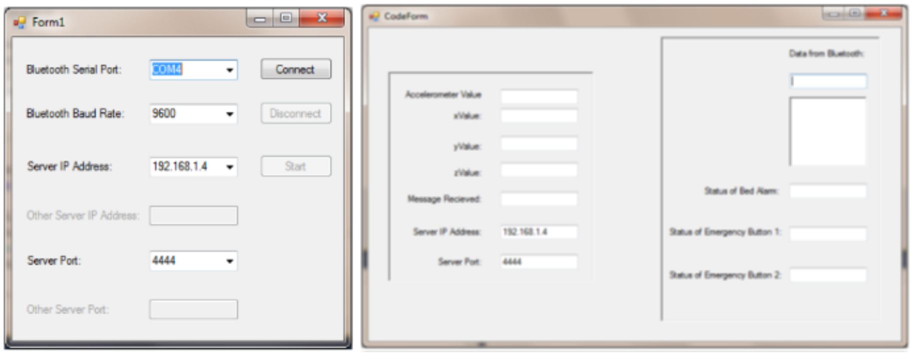
It is important to establish server/client communications which enables the telehealth device (clients) to be connected to the monitoring system (server) via Wi-Fi. The developed program based on Figure 7 enables the monitoring system to receive the data from the telehealth device via TCP/IP. It has been designed in such a way that the IP address of the server (“ServerIP2” from the code above) and the port number (“Port2” from the code above) can be easily changed by selecting the preferable IP address and port number. The personal computer sees the Bluetooth module as a serial port. Thus one can read the data received via Bluetooth in Visual Studio by adding a serial port listener. One must ensure the correct serial port number and baud rate are selected in order to capture the data sent by the Bluetooth module by monitoring system. The functionally of a background worker enables the visual studio to run multiple tasks simultaneously. The developed code enable repeating loop between the function e.g. separation and create graphs which are run parallel with the other program.

The developed program has the capability further analyze the raw data received, and separate the string received into single character based on the condition and pass the processed data to the other functions. As the system keep update the status of the devices, it means the diagrams are also been refreshed is term of milliseconds even though there is no change on the signal received. This will make the program unable to handle the refresh rate and make the program hang. To overcome this problem, a comparison function is developed where the graphical indicator will not be refreshed until there is a change on the signal received from the respective device.

Zed Graph is a tool that able one to performs graph plotting on various platform (Visual Basic, Visual Studio and *etc*.). The author uses the Zed Graph to perform dynamic real time graph potting on the monitoring system. To enable the monitoring system to send the “help request” via email automatically whenever there is an emergency alarm triggered, the Simple Mail Transfer Protocol (SMTP) is used. SMTP enables one to send mail automatically by just few steps of setting. The author uses a registered hotmail account to send the mail to the contact person. Different account provider has different server host and server port. The respective server host and server port could be easily found by perform a simple Google search.

5.2. Graphical User Interface (GUI)

There are total three GUIs are developed using Visual Basic. As shown in Figure 8a, this GUI is used for the initialization purpose. The serial port number which paired with the Bluetooth module, the baud rate, the IP address of the server (monitoring system), and the port number for the TCP/IP connection needed to be preset before the monitoring system runs. This GUI as shown in Figure 8b is designed to perform test and debugging for the program developed. All the data (either raw data or after processed) could be monitored though this GUI. The author could trace back the root causes easily if there is any problem occurs by using this form. Figure 9 shows the main GUI of the monitoring system. The graphs in the red box is plotted by using the data of the accelerometer sent by the Android based smart phone in x-axis, y-axis, and z-axis. Diagrams in the green box are the indicators for status of the selected area such as bed room, toilet, kitchen, and Android based smart phone. The diagrams are surrounded by the yellow box which is the indicator for the status of the emergency respond team. The blue box consists of the data sent by the android smart phone, a button to clear the graphs encircled in the red box, and a button to reset the status of the emergency respond team.



(a) (b)

Figure 8. The GUI of the Monitoring System

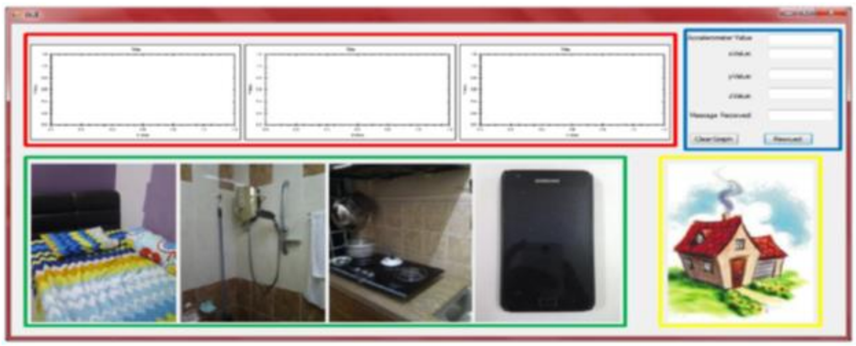


Figure 9. The Main GUI of the Monitoring System

6. System Implementation

6.1. Counter

The calculations for the counter get the period in five seconds as shown below. As the author using 20 MHz XTAL crystal, the frequency for the microprocessor

$= 20\ MHz / 4$

$= 5\ MHz$

$Time\ Period = 1/5\ MHz\ = 0.2\ uS$

$Prescaler\ Period = 0.2\ uS\ X\ 256$

$= 51.2\ uS$

Thus the microprocessor takes 51.2 uS to run a command line. As there are about total 220 lines of command for all the functions (depends on the condition of other functions, different condition will cause the number of command lines in other functions to vary).

The time used by the microprocessor to run a full loop for all the functions

$= 51.2\ uS\ X\ 220$

$= 11.264\ mS$

The number of counter needed to have a period of five seconds

= 5S / 11.264 mS

= 443.89

Thus the author takes 444 as the number of counter.

Table 1. Period of Time for the Counter to Count Five Seconds

Reading	1	2	3	4	5
Period (seconds)	4.9	5.0	4.9	4.8	4.9

Mean = (4.9 + 5 + 4.9 + 4.8 + 4.9) / 5
= 4.9 (seconds)

Table 1 shows the measured practical time for the counter to count five seconds by using a stopwatch. The mean value for the data observed is 4.9 seconds which is acceptable. Therefore, the counter value 444 is applicable to get the period of five second.

6.2. Sampling Rate for the Accelerometer on Monitoring System

The author set a delay of 100 mS before the "Send()" on the Android application. Thus the Android based smart phone will send the data to the monitoring system every 100mS.

The sampling rate for the data of the accelerometer *= 1 / 100 mS*

= 10 Hz

The actual sampling rate on the monitoring system is obtained by counting the dots (data) plotted in Zed Graph (as shown in Figure 10) within one second.

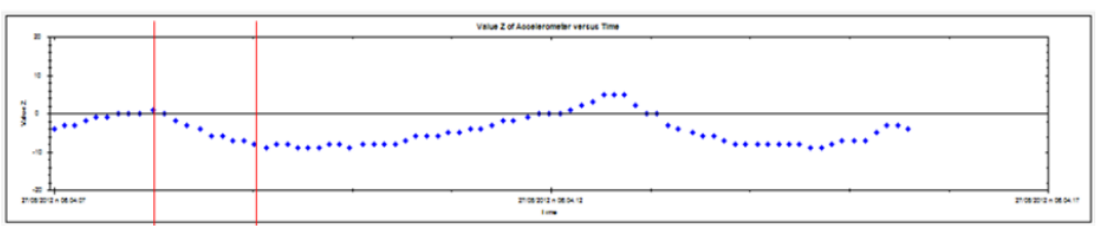


Figure 10. Dynamic Graph of Time versus Accelerometer Data

6.3. Demonstration- Communication between Telehealth Device and Monitoring System

If one pushes the "Help Button", the android application will tell the user that the panic button is being triggered by playing music and display a notify message on the screen. It will also show the user how to deactivate this help request as shown in Figure 11. The "help request" will be received by the monitoring system (as shown in Figure 12) for further process. One could cancel the "help request" by pressing and holding the "Help Button" until the "Cancellation" message has appeared as shown in Figure 13.

One could also send the data of the built-in accelerometer to the monitoring system by toggling the button beside the text "Send Data to Server" to ON state (as shown in Figure 14). The monitoring system will plot the dynamic real time graphs based on the valuables of the accelerometers as shown in Figure 15. To stop sending data of the accelerometer to the monitoring system, just toggle the button beside the text "Send Data to Server" back to OFF state. Figure 16 shows the e-mail of "help request" received by the contact person.

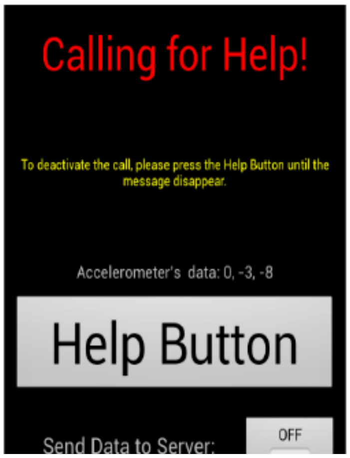


Figure 11. GUI of Android Application – Help Requested

Figure 12. GUI of Monitoring System – Help Requested via Android Phone

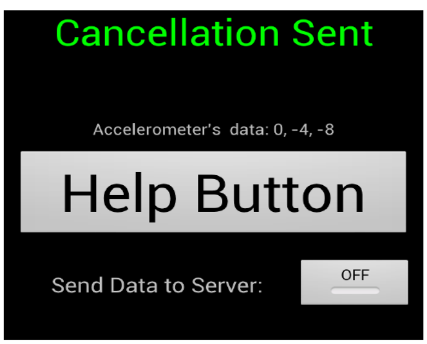


Figure 13. GUI of Android Application – Help Request Cancelled

Figure 14. GUI of Android Application-Send Data to Server

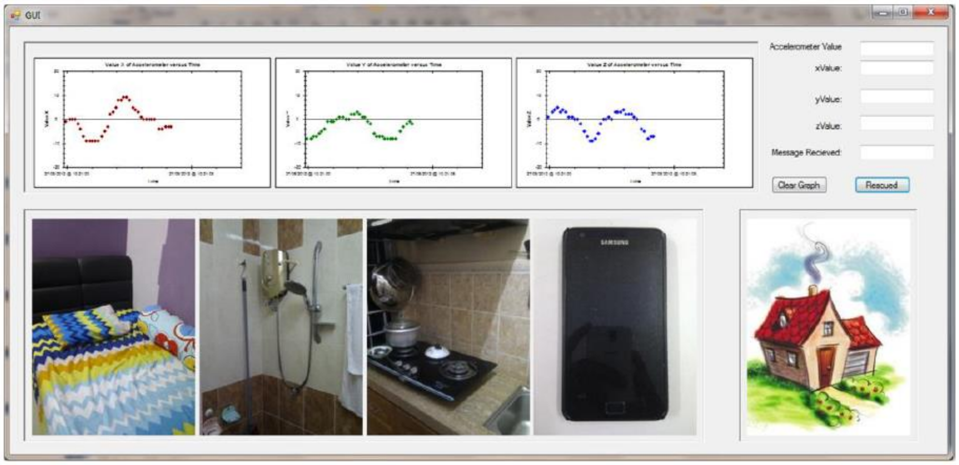


Figure 15. GUI of Monitoring System – Dynamic Graph Plotting

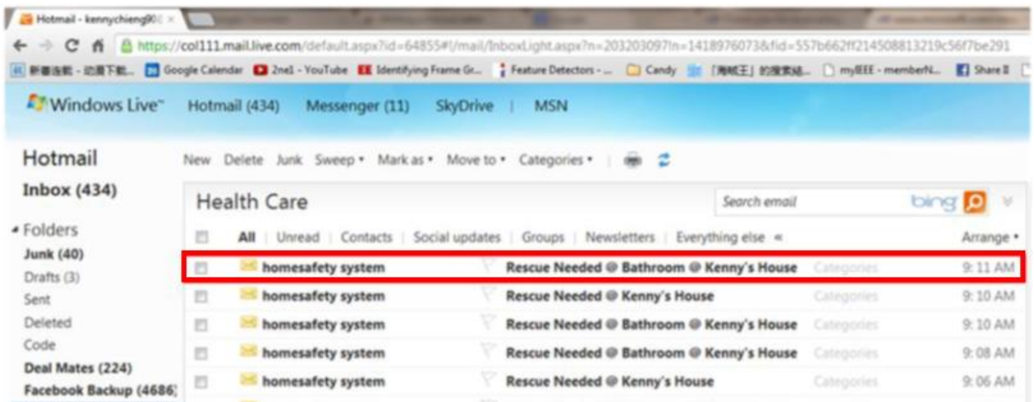


Figure 16. Help Request E-mail Received

6. Conclusions

An Android-based smart phone with 3-axial accelerometer is used as the telehealth device which could detect fall of the carrier. The smart phone is then connected to the monitoring system by using the TCP/IP networking method via Wi-Fi. A graphical user interface (GUI) is developed as the monitoring system which exhibits the information gathered from the system. The GUI opens an option to the user to examine the fall as well as making the confirmation or cancellation. A remote panic button has also been tested and implemented in the same android based smart phone. The remote panic button is connected to the monitoring system via Wi-Fi, thus the phone carrier can be monitored within the Wi-Fi coverage area. The system will increace the chances the elderly (or chronically ill) to be to rescued after an accident happened. The authorized social contact, care giver and/or emergency respond team can further access to the monitoring system for more information. In addition, the monitoring system can also answer the call automatically after the emergency alarm has started. With the developed system, elderly and chronically ill patients could stay independently in their own home with care facilities and secure in the knowledge that they are being monitored.

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Authors

Dr. Lee Jer-Vui is an Assistant Professor in the Department of Mechatronics and BioMedical Engineering, Faculty of Engineering & Science, Universiti Tunku Abdul Rahman, Malaysia. His research interests are in the field of automation and robotics.

Chuah Yea-Dat is the Department Head of Mechatronics and BioMedical Engineering, Faculty of Engineering & Science, Universiti Tunku Abdul Rahman, Malaysia. He is a Chartered Engineer and member of The Institution of Engineering and Technology (IET) UK. His research interests are in the field of mechatronics and biomedical engineering system design.

Kenny T.H. Chieng is an engineer and graduated student of Department of Mechatronics and BioMedical Engineering, Faculty of Engineering & Science, Universiti Tunku Abdul Rahman, Malaysia. His research interest is in the field of smart home system design.