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Fall Detection Sensor System for the Elderly

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Abstract

Many elderly people are living alone in their homes. If the elderly fall down, it may be difficult for them to request for help. The main objective of this work is to design an android-based fall detection sensor system at affordable cost for the elderly in Malaysia. This paper describes the design of the android-based fall detection sensor system. The system is able to acknowledge a falling incident to the contact person such that the incident can be reported to the ambulance department soonest possible, and to provide necessary medical treatments for the injured elderly. The design and implementation combines both hardware and software that work seamlessly in detecting and reporting a fall at home. The hardware part consists of the falling detection sensor that detects the body position of the user whether it is on a falling mode while the software side consists of some formulas that detect the fallings and triggers the alarm.

Keywords

Android-based, elderly, emergence SMS, falling detection, sensor.

1. Introduction

In Malaysia, there are many elderly people who live alone when their children go out for work. This means that no one can help them if any accidents happened during this time. If the elderly fell down and injured, they need to call the ambulance or their relatives to seek help which may not be possible. Currently, in Malaysia, systems that can detect a fall incident at home and send out signals to the relevant department to request for help is not available. Usually, not many people think about elderly people falling until some dreadful events happened such as someone has injured badly. Falls are a major problem in the elderly because they may cause significant morbidity and mortality. This is due to the complications arising from falls causing a significant decrease in functional status, serious injury, and an increase in the utilization of medical services [3]. According to the research “Risk factors of home injury among elderly people in Malaysia”, out of 4842 respondents aged ≥60 years, 279 (5.8%) had experienced some kind of home injury within the previous year. The most common types of injury were fall (n=205), cuts (n=43), and being struck by objects (n=14). The most common injury locations were the kitchen (n=81), garden (n=65), bathroom/toilet (n=45), living room (n=26), bedroom (n=22), and stairs (n=21). Falling is also the major cause of Traumatic Brain Injury (TBI) [4]. Figure 1 shows the percentage of external cause to TBI.

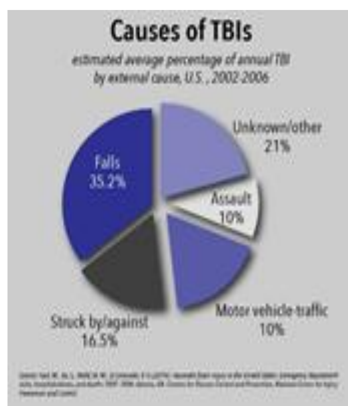

Figure 1: Causes of TBIs [4]

Elderly people’s falling percentage is higher because their body become weaker and their physical strength

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also become lower. Once they fall down they may not be able to stand up themselves or become unconscious, they need helps from others. Falling can cause a serious injury or death especially incidence that happen on human head part. Fall detection sensor system is the solution to solve these problems [1, 2].
This paper describes a system that is able to detect the falling of elderly people and send an emergency SMS to the contact person stored in the system to request help.

2. Background and Objectives

Before the system is designed, an interview was conducted on eight elderly from the Old Shepherd Retiring Home in Melaka city, Malaysia. Among the eight people, only three said that they can walk slowly without the need of a companion or an instrument to assists them; other five people needed a companion or instrument to assist them in walk. During the interview session, the respondents expressed that they feel faint if they stand up long time. It has been a burden to them to walk up and down the staircase. They need to walk slowly on the stairs to prevent falling; two of them had fallen down from the stairs. That has also caused traumatic experience for them to climb up the stairs. From the interview, we can conclude that the strength and energy of elderly people is very weak. Some of them need an instrument to assists them in walking. Due to the lack of strength and energy, fall incident can happen anytime.

Applications of wearable sensor systems in rehabilitation centres and smart home monitoring systems for elderly have been discussed in [5, 6]. In [7], an android application specifically for fall monitoring has also been described. All of these applications incurred a reasonable cost on the implementation and adoption. This work aimed to design an android-based fall detection sensor system at affordable cost for the elderly in Malaysia. Overall, the system is expected to help the elderly to call the ambulance when they fall down at home and unable to stand up. The main objectives of this work are: (1) To design a fall detection system using low cost fall detector sensors, (2) To develop an algorithm that can identify the body position of the elderly people whether it is in falling tendency, and (3) To construct a system that can send an emergency SMS to the contact person (e.g. next-of-kin or close relatives) stored in the system.

3. Falling Scenario

The workflow of the system is as follows:

- The elderly people wear the falling detection sensor devices on their waist or wrist.
- The sensor device runs an algorithm embedded with it to detect and measure the body position of the users.
- If the sensor devices detect the body position in falling mode, the system will trigger the alarm.
- To prevent false positive happen, a reset button to cancel the alarm is included, if the alarm did not cancel within 15 seconds by the user, the system will send an emergency SMS to the contact person.

The story board of falling down until an ambulance is informed is presented in Figure 2.

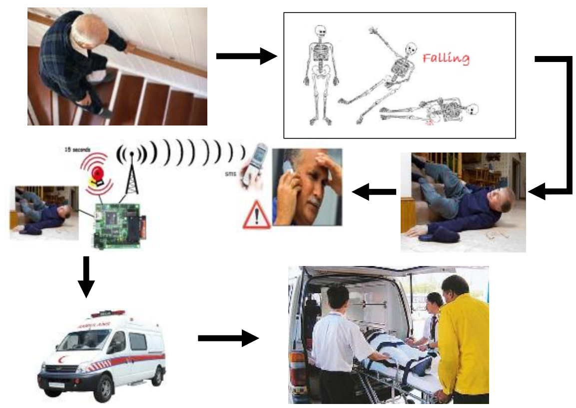

Figure 2: Falling story board

1. An elderly people is walking down on a stairs.
2. He misses the steps on the stairs and falling down from the stairs to the floor.
3. Fall detection sensor system will detect the falling through the algorithm system and then trigger the alarm. If the alarm is not reset within 15 seconds, the system will send a short-message (i.e., sms) to the contact person stored in the system. The contact person will track the falling location and contact ambulance for medical help.
4. Ambulance department will receive the call from the contact person and then send an ambulance car to that location of the victim.

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4. Design components

Fall detection sensor system uses a sensor device, a hardware that detects the body position and motion, which then communicates with the system (the software part) to send out an emergency SMS to the contact person if falling is detected. The system would only send the signal to ambulance after the alarm is triggered by the sensor for 15 seconds. The hardware needed is presented in Sections 4.1 and 4.2 while the software languages used in provided in Section 4.3.

4.1 Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328 (Figure 3). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get started [8, 9, 10, 11, 12].

Figure 3: Arduino UNO board

4.2 SIMCOM SIM900 Quad-band GSM GPRS Shield Development Board

The GPRS Shield is based on SIM900 module from SIMCOM and compatible with Arduino and its clones. The GPRS Shield provides you a way to communicate using the GSM cell phone network. The shield allows you to achieve SMS, MMS, GPRS and Audio via UART by sending AT commands (GSM 07.07 and 07.05, and SIMCOM enhanced AT Commands). The shield also has the 12 GPIOs, 2 PWMs and an ADC of the SIM900 module (They are all 2V8 logic) present onboard (Fig. 4). The GPRS Shield is based on SIM900 module from SIMCOM and compatible with Arduino and its clones. The GPRS Shield provides you a way to communicate using the GSM cell phone network. The shield allows you to achieve SMS, MMS, GPRS and Audio via UART by sending AT commands (GSM 07.07 and 07.05, and SIMCOM enhanced AT Commands). The shield also has the 12 GPIOs, 2 PWMs and an ADC of the SIM900 module (They are all 2V8 logic) present onboard (Figure 4).

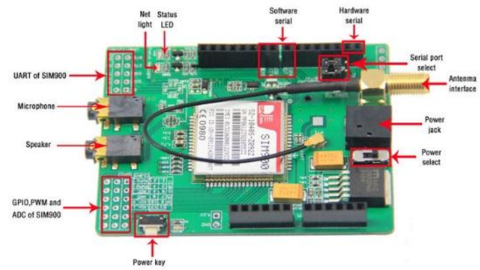

Figure 4: Hardware diagram of SIMCOM SIM900 Quad-band GSM GPRS shield development board

4.3 Arduino Programming Language

Arduino programs can be divided in three main parts: structure, values (variables and constants), and functions. The Arduino language is based on C/C++ and supports all standard C constructs and some C++ features. In Arduino, the standard program entry point (main) is defined in the core and calls into two functions in a sketch. The function setup() is called once, then loop() is called repeatedly until the board is reset. Besides, Arduino development environment, SPI Arduino Library and SoftwareSerial Arduino Library are also needed [13].

5. Configuration and Implementation

Steps in setting up the Arduino UNO board:

1. Download the Arduino development environment and install it.
2. After the Arduino environment is set up, locate the SPI and SoftwareSerial Arduino library.
3. Stack the SIMCOM SIM900 Quad-band GSM GPRS Shield Development Board above the Arduino UNO, then connect ADXL345 Breakout Board to the pin of SIMCOM SIM900 Quad-band GSM GPRS Shield Development Board:

- Connect Arduino 3.3V to ADXL345 VCC using female to male jumper wire.

- Connect Arduino GND to ADXL345 GND using female to male jumper wire.
- Connect ADXL345 CS to Arduino digital pin 10 using female to male jumper wire.
- Connect ADXL345 INT1 to Arduino digital pin 2 using female to male jumper wire.
- Connect ADXL345 SDO to Arduino digital pin 12 using female to male jumper wire.
- Connect ADXL345 SDA to Arduino digital pin 11 using female to male jumper wire.
- Connect ADXL345 SCL to Arduino digital pin 13 using female to male jumper wire.

4. Pin configuration and the top view of the hardware for the Fall Detection Sensor System are shown in Figure 5 and Figure 6 respectively.

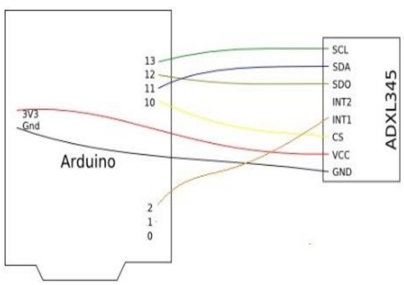

Figure 5: Pin configuration between Arduino UNO and ADXL345 breakout board

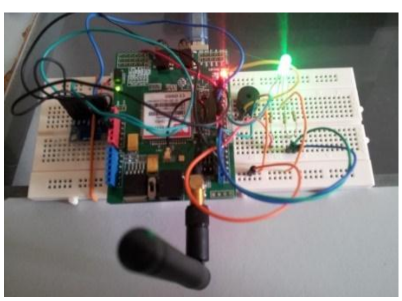

Figure 6: Top view of the hardware of the fall detection sensor system

5. Develop fall detection program on the Arduino development environment. Include ‘SPI.h’ header and ‘SoftwareSerial.h’ header inside the code for the Fall Detection Sensor System. Program snippets for fall detection are provided in Figure 7(a) – Figure 7(c).

```
//Add the SPI library; to communicate with the ADXL345 sensor
#include <SPI.h>
#include <SoftwareSerial.h>
SoftwareSerial SIM900(7, 8);
//Assign the Chip Select signal to pin 10
int CS=10;
const int redLEDPin = 4; // L E D connected to digital pin 4
const int greenLEDPin = 5; // L ED connected to digital pin 5
const int blueLEDPin = 6; // L ED connected to digital pin 6
//ADXL345 Register Addresses
#define DEVID 0x00 //Device ID Register
#define THRESH_TAP 0x1D //Tap Threshold
:
//This buffer will hold values read from the ADXL345 registers
char values[10];
char output[20];
//These variables will be used to hold the x, y and z axis accelerometer values
int x,y,z;
double xg, yg, zg;
char free_fallEvent = 0;

void setup(){
        SPI.begin(); //Initiate an SPI communication instance
        SPI.setDataMode(SPI_MODE3); //Configure the SPI connection for the ADXL345
        SIM900.begin(19200);
        SIM900power();
        delay(20000); // give time to log on to network
//Set up the Chip Select pin to be an output from the Arduino
        pinMode(greenLEDPin,OUTPUT);
        pinMode(redLEDPin,OUTPUT);
        pinMode(blueLEDPin,OUTPUT);
        digitalWrite(CS, HIGH);
//Create an interrupt that will trigger when an activity is detected
        attachInterrupt(0, fall, RISING);
//Put the ADXL345 into +/- 4G range by writing the value 0x01 to the DATA_FORM
        writeRegister(INT_ENABLE, 0x04) ; // Enable interrupts for FREEFALL
        writeRegister(POWER_CTL, 0x08); }
```

Figure 7(a): Setting up the environment

```
//Equivalent to pressing the GSM shield "power" button
void SIM900power(){
        digitalWrite(9, HIGH);
        delay(1000);
        digitalWrite(9, LOW);
        delay(5000);}

void sendSMS(){
        SIM900.print("AT+CMGF=1\r");
        delay(100);
        SIM900.println("AT + CMGS = \"+60162923680\"");
        delay(100);
        SIM900.println("Emergency! Falling incident happened.");
        delay(100);
        SIM900.println((char)26);
        delay(5000);
        SIM900power(); }
```

Figure 7(b): Sending emergency messages

```
void loop(){
        digitalWrite(greenLEDPin, HIGH);
        digitalWrite(blueLEDPin, LOW);
        digitalWrite(redLEDPin, LOW);
                :
//Reading 6 bytes of data starting at register DATAX0
        readRegister(DATAX0, 6, values);
//The X value is stored in values[0] and values[1]
        x = ((int)values[1]<<8)|(int)values[0];
        :
//Convert the accelerometer value to G's.
        xg = x * 0.0078;
        :
//Delay before next reading
        delay(100);
        if(free_fallEvent == 1){
             Serial.println("freefall");
             Serial.print(x, DEC);
             :
             Serial.println(z, DEC);
             digitalWrite(greenLEDPin, LOW);
             do{
                          digitalWrite(redLEDPin, HIGH);
                          delay(100);
                          digitalWrite(redLEDPin, LOW);
                          digitalWrite(blueLEDPin, HIGH);
                          delay(100);
                          digitalWrite(blueLEDPin, LOW);
                          delay(100);
                          int picth = map(i,1000,1023,50,4000);
                          tone(3,picth,10);
                          :
             } while (a<=50);
             sendSMS();
             free_fallEvent = 0; }
        detachInterrupt(0);
        delay(100);
        attachInterrupt(0, fall, RISING); }

//This function writes a value to a register on the ADXL345
void writeRegister(char registerAddress, char value){
             digitalWrite(CS, LOW);
             SPI.transfer(registerAddress);
             SPI.transfer(value);
             digitalWrite(CS, HIGH); }

void readRegister(char registerAddress, int numBytes, char * values){
             char address = 0x80 | registerAddress;
             if(numBytes > 1)address = address | 0x40;
                          digitalWrite(CS, LOW);
                          SPI.transfer(address);
                          for (int i=0; i<numBytes; i++) {
                          values[i] = SPI.transfer(0x00); }
                          digitalWrite(CS, HIGH); }
void fall(void){
             if((values[0] & 0x04)==0x04 )
                    free_fallEvent = 1;
             else   free_fallEvent = 0;
             readRegister(INT_SOURCE, 1, values); }
```

Figure 7(c): Detecting a falling position

Figure 8 gives a sketch of the configuration of Arduino/Arduino clone as serial link between PC and the GPRS Shield (Jumpers on SWserial side). PC would need serial terminal software to communicate with it - Window's built-in HyperTerminal, Arduino IDE's Serial Monitor, Serial Terminals (sscom32) or Bray++ Terminal.

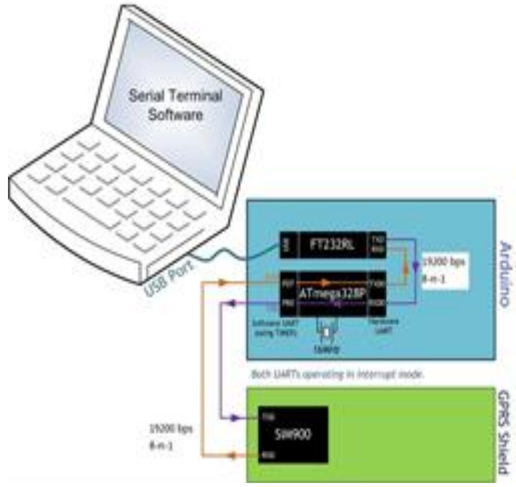

Figure 8: Configuration between PC with Arduino UNO and SIMCOM SIM900 quad-band GSM GPRS shield

6. Results Analysis

Figure 9(a)–Figure9 (j) illustrate the moving direction of the ADXL345 accelerometer and the reading of x-axis, y-axis, and z-axis in different situation.

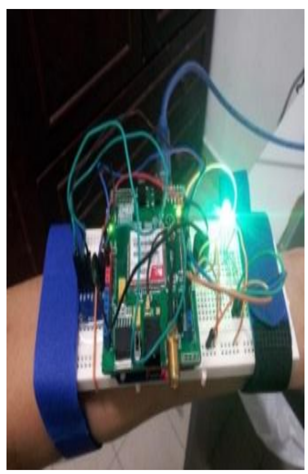

Figure 9(a): ADXL345 Accelerometer moving to North direction

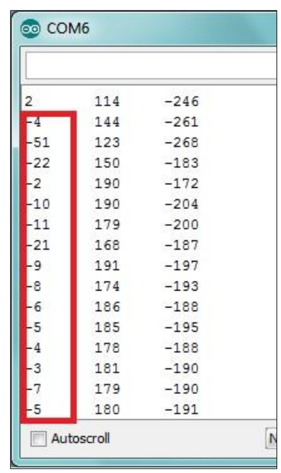

Figure 9(b): Reading x-axis value become negative when ADXL345 Accelerometer moving to North direction

Figure 9(c): ADXL345 Accelerometer moving to East direction

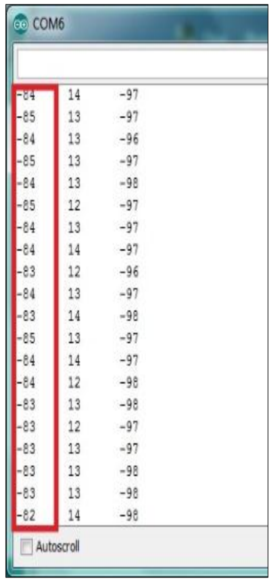

Figure 9(d): Reading x-axis value become negative when ADXL345 Accelerometer moving to East direction

Figure 9(e): ADXL345 Accelerometer moving to South direction

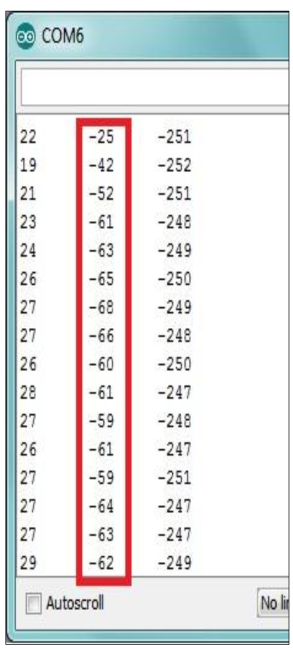

Figure 9(f): Reading y-axis value become negative when ADXL345 Accelerometer moving to South direction

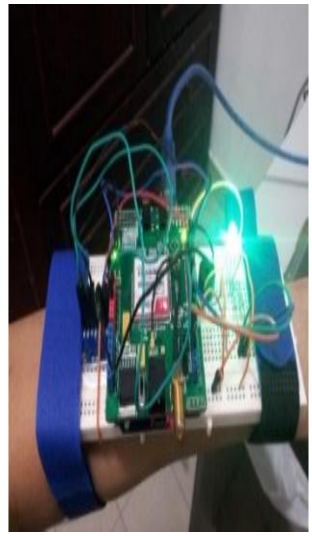

Figure 9(g): ADXL345 Accelerometer moving to West direction

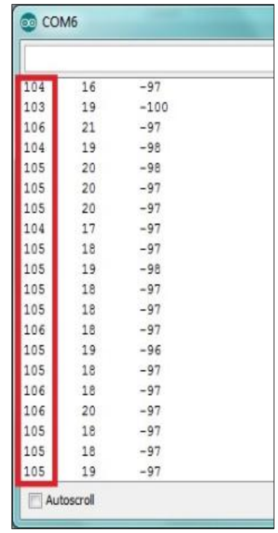

Figure 9(h): Reading y-axis value become positive when ADXL345 Accelerometer moving to West direction

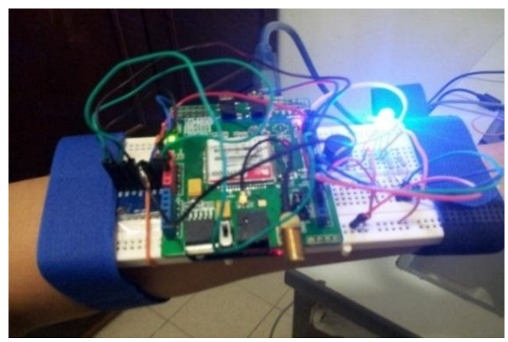

Figure 9(i): RGB LED light blinks red and blue colours continuously and the buzzer triggers alarm simultaneously for 15 seconds

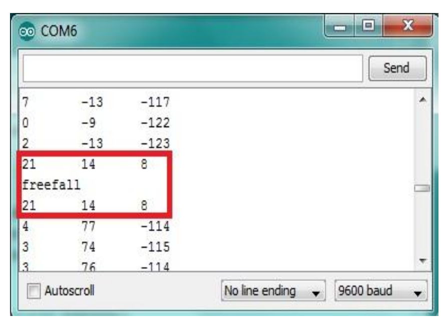

Figure 9(j): Reading x-axis, y-axis, and z-axis value when freefall

Figures 10–12 depict the acceleration change curves during the motions of sitting down, standing up from a chair, and falling.

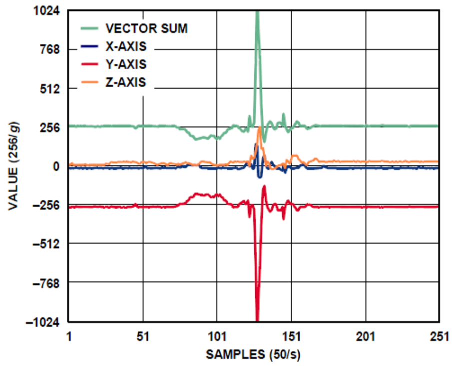

Figure 10: Acceleration change curves during the motion of sitting down

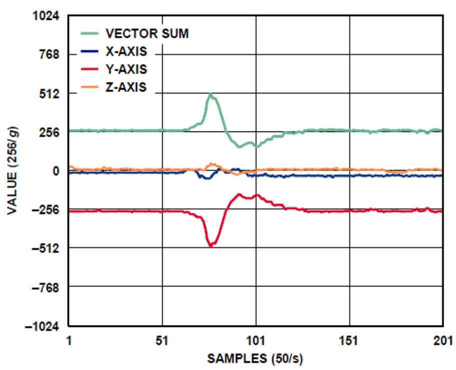

Figure 11: Acceleration change curves during the motion of standing up

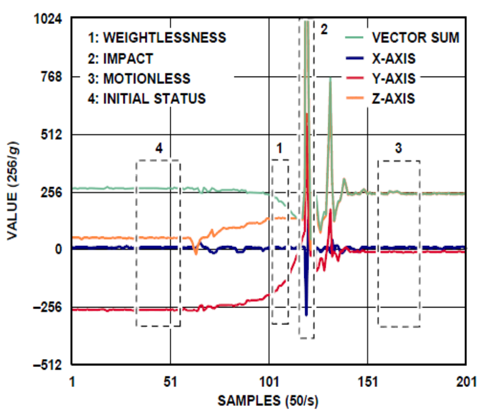

Figure 12: Acceleration change curves during the motion of falling down

By comparing Figure 12 with Figure 10 and Figure 11, it can be seen that there are four critical characteristics of a falling event, which are 'Weightlessness', 'Impact', 'Motionless' and 'Initial Status'. These four characteristics can be used as the criteria of the fall detection. They are marked by the boxes in Figure 12.

Some limitations of this system are the threshold value setting of the system; the system will only detect freefall when the threshold value during freefall is match with the threshold value set in the system. If the threshold value during freefall is less than the threshold value set in the system, the system will not detect freefall because the condition does not fulfil. This is one of the limitations of the system as we cannot predict the falling position of the elderly and the threshold value when the elderly is falling. Besides this, another limitation is that the system does not have a GPS module that can track the falling position of the elderly; it can only send a SMS to the contact person stored in the system but does not included the falling location of the elderly. The contact person who receives the SMS has to track where the SMS sent from, and then only can contact ambulance to request for medical help. This limitation causes delay of time for the ambulance's rescue worker to reach the falling location and giving first aid for the victim (the elderly).

7. Conclusion

This paper presented the design and implementation of a fall detection sensor system that uses the four characteristics (Weightlessness, Impact, Motionless, and Initial Status) described in Section 5 as the criteria for a fall detection and computation. This system is useful for the elderly people who live alone at home to ensure their personal safety, in which the system will inform the contact person after a fall incident happened. Ambulance department will also be contacted to arrive at the falling location and give medical treatment for the elderly as soon as possible.

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