Fall Detection and Balance Monitoring System for Older Persons

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***Abstract*— Fall is one of the most deadly events among senior citizens and medical attention may be required immediately. Automatic fall detection and balance monitoring systems could support an independent lifestyle for elderly without worrying about any possible fall events. A fall detection system in real time can help us detect falling incidents among the elderly immediately and besides that a balance monitoring system also can help warn users to maintain body balance thus further reducing the falling rate. In order to build a real-time system that not only distinguishes different types of falls but it must be portable, wearable, cheap and with high precision, the suggested system uses the accelerometer and gyroscope to detect fall and tilt position. Therefore, an early detection and engagement to help people after a fall is important since it helps the fallen person to heal and limit the long-term harm caused by the fall. A wearable fall detection and balance monitoring device is designed to address this problem. The device is operated most efficiently when put on a waist as the waist represents the centre of gravity in the human body. The system contains a fall detection system with a GSM instant feature that can send calls to caretakers for emergency services. It also involves the balance monitoring system that rings the alarm when the body is not balanced. The concept and implementation comprises both hardware and software, which detect and notify fall seamlessly and monitor a body balance. This project involves Proteus software to design the system, Arduino for programming and MATLAB software for the GUI system. The main objective of this project is to innovate new technology involving body balancing and fall detection devices that can monitor and protect the elderly.**

Keywords—fall, balance, accelerometer, gyroscope Proteus, MATLAB, GUI

I. INTRODUCTION

Fall is a risk for older people and much research on the subject found that falls in the elderly are a challenge that need to be overcome using the newest technology. Few reasons that cause the fall are cognitive disability, vision, muscle discomfort, gait and balance disorders, and sarcopenia. Balance collects sensory and proprioception inputs in order to produce motor responses that regulate the movement of the body[1]. Due to the disease and natural aging phase, this ability deteriorates and increases the risk of falling among elderly people[2]. The World Health Organization analysis predicts that by 2050 , people aged 65 can face life-threatening incidents which are falling. Elderly who have experienced a fall are at higher risk of falling again. Statistics show that 37.3 million people have suffered serious falls every year[3]. As prevention, a lot of exercise can be done to avoid such incidents. General effects of exercise in elderly people will typically result in building resilience, stamina, strength and balance. It is particularly essential to increase muscle strength and to bear weight for elderly since it prevents loss of muscle mass, bones and functional capabilities[4].

The purposes of this project are to design a wearable fall detection system that can help to prevent serious injury when a fall is detected and to design a balance monitoring system that can warn any possible fall events. Falling down and unconscious can be fatal if nobody knows it and can lead to more damage. It is critical to have a quick response and rescue time if a falling incident occurs. Moreover, an increase in sensors and unpleasant wear conditions attached to the human body is not appropriate for older people. Thus, wearable, compact and affordable fall detection and balance monitoring systems must be designed less complex. Finally, older people who have fallen are more likely to fall again. These give them fear. Therefore, the fall detection system can give assurance and send out alerts to call for help. To prevent any possible fall events, balance of the body is being monitored.

II. METHODOLOGY

A. *Project Overview*

First, this project will involve two systems which are fall detection system and balance monitoring system. As these two systems are very related to each other, the balance monitoring system is conducted simultaneously with the fall detection system. For the detection of fall and monitoring balance, it is investigated in three axes which are X, Y and Z axis. Specifically, the X-axis is used to sense the gravitational acceleration of the system while the value changes when the Y and Z axis is perpendicular to the gravity. Figure 1 shows the flow chart of the project. It begins with designing the fall detection and balance monitoring system, then simulating the system in Proteus Software. Next, the prototype is designed after the performance of the simulation is fulfilled.

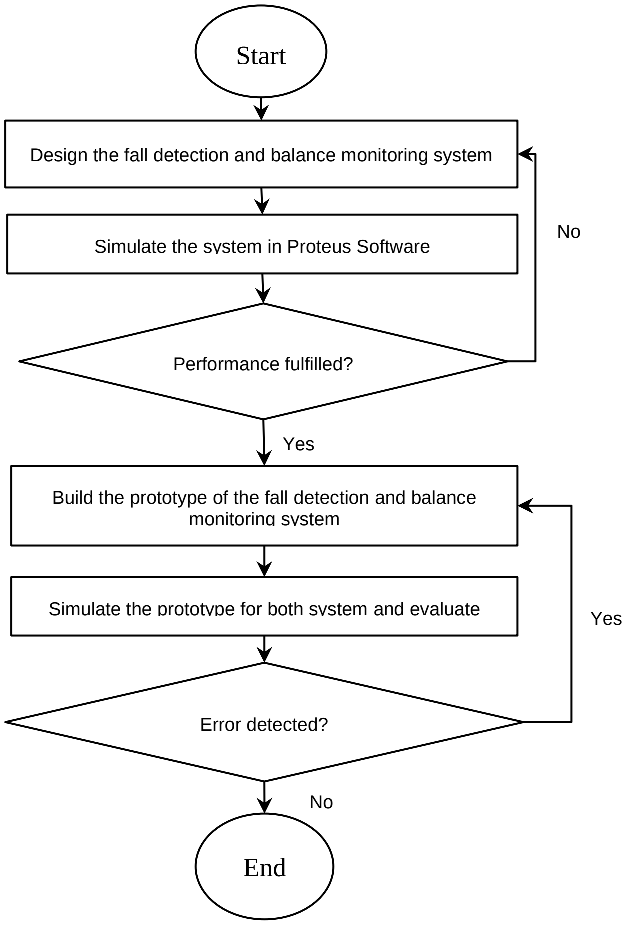

Figure 1: Flowchart of the project.

B. *Method of Research*

The procedure of the project begins with designing the fall detection system. This system focuses on detecting fall using a built in 3-axis accelerometer sensor in the MPU6050 module. This accelerometer detects changes in a person's motion and body position by monitoring changes in acceleration. Whereas for balance monitoring systems, it detects rotational and angular velocity along the X, Y, Z axes as the MPU6050 has a 3-axis gyroscope using Micro Electro Mechanical System (MEMS) technology. The combination of both systems is shown in Figure 2 which contains a microcontroller, MPU6050, GSM900, MATLAB GUI, mobile phone, a yellow LED and a buzzer.

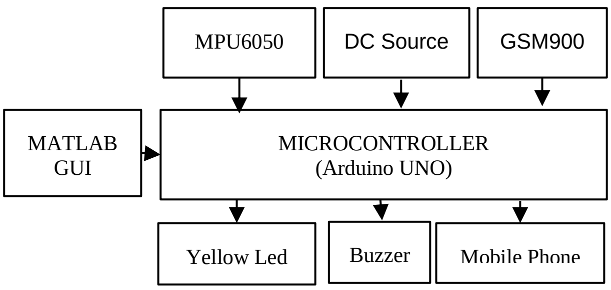

Figure 2: Block diagram of fall detection and balance monitoring system using MPU6050 sensor.

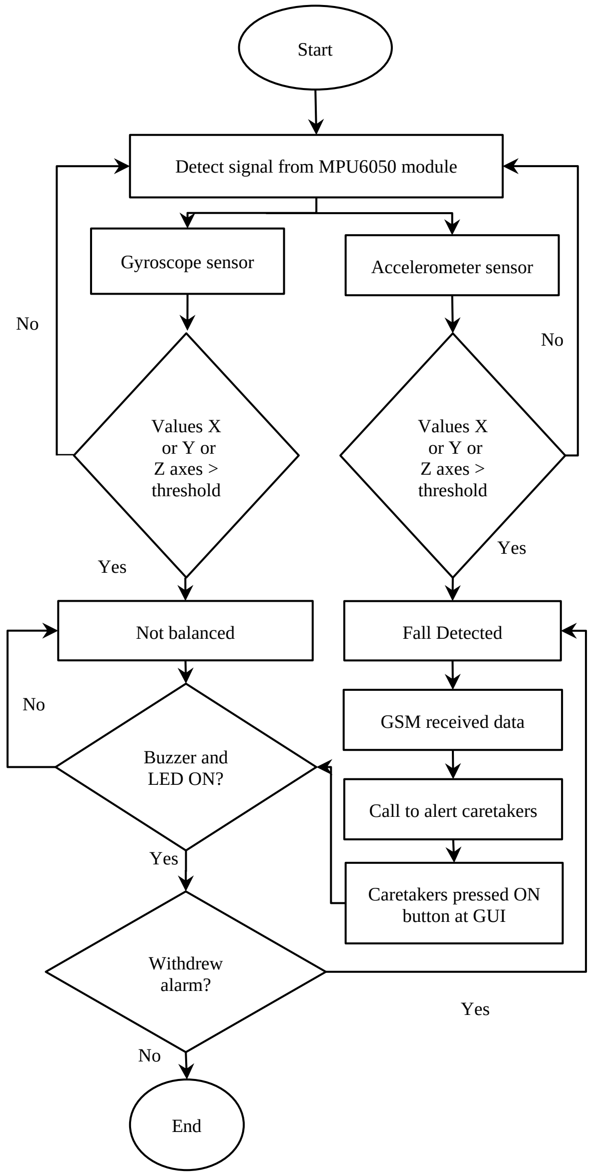

Figure 3: Flowchart of the fall detection and balance monitoring system.

If one of the values of x or y or z exceeds the threshold value, the fall is detected. GSM receives data and immediately updates users' status and calls the caretakers through the global mobile communications system (GSM). Then the caretakers will turn the system ON at GUI. The function of this GUI is to turn on the alarm sounds to warn a possible fall event. If the user did not turn off the fall alert, it would mean that the person that fell was still not being taken care of. In the case of this GUI system, the alarm will be controlled by the users until the fallen person is found by the caretakers. This GUI system can locate the fallen person through the sound of the alarm. On the other hand, the built-in gyroscope from the MPU6050 sensor measures the tilt and lateral orientation thus monitoring the body balance of a person. If one of the values of x or y or z exceeds the threshold value, the body is not balanced. Thus, the system will turn on the buzzer and the led to warn and avoid any possible fall events.

C. Simulation design

The fall detection system and balance monitoring system's electronic circuitry is designed with Proteus 8 Professional while the coding of the system is written in the Arduino Software. The three potentiometers represent the accelerometer when the relation of the electronic components is built. It acts as a variable voltage source for each axis, this is because the acceleration and velocity in the MPU6050 module is directly proportional to the output voltage of each axis. The 3 axes value will be controlled. When the microcontroller detects changes in values of acceleration or angular velocity which are more than the preset values of an axis in three orthogonal directions then the microcontroller initiates the buzzer and displays the alarm status on the virtual terminal and the system will be high and GSM900D will send notification.

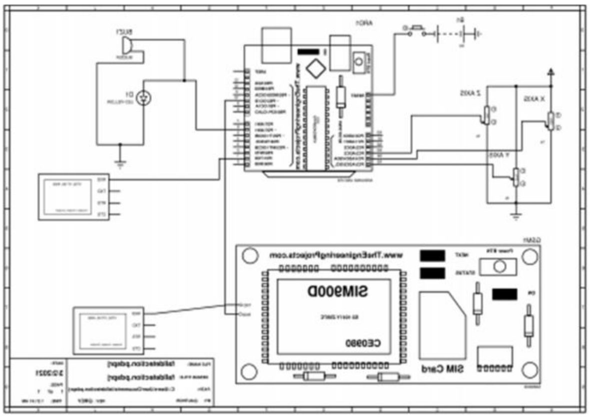

Figure 4: The fall detection and balance monitoring system simulation in Proteus 8 Professional.

D. GUI design

This is the design on MATLAB GUI. Function of this requires just a click on the simple button in order to use its features. It is quite easy for novices to use as it is user friendly. The design contains two buttons to ON the system and another one to turn it OFF. Figure 5 shows the design of the GUI in MATLAB software.

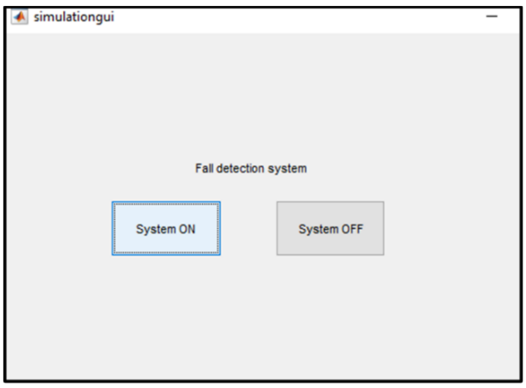

Figure 5: MATLAB GUI

E. Hardware Implementation

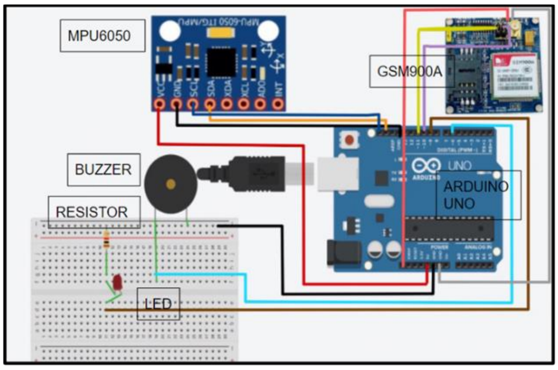

Figure 6: The circuit diagram of fall detection and balance monitoring system.

Steps in connecting the components:

- Connect Arduino 3.3V to MPU6050 VCC.
- Connect Arduino GND to MPU6050 GND.
- Connect MPU6050 SDA to Arduino SDA.
- Connect MPU6050 SCL to Arduino SCL.
- Connect buzzer to D6 Arduino.
- Connect led to D9 Arduino.
- Connect GSM's 5VT to D10 Arduino
- Connect GSM's 5VR to D11 Arduino.
- Connect Arduino 5V to GSM VCC
- Connect Arduino GND to GSM GND

Figure 7: The prototype in the waist bag.

III. RESULTS AND DISCUSSION

A proposed wearable fall detection and balance monitoring system based on a single MPU6050 module will be discussed in this chapter. The proposed waist-shaped device includes built-in 3-axial accelerometer and gyroscope sensors in the module to detect the subject's movement and position. The data is then obtained by the module to identify any fall events and monitor the unbalanced body's values.

A. Simulation

The system is simulated on Proteus Software and both systems could only be done separately as the actual library of the sensor is unavailable but theoritically the output results are the same. As shown in Figure 8 the output results for fall detection system where GSM module sends notification. The condition that means if only one axis exceeds the threshold values, the system will be high meaning that a fall is detected. Finally, for a balance monitoring system if only one axis exceeds the threshold values, the system will be high meaning that the body is not balanced. As shown in Figure 9 for balance monitoring system, the led will light up and the buzzer will turn on.

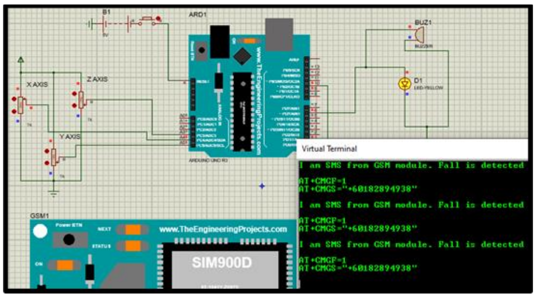

Figure 8 : Output results when X axis is HIGH for fall detection system.

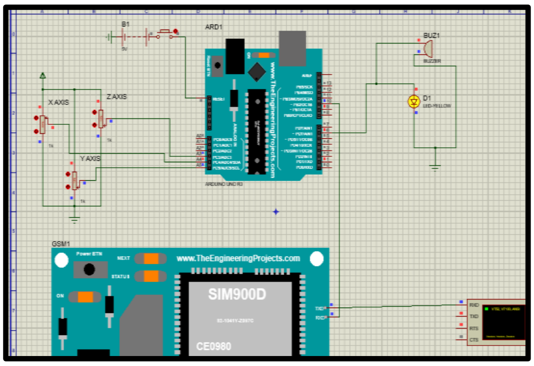

Figure 9: Output results when X axis is HIGH for balance monitoring system.

B. Hardware Implementation

The system first will initialize the MPU6050 module and check the whole wiring connection. Figure 10 shows the command window for the output results of the system. They are specified into two parts of output values where Xaccel, Yaccel and Zaccel are for the values of acceleration in m/s^2 while Xgyro, Ygyro and Zgyro are for gyro values in degree/sec.

```
COM3

Initialize MPU6050

 * Sleep Mode:               Disabled
 * Clock Source:             PLL with X axis gyroscope reference
 * Accelerometer:            +/- 2 g
 * Accelerometer offsets: -1360 / -2569 / 992

 * Gyroscope:           250 dps
 * Gyroscope offsets: 0 / 0 / 0

 Xaccel = -2.44 Yaccel = 0.60 Zaccel = 9.28
 Xgyro = 5595.00 Ygyro = -14.00 Zgyro = 13272.00
```

Figure 10: Command window for the output results.

For the fall detection system, Figure 11 shows the output result when the axis exceeds the threshold value. Only when the threshold value during freefall exceeds the threshold value set in the system will identify freefall. The changes in angular velocity are depicted in Figures 12 for the balance monitoring system where the concepts implemented are the same as fall detection system.

```
 Xaccel = 19.20 Yaccel = 14.80 Zaccel = 5.54
 Xgyro = 1111.00 Ygyro = 201.00 Zgyro = -694.00
fall detected.
Calling caretakers
```

Figure 11: Output results when Xaccel exceeds 15 m/s^2.

```
 Xgyro = -552.00 Ygyro = -115.00 Zgyro = 326.00
 Xaccel = -2.18 Yaccel = 0.62 Zaccel = 9.21
 Xgyro = -285.00 Ygyro = 496.00 Zgyro = 195.00
 Xaccel = -2.44 Yaccel = 0.67 Zaccel = 8.71
 Xgyro = 4085.00 Ygyro = -1961.00 Zgyro = -5811.00
not balanced
```

Figure 12: Output results when Xgyro exceeds 2500 deg/sec.

The fall detection system and balance monitoring system will run simultaneously in real-time status. The reading for the X, Y and Z axis becomes negative when the sensor is moving in North and East direction while positive when the sensor moves in West and South direction. When the Xaccel axis exceeds 15m/s^2 as shown in Figure 11, then the GSM900A will call caretakers as a fall is detected. As shown in figure 4.3.2, the caretakers receive the call from GSM900A.

Figure 13: The call from GSM900A when fall is detected.

The reason that the threshold value for fall detection is set as 15 m/s^2 is because the normal freefall value of an object stated by Newton's second law is 9.8 m/s^2. Whereas for balance based on [5], average body stability based on directional control is around 74.95 deg/sec for male and 73.13 deg/sec for females but the threshold value is assumed higher than that stated value because the sensor is very sensitive to smaller values. That is one of the system's limitations as when the elderly fall or when the body is not balanced we can't foresee the exact threshold value.

C. GUI system

Following the system calling the caretakers through the GSM system, the caretakers then will turn the system ON at GUI. In order to notify a probable fall occurrence, this GUI operates to activate alarm sounds. If the user did not turn off the fall warning, the individual who fell would still not be taken care of. In the case of this GUI system, the alarm will be controlled by the users until the fallen person is found by the caretakers. In fact, the GUI system will replace GPS in order to save costs. When caretakers enable the GUI system, the falling person can be found by the sound of the alarm. Figure 14 shows the result from MATLAB GUI. When the system ON led will light up and the buzzer will turn on. In the programming, the D9 of the Arduino is set as the LED and D6 as the buzzer.

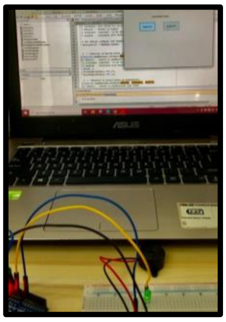

Figure 14: The led will light up and the buzzer will turn on when the system is ON

D. Summary

To summarize, the expected results for simulation and hardware have been successfully obtained. The buzzer and led turned on when the value of any axis exceeded the threshold value when the body is not balanced whereas the call is received after a fall is detected. This fall detection and balance monitoring system helps instantly discover falling events among the elderly aged 50 years and above. It also successfully assists users to monitor the body balance so that the falling rate is further decreased.

IV. CONCLUSION

In conclusion, all objectives of the project have been achieved where a wearable device has been successfully designed that can help to prevent serious injury and ensure the elderly personal safety when a fall is detected and can warn of any possible fall events by monitoring the body balance. The buzzer and led turned on when the value of any axis exceeded the threshold value when the body is not balanced whereas the call is received after a fall is detected. Since a solid outcome has been achieved and the project works in accordance with the flowchart, the whole system may be regarded to be effectively built. As the system enables convenient wear, less sophisticated as compared to others, rapid fall reaction, accurate and cost-effective, it may be seen as an alternative to current available devices. One of the limitations of the system is the threshold value can't be foreseen as it differs for every person. Thus, thorough data should be taken and analyzed so that the average value can be obtained and improved the accuracy of the system. The system can be improved by using data driven approaches as these approaches are more relevant and accurate nowadays as it uses machine learning and deep learning where algorithms are used for analysing data gathered on wearable devices. As already indicated, the non-linear combination of multiple sensors may be extremely successfully represented by means of machine learning. Next, threshold-based techniques are still less preferred with the breakthrough of deep learning as this method is based on data and robust compared to threshold-based methods. On the other hand, GPS can be added to improve the accuracy of location. The mobile application also can be improved using the newest technologies.

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