Real-time monitoring system for elderly people in detecting falling movement using accelerometer and gyroscope

B Siregar¹, U Andayani¹, R P Bahri¹, Seniman¹ and F Fahmi²,*

¹Faculty of Computer Science and Information Technology, Universitas Sumatera Utara, Medan Indonesia
²Department of Electrical Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan Indonesia

*Email: fahmimn@usu.ac.id

Abstract. Most of the elderly people is experiencing a decrease in physical quality, especially the weakness in the legs. This will cause elderly easy to fall and can have a serious impact on their health if not getting help very quickly. It is, therefore, necessary to take immediate action against the falling cases experienced by the elderly. One such action is by developing supervision and detecting of falling movements in real-time, which is then the connection to a member of the family. In this research, we used Arduino Uno as a microcontroller, sensor accelerometer, and gyroscope that serves to measure falling movement of the elderly person and supported by GPS technology Ublox Neo 6M to provide information about coordinates. The result was the high accuracy of delivering notification data to server and accuracy of data delivery to family notification equal to 93.75%. The system successfully detects the direction of falling: forward, backward, left or right and able to distinguish between unintentional falling and conscious falling like a bow or prostrate position.

1. Introduction
When a person has advanced age, the person is likely to experience a decrease in physical quality, one of the weaknesses (physical decline) experienced by the elderly is a weakness in his legs, and this will make them easier to fall. Falling is an event that causes a conscious subject to be on the ground unintentionally. Factors that cause falls are ill-informed like stroke [1,2], slippery or wet floors, holding places that are not strong or not easily held.

Supervision of the elderly is an important thing done because it allows the occurrence of accidents, such as falls. Falling experienced can have a very serious impact on the person’s health if they do not get help quickly. Therefore, a solution is needed to monitor the movement of the elderly in real-time connected with interested parties, such as medical or family personnel.

Oversight of the elderly is something that is sometimes neglected by the family because they can not always be beside the person. Delays in handling fall often occur due to delays in information received, so unknown fall of elderly parents. It has shortcomings on the side of providing information to the family. With the application system it is expected to help to monitor the elderly and can detect the movement of the fall.

In the year 2012, there was research for Monitoring Against Physical Activity Users and Tracking Position with Real-time. This study aims to detect daily activities such as walking, running, and supine using the method of Decision Tree and naive Bayesian. By using the accelerometer, data will be done
pattern recognition process to recognize user activity called Activity Recognition. Testing is done to test the functionality of the created system. Assaying accuracy on the Naïve Bayesian classification method resulted in a high accuracy rate (98.67%) compared to the Decision Tree method (92.33%) for all activities tested with several variations of sampling length [3].

Furthermore, another research in 2013 was done by putting the smartphone in the pocket user, and then system will detect the user's physical activity at the time of falling. After sensor data is obtained, the system will use windows sampling technique and overlapping method to process sensor data. Application of fall detection system has been implemented and able to detect the user's physical activity when dropped with the accuracy level of 91.75% and can send notification via e-mail [4]. In the year 2014 a study was conducted to calculate the acceleration quantity of the accelerometer sensor in measuring the total acceleration, the total difference of acceleration and the angle of the slope. Time of fall is detected based on the total value of acceleration and the amount of difference of total acceleration. This study made a comparison between techniques that used the total difference amount of acceleration and which did not use. In the test results showed both have the same sensitivity and specificity, which is 90% and 94% of 490 movements [5].

In 2014 a research was done by detecting falls using 3-axis acceleration sensors to measure and collect data. This research uses Zigbee-3G method and one-class SVM classification algorithm. This study analyzes the speed, angular displacement. An analysis is performed if the threshold range exceeds [6]. Another approach is based on image processing as implemented in medical device technology [7], another study shows the implementation of real-time application for water pollution has been referred [8].

In this study, we used accelerometer and gyroscope sensors to monitor and detect movement in the elderly. The input of this system is elderly parents. In the study we used accelerometer and gyroscope sensors that function to take every movement of the elderly and supported by GPS technology in getting the coordinates in order to be able to monitor the falling movement of elderly people.

2. Methodology

The general architecture of this study can be seen in Figure 1.

![Figure 1. General Architecture](image)

2.1. Hardware

The first process of the general architecture is to place sensors on the right side of the waist, in the form of a box that has Accelerometer sensor and Gyroscope. Accelerometer and Gyroscope Sensor has 3 axis...
coordinates that are the axis X, Y, and Z. This device will detect the movement that occurs. Data experiments were detected as falling, falling forward, falling backward, falling right and falling left. When the user is on the move, the application will retrieve the Accelerometer and Gyroscope data. After that, the system receives input in the form of coordinates to be provided by GPS Module, and SIM 800L mounted on Arduino and sensor MPU6050. Elderly coordinates are obtained from GPS Modules that have been assembled on Arduino.

There are three modules that will be paired with an elderly person, Arduino, MPU6050, NEO-6M GPS Module, SIM 800L. Arduino as the main board and MPU6050 which functions as Accelerometer and Gyroscope data from the elderly activity, NEO-6M GPS module that serves to determine the coordinates of the elderly location, as well as SIM 800L to transmit data to the server. Arduino is still empty, will be uploaded a program to be able to run data obtained from Accelerometer, Gyroscope and to know the coordinate point of elderly location. After that, SIM 800L will send coordinate points to the server based on the server's IP address; the server will store the data aged activity and coordinate point into the database and send it to the user.

The user is a family or relative associated with an elderly person and who will monitor the location of the fall. Users can monitor elderly location through the elderly monitoring system. Arduino will convert the analog signal into a digital signal. The motion activity that has been obtained is sent to real-time monitoring application system using the SIM800L sensor.

2.2 The Elderly Monitoring Application System
Monitoring application system to be built is a web-based application system using PHP.

2.2.1 Web Server
The web server to be used is a self-built web server. The web server serves as a place of service and data processing between Arduino, database, and client. The web server will receive data from Arduino in the form of user movement activities such as walking, falling forward, falling backward, falling to the right, and falling to the left. This data will then be stored in the database and ready to be processed to show back to the client in the form of GPS coordinates.

2.2.2 Client
The client will access a web page on the web server for monitoring. This page will contain the GPS coordinates of each elderly activity, and these coordinates will always move and updated automatically every second without the client needing to refresh the web page. If the data received is beyond a predetermined threshold, the system will display a notification to alert the user of the system in the form of an SMS to the family.

2.3 Fall Detection
In determining the condition of the fall of the elderly can be seen from the angle of slope. The angle of the slope is determined from the X and Y axes (Table 1)

| No. | angle (x, y) | Condition   | Note  |
|-----|-------------|-------------|-------|
| 1.  | (0,25)      | StartTimer  | Forward |
| 2.  | (0,50)      | End Timer   |       |
| 3.  | (0, -25)    | StartTimer  | Backward |
| 4.  | (0,-50)     | End Timer   |       |
| 5.  | (25,0)      | StartTimer  |       |
| 6.  | (50, 0)     | End Timer   | Right |
| 7.  | (-25, 0)    | StartTimer  |       |
| 8.  | (-50, 0)    | End Timer   | Left  |

Table 1. Fall detection condition
In this study determined the following conditions:
- If the time is greater than 200ms, then the condition is declared Normal.
- If the time is less than 200ms, then the condition is declared Fall.

3. Hardware Design

3.1 Design of Arduino Uno and Sensor MPU6050
The Serial Data Pin (SDA) of the MPU6050 is connected to the Analog 4 (A4) pin residing on the Arduino Uno. Pin Serial Clock (SCL) MPU6050 is connected to Analog 5 (A5) pin located on Arduino Uno. Ground Pin (GND) MPU6050 is connected to Ground resources. The VCC pin of MPU6050 is connected to the VCC resource.

3.2 Design of Arduino Uno and SIM800L
Pin Rx (Receiver) SIM800L is connected to Analog 2 (A2) pin located on Arduino Uno. Pin Tx (Transmitter) SIM80L is connected to Analog 3 (A3) pin located on Arduino Uno. Pin Ground SIM800L is connected to a Ground resource. Pin VCC SIM800L is connected to VCC resource.

3.3 Arduino Uno Scheme to GPS NEO6M
The NEO6M GPS Tx (Transmitter) pin is connected to the Digital 0 (PD0) pin that resides on the Arduino Uno. The NEO6M GPS pin Rx (Receiver) is connected to a Digital 1 (PD1) pin that resides on the Arduino Uno. NEO6M GPS Ground Pin is connected to Ground resources. VCC GPS pin NEO6M is connected to VCC resource.

3.4 Power Scheme to LM2596
The power supply is connected to the switch, and the positive voltage of the power supply (PS) is connected to the positive pin IN StepDown LM2596, while the negative PS voltage is connected to the negative pin IN. Then the positive LM2596 pinout is made as VCC power source and connected to positive LED foot; then the negative LED foot is connected to one of the legs of the resistor. The other leg of the resistor is connected to the Ground resource while the negative LM2596 pinout is used as a Ground resource. Resources are the source of StepDown LM2596.

The design of the hardware can be seen in Figure 2.

![Figure 2. Hardware Design](image-url)
4. Result and discussion

Prototype form that will be designed in the form of a box. The shape of the prototype that has been designed can be seen in Figure 3.

![Prototype Designed](image_url)

Hardware that has been designed will be programmed through the program on the computer through a connecting cable. Initially, the program will run on SIM800L. The SIM card will search for the signal first. If the SIM card has got the network to transmit coordinate data obtained through the GPS module, it will display a notification in the form of the words "GPRS OK" on the computer monitor series. In the box, there are 3 pieces indicator lights. The light on the right will turn green indicating that the device is active. The light in the middle will turn red indicating that GSM has been active in the light in the middle of the blinking faster indicates that the internet is stable. The light on the left will turn red indicating that the GPS is active. On the right side, there is an emergency button that serves as an additional tool for notification to the family.

4.1 System Performance Testing

At this stage discusses the problem of performance testing system or tool built to determine the performance of the system in doing the detection whether it is running well. The sensor is placed at the right waist in the elderly. To test the data delivery system from SIM800L to the server by using GSM / GPRS module. This study tested 4 different fall angles and monitored the testing of data transmission to the server and notification to the family in the form of SMS.

Testing by Angle by angle of front view (0,10) (0,15) (0,20) (0,25) and side view (10,0) (15,0) (20,0) (25,0). Test results at the angle (0.10) a box are placed on the right side; front view has front and rear sides. In this test the condition of elderly is still in a normal state, this is because the tool or sensor has not detected any reaction from the elderly. The view at the angle (0.10) can be seen in Figure 4a. Testing at the angle (0.25) a box is placed on the right side; front view has a front and back side. In this test, the elderly condition is still in the normal state, but at an angle (0.25) starts the initial process calculation to detect the fall but the system does not send a notification to the server or to the family. The view at the angle (0.25) can be seen in Figure 4b.

4.2 Testing Data Delivery

Testing data delivery based on notification time on server and time of family notification. The application system testing can be seen in Table 2.
Figure 4. Testing at an angle (a) 0.10 and (b) 0.25

Table 2. Testing Data Delivery

| NO | Server HTTP | Notification |
|----|-------------|--------------|
| 1  | 18.55       | 18.55        |
| 2  | 19.00       | 19.00        |
| 3  | 19.07       | 19.07        |
| 4  | 19.12       | 19.12        |
| 5  | 19.17       | 19.17        |
| 6  | 19.22       | 19.22        |
| 7  | 19.29       | 19.29        |
| 8  | 19.34       | 19.34        |
| 9  | 19.41       | 19.41        |
| 10 | 19.46       | 19.46        |
| 11 | 19.51       | 19.51        |
| 12 | 19.58       | 19.58        |
| 13 | 20.03       | 20.03        |
| 14 | 20.10       | 20.10        |
| 15 | 20.17       | -            |
| 16 | 20.23       | 20.23        |
| 17 | 20.30       | 20.30        |
| 18 | 20.35       | 20.35        |
| 19 | 20.41       | 20.41        |
| 20 | 20.46       | 20.46        |
| 21 | 20.52       | 20.52        |
| 22 | 20.59       | 20.59        |
| 23 | 21.04       | 21.04        |
| 24 | 21.11       | 21.11        |
| 25 | 21.16       | 21.16        |
| 26 | 21.23       | 21.23        |
| 27 | 21.28       | 21.28        |
| 28 | 21.33       | 21.33        |
| 29 | 21.40       | 21.40        |
| 30 | 21.46       | 21.46        |
| 31 | 21.51       | 21.51        |
| 32 | 22.00       | 22.00        |
| 33 | 22.07       | 22.07        |
| 34 | 22.08       | -            |
| 35 | 22.13       | 22.13        |
| 36 | 22.20       | 22.20        |
| 37 | 22.26       | 22.26        |
| 38 | 22.32       | 22.32        |
| 39 | 22.37       | 22.37        |
| 40 | 22.43       | 22.43        |
| 41 | 22.50       | 22.50        |
| 42 | 22.56       | 22.56        |
| 43 | 23.02       | 23.02        |
| 44 | 23.07       | 23.07        |
| 45 | 23.15       | 23.15        |
| 46 | 23.21       | -            |
| 47 | 23.27       | 23.27        |
| 48 | 23.32       | 23.32        |
| 49 | 23.40       | 23.40        |
| 50 | 23.46       | 23.46        |
| 51 | 23.52       | 23.52        |
| 52 | 23.58       | 23.58        |
| 53 | 00.04       | 00.04        |
| 54 | 00.10       | 00.10        |
| 55 | 00.15       | 00.15        |
| 56 | 00.21       | 00.21        |
| 57 | 00.28       | 00.28        |
| 58 | 00.29       | -            |
| 59 | 00.35       | 00.35        |
| 60 | 00.40       | 00.40        |
| 61 | 00.46       | 00.46        |
| 62 | 00.52       | 00.52        |
| 63 | 00.58       | 00.58        |
| 64 | 01.04       | 01.04        |
| 65 | 01.10       | 01.10        |
| 66 | 01.16       | 01.16        |
| 67 | 01.21       | 01.21        |
| 68 | 01.27       | 01.27        |
| 69 | 01.32       | 01.32        |
| 70 | 01.38       | 01.38        |
Table 2 shows the test results of sending data from the web server to the family by using SIM800L under normal conditions notifications will update automatically on the server every 2 minutes. In the elderly conditions in a state of falling so that the device sends a notification to the family to do the help and notification will be updated automatically on the server built, this is because of the network conditions on the tool and server in good condition.

At the time of the fall the family will receive notification in the form of SMS at the same time according to the old time declared in the fall state, but the notification does not go to the server because the internet connection on the server is not stable so the notification on the web cannot be updated in real-time.

4.3 Notification page

Notification page is one page that aims to send a notification to the family if the user of the tool is dropped, the tool automatically sends a notification to the client (family), and notification will be sent to the client (family) in the form of SMS. The notification page view can be seen in Figure 5.

5. Conclusions

This system uses Arduino as a microcontroller to monitor real-time movement in real-time and for data communication using GSM / GPRS network and provider card that serves to measure falling movement of the elderly person. The accuracy of sending notification data to the server is 100% and the accuracy of sending data to family notification in the form of SMS equal to 93.75%. The system successfully detects the direction of falling: forward, backward, left or right and able to distinguish between unintentional falling and conscious falling like a bow or prostrate position based on acceleration moment of falling. At the time of online testing, internet connection plays an important role in the smooth use of the system: some suggestions that can be considered for further research include more stable internet connection. Further development is recommended to determine the location of the more effective sensor installation.
References

[1] Fahmi F, Beenen L F M, Streekstra G J, Janssen N Y, de Jong H W, Riordan A and Marquering H A 2013 Head movement during CT brain perfusion acquisition of patients with suspected acute ischemic stroke European journal of radiology, 82(12), 2334-2341

[2] Fahmi F, Riordan A, Beenen L F M, Streekstra G J, Janssen, N Y, de Jong H W and Marquering H A 2014 The effect of head movement on CT perfusion summary maps: simulations with CT hybrid phantom data Medical & biological engineering & computing, 52(2), 141-147

[3] Hilman A and Wibisono W 2012 Sistem Monitoring dan Tracking Aktivitas Fisik User Bergerak Berbasis Sensor Accelerometer dan GPS pada Perangkat Mobile Berbasis Android Menggunakan Metode Klasifikasi Decision Tree dan Naive Bayesian, Jurnal Teknik POMITS Vol 1(1) p1-6

[4] Arifin D N, Wibisono W and Pratomo BA 2013 Rancang Bangun Sistem Fall Detection untuk Pengguna Bergerak Berbasis Sensor Accelerometer dan Sensor Gyroscope pada Perangkat Mobile, Jurnal Teknik POMITS Vol 2(1)

[5] Liandana M 2014 Deteksi Jatuh Untuk Lanjut Usia dengan Menggunakan Total Akselerasi dan Sudut Kemiringan Berbasis Smartphone Android, Thesis Universitas Gadjah Mada

[6] Ye Z, Li Y, Zhao Q and Liu X 2014 A Falling Detection System with wireless sensor for the Elderly People Based on Ergnomic, Int. J. Smart Home Vol 8, p187-96

[7] Fahmi F, Marquering H , Streekstra G , Beenen L , Janssen N , Majoie C and vanBavel E 2014 Automatic detection of CT perfusion datasets unsuitable for analysis due to head movement of acute ischemic stroke patients J. healthcare eng. 5(1), 67-78

[8] Rahmat R F, Athmanathan A, Syahputra M F and Lydia M S 2016 Real time monitoring system for water pollution in Lake Toba Int. Conf. Informatics Comput. (ICIC) pp. 383–388