Fall Detection System Using Accelerometer and Gyroscope Based on Smartphone

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Fall Detection System Using Accelerometer and Gyroscope Based on Smartphone

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***Abstract*—Most of people likes living independently at home. Some activity in our daily life is prone to have some accidents, such as falls. Falls can make people in fatal conditions, even death. A prototype of fall detection system using accelerometer and gyroscope based on smartphone is presented in this paper. Accelerometer and gyroscope sensors are embedded in smartphone to get the result of fall detection more accurately. Automatic call as an alert will be sent to family members if someone using this application in fatal condition and need some help. This research also can distinguish condition of people between falls and activity daily living. Several scenarios were used in these experiments. The result showed that the proposed system could successfully record level of accuracy of the fall detection system till 93.3% in activity daily living and error detected of fall was 2%.**

Keywords— ***falling detection, accelerometer, gyroscope, smartphone***

I. INTRODUCTION

Falling is an accident that threats the health, especially happened to older people. Caused by reducing levels of strength and stability of the body of a person. Fall detection is very important to monitor someone, especially if the person is elderly.

Many applications fall detector or sold in the market but the reality is that these tools are not widely used. There are several reasons why research on biomedical increased in recent years. However, especially for fall detection is still lacking special attention. In 2008 the work Noury et al [1] can be considered the first in this field.

According to N. Noury, more than 33% of people with over 65 years fall each year [2]. Dangers arising from fall like a minor injury, serious injury, dehydration and even death if there is no fast treatment. Falling is a common problem, but it is quite difficult to define accurately. Since fall is usually characterized by a greater acceleration than the day-to-day activities, the methods are used to measure acceleration usually happens just by using the accelerometer.

Monitoring is necessary for the elderly with a high degree of potential fall. Monitoring can be done by family members or significant others. Surely someone who oversees the elderly should always be near of them so that when the elderly will soon be able to help. But this is it hard for people who care for 24 hours a day. Therefore, monitoring can be done indirectly by utilizing communications technology today that is the smartphone.

Smartphones have been chosen because they are relatively small size with lightweight. This is become added value because it will not charge the elderly because it just simply only put in the pocket. Smartphones do not require additional electronic device has embedded therein for a wide variety of sensors such as an accelerometer, gyroscope, GPS, microphone, camera and others [3]. Additionally in terms the price of smartphone is relatively affordable.

With the gyroscope technology embedded in smartphones, we expect that the use of an accelerometer coupled with a gyroscope can generate better accuracy rate. Gyroscope is used to measure the angle when someone falls, while the accelerometer is used to see the acceleration that occurs in the fall.

This study uses a smartphone with android operating system. While the sensors used are accelerometer and gyroscope sensor.

II. LITERATURE REVIEW

There are several approaches that can be used for fall-detection such as by using the camera like the research done by Koray Ozcan [4]. The Ozcan's study makes the camera attached to the body. So, if there is a change in the orientation of the camera it can be concluded that the person fell. From his research obtained quite good results, it is 86.66%. Nevertheless some improvements must be considered as there are still quite a lot of positives false occurs.

But in another case, some research conducted by Anh Tuan Nghiem by using of the kinect camera that placed in the corner of the room to monitor the movement of a person [5]. The camera will capture the movement of a person and as the camera find a rapidly change in position and end up in the

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supine position, it can be concluded that the person fell. This result is very good even though just in certain viewpoint of kinect. In addition the detection of fall can be done using sensors.

There are several commonly used sensors such as an accelerometer and a gyroscope. Among them is YanjunLi who tried to use the accelerometer sensor [6]. His research by using Telos W as the chipset that connected to the computer with a wireless connection, but in a small scale. So, this detection-fall system is only optimum if indoors.

The research conducted by Qiang Li is utilizing the accelerometer and gyroscope [7]. Basically the two sensors have in common, each has 3 axis. Accelerometer records the acceleration and gyroscope function is knowing the tilt angle of the subject.

The research on the detection-fall we did is using two sensors as performed by Qiang Li, and we take the advantage of the smartphone, because many people who own a smartphone nowadays. And also the smartphone have been embedded in some of the sensors that we need and support systems such as communication networks, the UI (user interface) and battery.

Similar research that inspired us previously done by Waskito Wibisono which is using smartphone [8]. But our research using different method of threshold and our research intended to use in people daily life.

The reason we chose smartphone because they don't look like specific monitoring tools that may reduce the user convenience, so that users do not like being watched. It also can be placed on the right waist or on the left upper pocket such as regular phones.

III. FALL DETECTION SYSTEM

The proposed system utilized a tri-axis accelerometer and gyroscope contained on the smartphones as seen in Figure 1. The fall-detection system that will be made, shall adopt several methods used by previous researchers [8], [9],[10].

The study used a linear acceleration along the X, Y and Z axis, denoted as $(aX), (aX)$ and (aZ) While the gyroscope sensor roll, pitch and yaw denoted as $(gX), (gX)$ and (gZ).

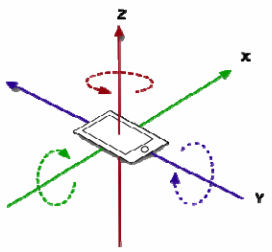

Fig. 1. Axis of the gyroscope ond accelerometer

Based on the value generated by the accelerometer, axis made on the magnitude of these axis were denoted as:

$$AT_t = \sqrt{aX_t{}^2 + aY_t{}^2 + aZ_t{}^2}$$

Meanwhile, the gyroscope applied the same formula as:

$$GT_t = \sqrt{gX_t{}^2 + gY_t{}^2 + gZ_t{}^2}$$

After discovering the magnitude of the sensor, the next step is to find the maximum and minimum value of the sensor. Below is the formula to find the maximum and minimum value:

$$\text{MAX}[AT_t..AT_{t-n}] \text{ dan MIN } [AT_t..AT_{t-n}]$$
$$\text{MAX}[GT_t..GT_{t-n}] \text{ dan MIN } [GT_t..GT_{t-n}]$$

Once the maximum and minimum values are obtained, the following is the formula to find the value sought:

$$angle_{(x,y,z)} = \arccos\frac{acc(x,y,z)}{g} x180$$

g is the constant of gravity that is 9.8 m/s^2.

The algorithm for detecting falling, were divided into four parts as shown in Figure 2. Detection of falling will work by detecting the instability of a user's first step. First by comparing the difference of the maximum and minimum values in the sample and the last with a specific threshold.

Second, the $angle$ value (in degrees) is used to measure the posture, whether a person is standing or falling with the assumption that those who fell will be on the floor (lying or facing up). It can be use to determine whether the user actually fell or stood up quickly [7].

Third, if the value of those points are met then the next step is to test its' threshold value. This threshold value determines whether the user experienced sudden acceleration

Fourth, after all points are fulfilled, the last is to observe the specific direction of the user when they fell.

Here is a flowchart of the application made.

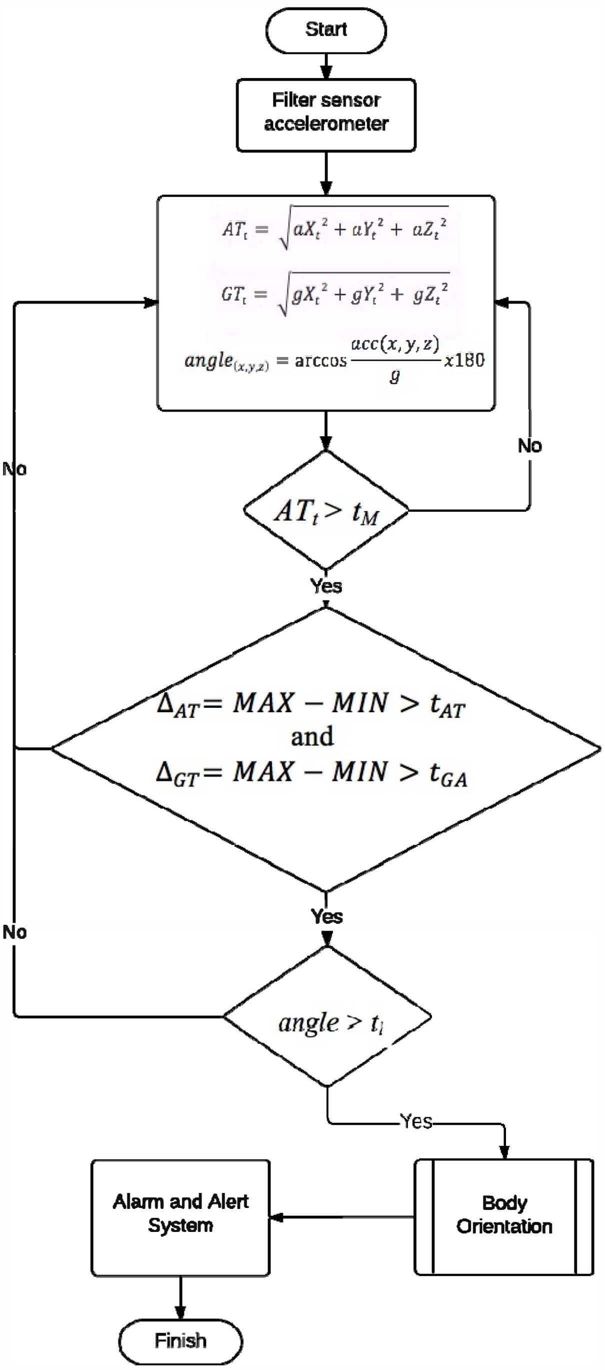

Fig. 2. Flowchart of the Falling Detection Algorithm

In this study, the smartphone that became the monitor is placed in the left shirt pocket. This is done to find a well-positioned condition to capture the data [7][10]. Further, this does not burden the user so the user can still feel comfortable.

IV. CALIBRATION

In order to evaluate the accuracy of the proposed models and prototypes, some scenarios were experimented. Evaluation was done in three different scenarios to observe the performance of the proposed approach and its implementation of the smartphone, equipped with an accelerometer and gyroscope sensors.

The first scenario involved immediately sitting down. Sitting down was one of the conditions, in which previous researchers' system have failed to differentiate with falling. However, by adding the orientation of the gyroscope position, this situation can be prevented.

The second scenario was running. Running is an activity that causes similar acceleration to a fall. But a gyroscope can also prevent it.

The third scenario is falling, which used a combination of the two sensors (accelerometer and gyroscope). It could be detected. Here is a visualization of the data recorded.

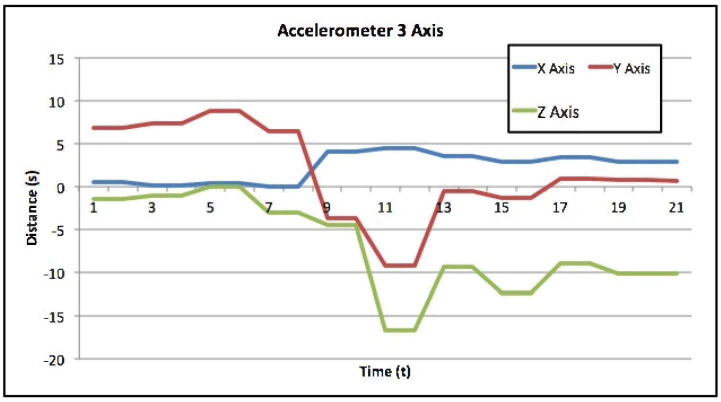

Fig. 3. Accelerometer data raw

The data displayed above is a 3-axis accelerometer data, x, y and z. the data is to be processed so that the threshold can be determined during a fall.

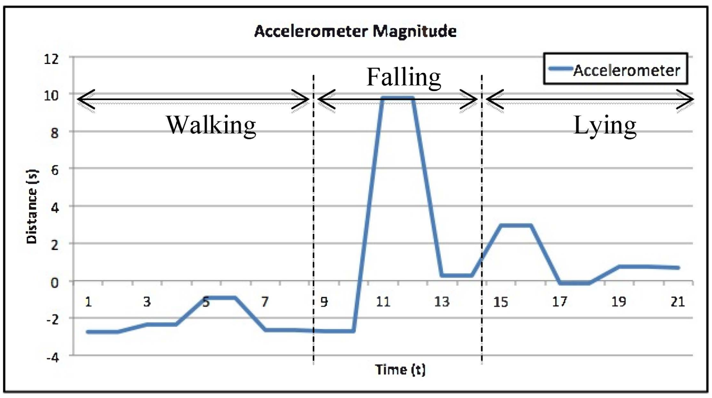

Fig. 4. Magnitude accelerometer data

Having obtained the raw data that was processed by formula $AT_t = \sqrt{accX_t^{\,2} + accY_t^{\,2} + accZ_t^{\,2}}$ the magnitude value was able to be gained. It is then filtered with a high pass filter to eliminate the value of the amount of gravity that is 9.8 m/s^2.

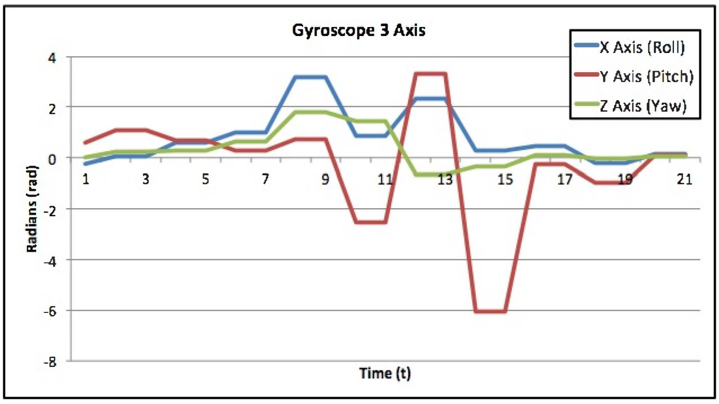

Fig. 5. Gyroscope data raw

These data were taken using a gyroscope sensor. Gyroscope sensor function determined the orientation angle that provided information on whether the user fell down.

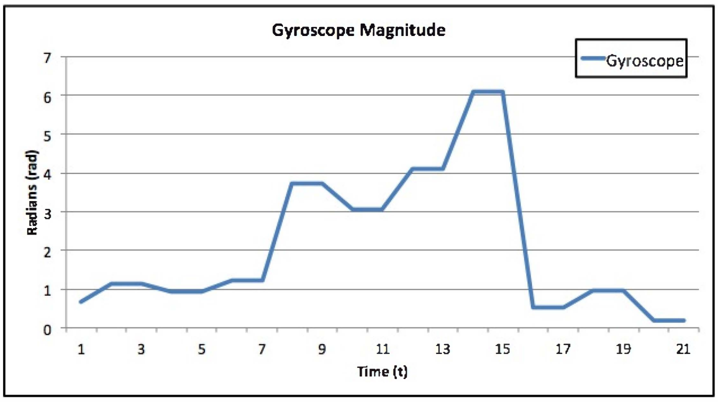

Fig. 6. Magnitude gyroscope data

Once the raw data is obtained from the gyroscope, the next magnitude will be sought by formula $GT_t = \sqrt{gyroX_t^{\,2} + gyroY_t^{\,2} + gyroZ_t^{\,2}}$. Using this data the system can determine whether the user fell down or ran.

We proposed a prototype system that runs on smartphones with an Android operating system. Here is a picture of the system that we have created. The use of smartphones has been most easily perceived in its implementation. Nowadays, the smartphone is no longer a luxury item that is hard to come by. From there, we designed a system based on android smartphones.

V. Experimenter Setting

In this research, experiments was carried out by a test subject with a height of 170cm with a threshold listed in the following algorithm: t_{AT} = 4.2, t_{GT} = 3 ,t_l = 60 and t_M = 9.

This research was conducted in the laboratory of the electrical engineering department of computer networks and information technology UGM. In this experiment the researchers used mobile devices such as smartphones with specifications as follows:

Device type	: Smartphone
Operating System	: Android 4.4.2
Brand	: Samsung Galaxy S4

In this study the sensors used an accelerometer and gyroscope. These have been embedded in the mobile device. In this research, experiments have been conducted 330 times. They divide 120 times falling and 210 experiments on activity daily living (ADL).

VI. Results And Discussion

The testing for fall detection was done on the matt, the subject of the research was carried out by a man who weigh 58 kg with a height 170 cm. The smartphone was placed on the left chest. Here is a scenario of the fall.

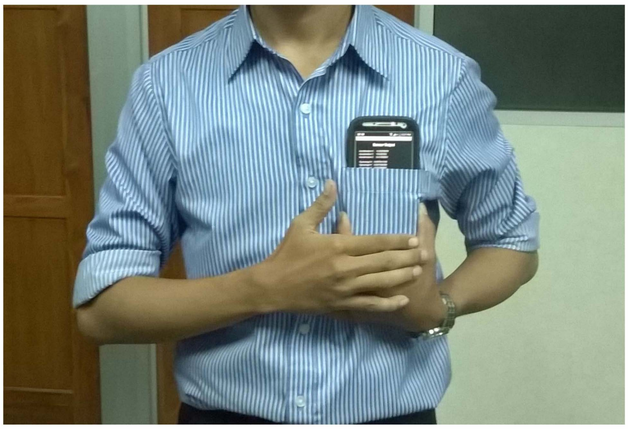

Fig. 7. The position of smartphone

TABLE I. FALLING SCENARIO

Category	*Scenario*
Fall Forward	Walked - fell forward- ended face-down
Fall Backward	Walked - fell backward - ended laying on the floor
Fall to the left	Walked - fell to the left - ended with laying on the floor
Fall to the right	Walked - fell to the right - ended with laying on the floor

Several falling scenarios were exhibited by 1 person who experimented on it 30 times in each scenario.

Fig. 8. Scenario of fall

TABLE II. ACTIVITY DAILY LIVING (ADL) SCENARIO

Category	*Scenario*
Walk	Walked
Run	Ran
Sit down quickly	Stood up straight - sat down
Lying on bad	Sat on a bed - laying on a bed
Bow	Stood up straight - bowed
Up Stairs	Walked upstairs
Down Stairs	Walked downstairs

ADL Experiments was used to determine the accuracy of fall detection algorithm.

TABLE III. FALLING RESULT TEST

Category	*Total*	*Alarm*		*Accuracy*
		Yes	*No*	
Fall forward	30	29	1	96,67%
Fall backward	30	26	4	86,67%
Fall to the left	30	29	1	96,67%
Fall to the right	30	28	2	93,33%

Table 1 showed the accuracy of fall detection algorithm that was applied. Each scenario were carried 30 times for maximum clearance.

TABLE IV. ACTIVITY DAILY LIVING RESULT (ADL)

Category	*Total*	*Alarm*		*Accuracy*
		Yes	*No*	
Walk	30	0	30	100%
Run	30	2	29	93,33%
Sit down quickly	30	0	30	100%
Lying on bed	30	2	28	93,33%
Bow	30	0	30	100%
Up stairs	30	0	30	100%
Down stairs	30	3	27	86.67%

Based on Table II, the algorithm still detected the occurrence of falling in some daily activities. For instance, during the ADL experiment, 2 of 30 attempts at running were detected as a falling state. When laying down there were 2 of 30 attempts that were detected as a falling state. In another case, moving down the stairs was also detected as a falling state due to the gravity level affecting the acceleration of the detector device.

VII. CONCLUSION

In this paper, a fall detection system prototype for smart phones was proposed. Sensor data was sampled from a smart phone user who had it placed on their left chest.

Falling detection based on threshold detection algorithm was modified. The prototype system gave promising results, the results of tests that were conducted obtained an accuracy of 93.33% of the 120 trials fall, and an average accuracy of 98% of the ADL 210 times the total experiment.

The moment a person fell, the system will detect and activate an alarm system. However, further work is still needed in order to handle different types of falling situations that could happen.

This research is still limited to detection. Future development can be done with the addition of several features such as sending short messages (SMS) and position determination using GPS.

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