Epileptic Alert System on Smartphone

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***Abstract*—Epilepsy is nervous system disorder that can be high risk for someone who experience long unconscious attack without any help. Smartphones' motion sensors can be utilized as alert system using "fall detection" algorithm. It can drive SOS alarm sound, then trigger Smartphone's direct call and send text alert with GPS coordinates information. This alert system has been tested in laboratory level by 4 categories, consisting of smartphone installation, GPS coordinates function, quality of mobile network, and people's age-based. The Smartphone on the upper arm and forehead are the best instalment. In GPS location-based has success rate 90% by subject falling on the bed. Quality of mobile communication has success rate about 100%. Last category is age-based between 7 to 32 years old, success rate is between 60- 70%. In conclusion, aid tool of epilepsy could detect a moment of falling and give SOS alert sound, direct call, SMS, and GPS coordinates to be sent for relative and healthcare giver to get help faster.**

Keywords—Epilepsy; fall detection algoritm; smartphone motion sensors; SOS alarm.

I. INTRODUCTION

It was reported that the number of epilepsy patient is 0.5 - 1% of the world population of serious neurological disorders, which is the second most common serious one after stroke [1]. Epilepsy is a disorder that occurs due to a disruption in brain nerve transmission. The causes of disorder could be due to genetic factors (idiopathic) or other causes (symptomatic) for their local pathology of the brain that may influence by stroke, tumors, cysts, trauma, sclerosis, brain disorder, or infection. Although, in fact 70% of the causes of epilepsy in children and adults are unknown. Hence, epilepsy is not a disease, but rather a spectrum condition characterized by unpredictable, recurrent seizures [2]. Not all people will experience the same symptoms of epilepsy, and the seizures can be in various range from mild to severe. The main symptoms of epilepsy are partial (focal) seizures and primarily generalized seizures. For generalized seizures, the patient may experience an atonic spasm, difficulty in breathing, or unconsciousness that may endanger his or her safety. The seizure process occurs because the movement signal instructions sent by the brain are impaired and make the body's muscles contract uncontrollably [3]. Almost all people with seizures will be cured or self-conscious after 5 minutes without special treatment. However, during an uncontrolled muscle reaction and unexpected times and places, the person may be injured with the worst risk of death [4].

There are three types of alert devices available today based on motion detection for epilepsy, such as mattress devices, watch devices, and camera devices. Mattress devices are usually placed under a mattress to detect vibrations. When a seizure-like movement is detected an alarm will sound. There are two existing commercial products namely MedpageTM Model MP5 and EmFit. Watch devices are wristwatches with accelerometers and GPS. This tool can detect repetitive movements and alert someone with sending text message, sound, or e-mail. Some models are equipped with GPS to monitor and detect one's location. There are two commercial products today, Smart-Watch (www.smart-monitor.com) and Embrace (www.empatica.com/product-embrace). Camera devices record audio and video information from a remote infrared video camera. This information will be sent to the Smartphone and the app will analyse the video for seizures like activities. When unusual events are detected, an alarm will start to sound followed by recording of live sound and video camera. The current commercial product is SAMi.

Instead of imitating all features that is provided by the commercial product, this study focusses on seizure occurrences that can cause people to fall because of unconsciousness moment. There is a "fall detection" algorithm initiated by M. Kangas, 2011 [5] to detect the falling moments using a prototype device integrated with ADXL 330 a ± triaxial capacitive accelerometer. The device in real life is fastened to the waist using an elastic belt. We proposed to develop such as system to detect fall, partially for specific epileptic seizures. The "fall detection" algorithm is used for similar purpose with previous research on smartphone that has built-in motion. Instead of wristwatch as commercial product used, smartphone is considered the most widely owned by many people and has a widescreen to provide more flexibility than the tiny screen.

II. RESEACH METHODS

A. Alert System Design

Smartphone currently has a wider screen size than before. Although in certain conditions it will be very beneficial when reading, writing, and perform operations, but on the other hand this big size will be annoying especially when wanting to store it into a pocket.

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Illustrations shown in Fig. 1(a) determine when a person falls into 4 stages of a falling process. For applying the alert epileptic system, the subject must wear the Smartphone on the upper arm using a good flexible belt. Stage (1) Start to fall is a condition when subject intends to fall. Stage (2) Impact is circumstance in which the subject has a collision with the ground. Next stage (3) End posture, the subject has already experienced a fall event which subject's posture is in laying state. At this stage, mobile applications that have detected extreme motion are driving the alarm SOS sound within mobile device. This loud sound notifies people around that there is a patient get attacked and unconscious. When someone comes to help, the mobile app will guide them through a series of guided texts that will appear on the smartphone screen with voice guidance. If after a few minutes nobody around the subject comes to the rescue, then stage (4), the mobile app will send a short text message containing the coordinates of the subject's fall location. The short message is sent to all the phone numbers already registered in the application. In addition, the app also makes direct calls with active speaker to the first phone number on the call list. The called person can speak and hear to guess the environment condition where subject has fallen.

B. *Android Developing Environment*

Epileptic alarm apps created using the Android Software Development Kit (Android SDK) with targeted android Smartphone devices equipped with GPS, motion sensor and position sensor [6]–[7]. GPS is a satellite-based navigation system, consisting of 24 satellite networks, housed in orbit by the US Department of Defence [8]–[9]. Positioning on Android-based smartphones runs using a built-in locator module that contains navigation software, GSM communications, and GPS chips [10]. To enable SMS and direct calls, the Android system requires a call number recorded on shared preferences.

C. *Fall Detection*

Most sophisticated smartphones have built-in sensors that can be used to measure motion, orientation, and changing environmental conditions. To detect the process of falling subject-attached device smartphone (such Figure 1(a)) requires motion sensors (including accelerometer sensors, gravity sensors, and gyroscopes) that can measure acceleration forces and rotational forces along three axes. While to know the position of the fall of the subject required position sensors including orientation sensors and magnetometers which measures the physical position of the device is located [11].

Accelerometers are designed to respond to vibrations due to movement. It uses microscopic crystals that work based on stress when vibration occurs. The shift stress will produce a voltage to represent acceleration at that moment. The values generated by the accelerometer sensor to measure acceleration force in m/s^2 that applied to this device become the reference in determining the acceleration value on the x, y, and z axes including the gravity force [11]. However, sampling frequency generated by the acelerometer on Android device is often irregular. This is due to the limitations in the Android API and heavy load on mobile processors [9]. For devices running on the Android platform, the value changes on the sensors only can be accessed via onSensorChanged module which is not always in synchronize with the sampling frequency designated by the developer. A linear interpolation (Equation 1) is needed to set sampling rate to 50Hz so the raw data can be interpolated linearly by android application [12]. If $s_d(t_i)$ is signature data, where s $\{a, g\}$ (a for accelerometer, g for gyroscope). There are two points $s_d(t_i)$ and $s_d(t_{i+1})$ sampled at t_i and t_{i+1}, a linearly interpolated for time point t (t_i, t_{i+1}) becomes:

$$s_d(t) = s_d(t_i) + \left(s_d(t_{i+1}) - s_d(t_i)\right)\frac{t - t_i}{t_{i+1} - t_i}. \qquad (1)$$

Then, the resampling data of the x, y, and z axes will be recalculated using the Fall Detection Algorithm.

The use of fall detection algorithm (Start to Fall + Impact + End posture) can detect Start to Fall by monitoring SV_{TOT} (*Total Sum Vector*) lower than 0.6g threshold value. It followed by detecting Impact in 1 second time frame with threshold value of SV_{TOT}, and then followed by monitoring posture [5]. The value of SV_{TOT} has two components: static and dynamic acceleration, these two components have been calculated from resample data like Equation (2). Static acceleration means the subject is in static posture such standing, sitting, and lying, whereas dynamic occurs due to the movement of the device because the subject is falling.

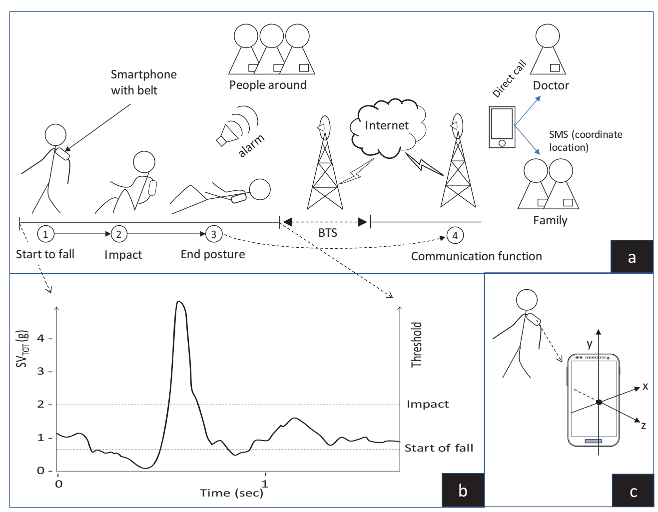

Figure 1. (a) Epileptic Alert system design, (b) Fall steps 3D (x,y,z) acceleration sum vector (SV) detected by threshold, and (c) Coordinate system relative to a smartphone that's used by the Android Sensor API

Based on Bourke *et.al* [13] fall can be determined from activity daily life with a threshold value for video-based vertical velocity. Wu & Xue 2008 [14] has reported that the integrated velocity (Fig. 1(b)) of the acceleration sum vector, SV (Equation 2) is proportional to the vertical velocity of video-movement analysis by Bourke *et.al* [13]. Fig. 1(c) is an illustration of fall stages SVTOT detected by thresholds based from Start to fall, Impact, and End of posture. Starting fall or pre-impact is detected before the impact marked by high peak in signal.

$$SV = \sqrt{(A_x)^2 + (A_y)^2 + (A_z)^2} \qquad (2)$$

The A_x, A_y, and A_z are the acceleration (g) of the x, y, and z axes with sum of vector (SV) formulated in Equation 2. When the subject is standing, SV_{TOT} has a value of 1g (1g = 9.8 ms^{-2}, gravitational unit). Start to fall occurs during time delay is about 1000 milliseconds before the impact stage where SV_{TOT} value < 0.6g.

$$SV = \sqrt{A_x^2 + A_y^2 + A_z^2} < 0.6g \quad \text{(start to fall)}$$
$$+$$
$$SV > 2g \quad \text{(impact)}$$
$$+$$
$$Posture = \overline{A}_{x,\,LPF} < 0.5g \quad \text{(end posture)}$$

Figure 2. The used threshold values in Fall Detection algorithm

The average SV_{TOT} signal value for Start to fall testing in laboratory environments uses a 50 Hz frequency sampling of raw data. The average value is aligned with the SV_{TOT} signal at the impact data point, where SV_{TOT} is > 2g. This data point is selected based on the threshold used to detect impact on the fall detection algorithm.

End Posture can be detected 2.4 milliseconds after impact from LPF (Low pass filter) signal, based on average acceleration with 0.4 second interval time, and less than 0.5g to declare subject stage in lying or End Posture [15].

To facilitate understanding of the fall detection work process on alert system, the flowchart has been provided as shown below (Fig. 3).

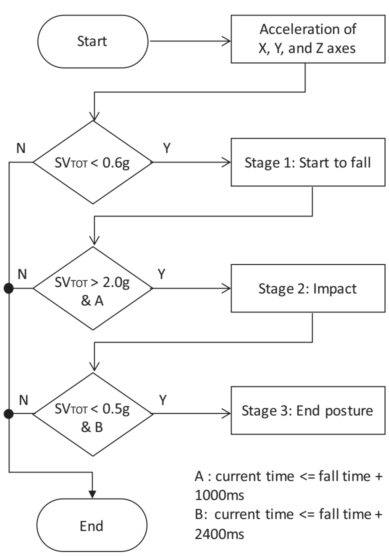

Figure 3. Flowchart Fall Detection algorithm in Elliptic Alert System

III. RESULT AND DISCUSSION

The experiments are done in laboratory environment to test this Alert System in several categories including smartphone installation, GPS coordinates function, quality of mobile network, and people's age-based with each of 10 trials presented in this section. Doing lab experiment for testing the threshold value of each stages, Start to fall, Impact, and End posture, respectively are described in Table I. Table I is only an example of SV_{TOT} values. It is seen that the maximum and minimum values for Start to fall are 0.1877- 0.5939 <0.6g, for Impact at 2,0237 - 2.7396 >2g, and End posture at 0.9470-1.0278 >0.5g. To detect End posture using several variations of android Smartphone, the value of the range is relatively higher than its threshold value. As for Start to fall, and especially Impact, the value of the range is narrower and thus requires more accuracy value.

Based on Table II and Table III, the Alert System more optimally detects fall when starting from a standing position. This is demonstrated by a 90% percentage of success for falling indoors and 70% success for falling while driving or inside the vehicle. The Alert System runs optimally when the Smartphone is placed on the arm and head compared to the waist. But the placement on the head will disrupt person's activities so it is not appropriate to use it in daily life. Alert System was running perfectly well using service providers contained in Table IV, except XL provider who experienced 1 failure when making direct calls. This obtained result is from the experiments in the urban area, the results elsewhere may change depending on the availability of providers. For the age category in Table V the percentage of success ranges from 60-70% with its own attributes, it states that this prototype system can be used for all ages with varying weight and height.

TABLE I. SAMPLE OF SV_{TOT} VALUES ON FALL DETECTION

No	Start to fall < 0.6g	Impact > 2g	End Posture > 0.5g
1	0.1877	2.0386	0.9777
2	0.4838	2.0749	0.9860
3	0.3358	2.1601	0.9845
4	0.4440	2.0976	0.9910
5	0.5436	2.7396	1.0019
6	0.3029	2.0775	0.9538
7	0.5765	2.0751	0.9470
8	0.5681	2.0948	1.0122
9	0.3384	2.1085	0.9903
10	0.2556	2.0853	0.9949
11	0.5029	2.0823	0.9984
12	0.4657	2.1025	0.9983
13	0.5199	2.1806	1.0106
14	0.5939	2.1226	0.9889
15	0.4920	2.1021	1.0264
16	0.5002	2.0237	0.9684
17	0.5631	2.1689	1.0053
18	0.5301	2.1084	1.0138
19	0.2151	2.1213	0.9550
20	0.5550	2.1346	1.0278
min	*0.1877*	*2.0237*	*0.9470*
max	*0.5939*	*2.7396*	*1.0278*

TABLE II. SMARTPHONE INSTALLATION

Smartphone Position	Fall Detection
Waist	90%
Upper arm	100%
Head	100%

TABLE III. GPS COORDINATE FUNCTION

Location	Fall Detection
Bed room	90%
Public transport (sit down)	20%
Public transport (stand)	70%

TABLE IV. QUALITY OF MOBILE NETWORK IN INDONESIA

Provider	Direct Call	SMS	GPS Coordinate
Simpati	100%	100%	100%
XL	90%	100%	100%
IM3	100%	100%	100%

TABLE V. PEOPLE AGE'S-BASED

Age (years)	Gender	Weight (Kg)	Height (cm)	Fall Detection
7	Male	21.5	92	70%
11	Male	25.3	115	70%
17	Female	42.0	165	60%
23	Male	83.6	178	70%
26	Male	59.9	165	60%
32	Male	57.1	175	70%

IV. CONCLUSION

This prototype of alert systems built using motion sensors on smartphones and fall detection algorithms make it possible to be used for epilepsy sufferers, but require further testing in real environments. Further development can be implemented by adding other sensors such as heart beat sensors, medical stress sensors, temperature sensors, etc. to monitor the health condition of the patient so that appropriate treatment can be done accurately.

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