Emergency Notification System for the Detection of Falling, Car Accident and Heart Rate Failure Using Smart phone and Smart watch.

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Abstract:

There are a lot of people facing a problem of unexpected death or health damage due to the lack of medical care at the right time, especially elderly people, patient with disabilities and people that are living alone who are required to be continuously under surveillance for the purpose of safety and emergency response. As the smartphone becomes an integrated part of human daily life which has the ability of complex computation, internet connection and also contains large number of hardware sensors, encourage implementation of the proposed system based on smartphone to be utilized in the public healthcare. Most of the works done in this field imposed the restriction of fixing the smartphone in certain position on human body to easy infer the emergence case from the data of the smartphone sensors. To overcome this restriction, the proposed system incorporated a smartwatch, together with smartphone freely carried by the user, for better performance results. The use of smartwatch assisted in providing distinct separable signal variation from the smartwatch accelerometer and gyroscope sensors to recognize emergency case such as falling, car accident and heart rate failure. Immediately after cases that are mentioned previously the proposed systems ends details information such as videos, location, heart rate etc. to the emergency center and emergency contact to provide help at the right time. The system was practically tested in real simulated environment and achieved quite very good performance results.

Keyword: Emergency Notification, Healthcare, Falling, Car Accident Detection Smartphone, Smartwatch

انشاء نظام ارسال اشعارات طوارئ عند حالات الاغماء او حادث سيارة او فشل في معدل دقات القلب باستخدام الهاتف الذكي وساعة ذكية

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الكثير من الأشخاص يتعرضون الى حالات موت مفاجئة نتيجة عدم حصولهم على رعاية صحية في الوقت المناسب خصوصاً كبار السن والعجزة والأشخاص الذين يعيشون بمفردهم سواء بشكل دائمي او جزئي والذين هم بحاجة الى رعاية صحية أكثر من غيرهم. أصبح الهاتف الذكي جزء من حياه الكثير من الأشخاص خصوصا مع تطور قدرته على معالجة البيانات وارسال البيانات واحتوائه على حساسات كثيرة كل هذه العوامل ساعدت على بناء نظام رعاية صحية يعتمد على الهاتف الذكي. الكثير من الانظمة المشابهة تعتمد على تثبيت الهاتف الذكي في مكان معين من جسم الانسان للحصول على بيانات واضحة لتشخيص حالات الطوارئ وهذا الشرط يسبب صعوبة وعدم راحة للمستخدم خوصا مع ازدياد استخدام الهاتف الذكي الذي يتطلب تحريك الهاتف من مكانة المثبت. النظام المقترح يستخدم بالإضافة الى الهاتف الذكي ساعة ذكية مثبتة على كاحل المستخدم وبدون أي قيود على مكان او حركة الهاتف والذي يمكن النظام من الحصول على بيانات واضحة للتشخيص حالات الطوارئ مثل الاغماء او حدوث حادث سيارة او فشل في معدل دقات القلب. تم فحص النظام المقترح في بيئة مشابهه لحالات الطوارئ المذكورة سابقا وحقق النظام نسبة نجاح عالية جدا.

الكلمات المفتاحية: اشعارات طوارئ، رعاية صحية، حالات الاغماء او حادث سيارة، الهاتف الذكي.

Introduction

Recently, smartphone becomes an integrated part of human daily life which becomes more and more sophisticated with growing the computation power, network capability and sensing powers. Smartphone contains large number of hardware sensors that encourage implementation healthcare system such as accelerometer, gyroscope, compasses, barometer, temperature, humidity, light sensor and GPS receiver. All the features that are mentioned above make the smartphone to become a rich environment for many systems like healthcare system that called Mobile Health (mHealth) system. Mobile Health system is the intersection between Electronic Health (eHealth) and smartphone technology[1]. For car accident detection most of the smartphone based car accident detection systems depend on the high speed of the vehicle (extracted from the smartphone GPS receiver) and the G-Force value (extracted from smartphone accelerometer sensor) to detect car accident. On the other hand, the system will be failed when an accidents occur at low speed of the vehicle. The main obstacle that encounters the low speed accident is how to discriminate between whether the user is inside the vehicle or outside the vehicle especially when the car is traveling in a speed fairly to be walking or running speed. Hence, in addition to the high speed car accident the proposed system has the ability to detect low speed car accident by using both smartphone and smartwatch sensors. For falling incident most of the smartphone based falling detection is depending on a fixed smartphone on the user body. This condition is cumbersome and annoys the user from having always keeping the smartphone in one position. Using both smartphone and smartwatch give the proposed system ability to detect falling incident without any restricted on the smartphone position or orientation. In the proposed system both smartphone and smartwatch sensors are become sours row data to detect falling, car accident and heart rate failure. The proposed system increases self-dependency and providing better quality of live for people that are living alone for a full time or part time especially elderly people, patient with disabilities who are required to be continuously under watching for the purpose of safety and emergency response at the right time. figure 1 present overall proposed system structure

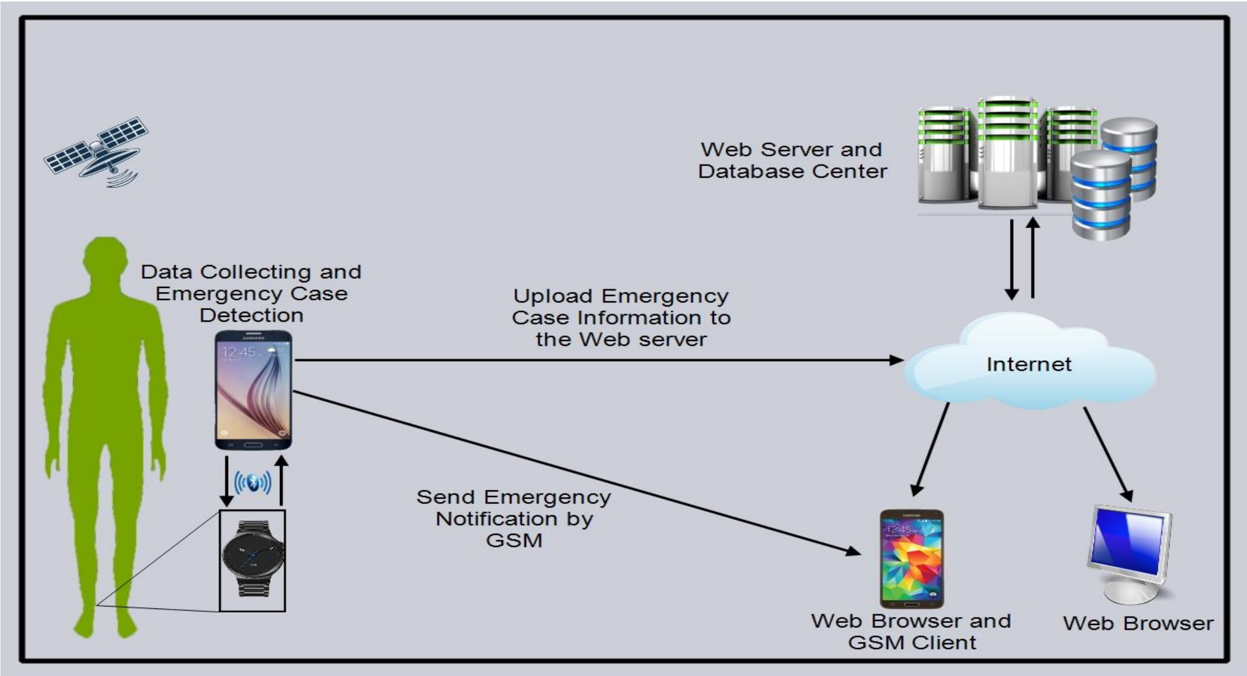

Figure 1 Overall proposed system structure

I. Proposed System Design

The proposed system, called Emergency Notification System for Falling, Car Accident and Heart Rate Failure Using Smartphone and Smartwatch, consists of two phases; the detection phase, explained in the next section II-A, is used to identify the occurrence of falling, car accident and heart rate failure, and notification phase, explained later in the section II-B, is used to inform an emergency center for fast response and recovery.

A-Detection phase

After studying and analyzing most up-to-date related works that are depending on the smartphone inertial sensors to accomplish such systems. Actually, there are so many factors and restrictions that prevent the above mentioned approaches from achieving perfect accurate results. These factors and restrictions are explained later when the proposed system mechanism is discussed in details. The main contribution of this work is the incorporation of android smartwatch as a part of the system components which in turn is used in conjunction with smartphone for better accurate result. As a consequence, the proposed system integrated the use of smartwatch fixed on user ankle together with smartphone carried, by the user, in any position and orientation. The main technical reason behind using the smartwatch is to place the smartwatch sensors (accelerometer and gyroscope coordinates) in a position that become precisely sensitive to human body movements.

Having justified the use of android watch in the proposed system, Figure 2 shows the overall system design mechanism and its interoperated components that are working simultaneously to achieve the proposed system specifications. The detection phase of the proposed system consists of the following main steps:

1- Data Collection: This component is responsible for reading raw data from the smartwatch and smartphone sensors.
2- Windowing: This component is responsible for portioning the raw data into segments called windows suitable for feature extraction.
3- Feature Extraction: This is responsible for examining each window; produced from step 2 above, scale and arrange the data inside each window that are used to detect emergency case.
4- Classification: This is responsible for checking the data facts produced from step 3 above, and then determine if the emergency case occur or not.

Each step and its functionality are described in detail in the next sections.

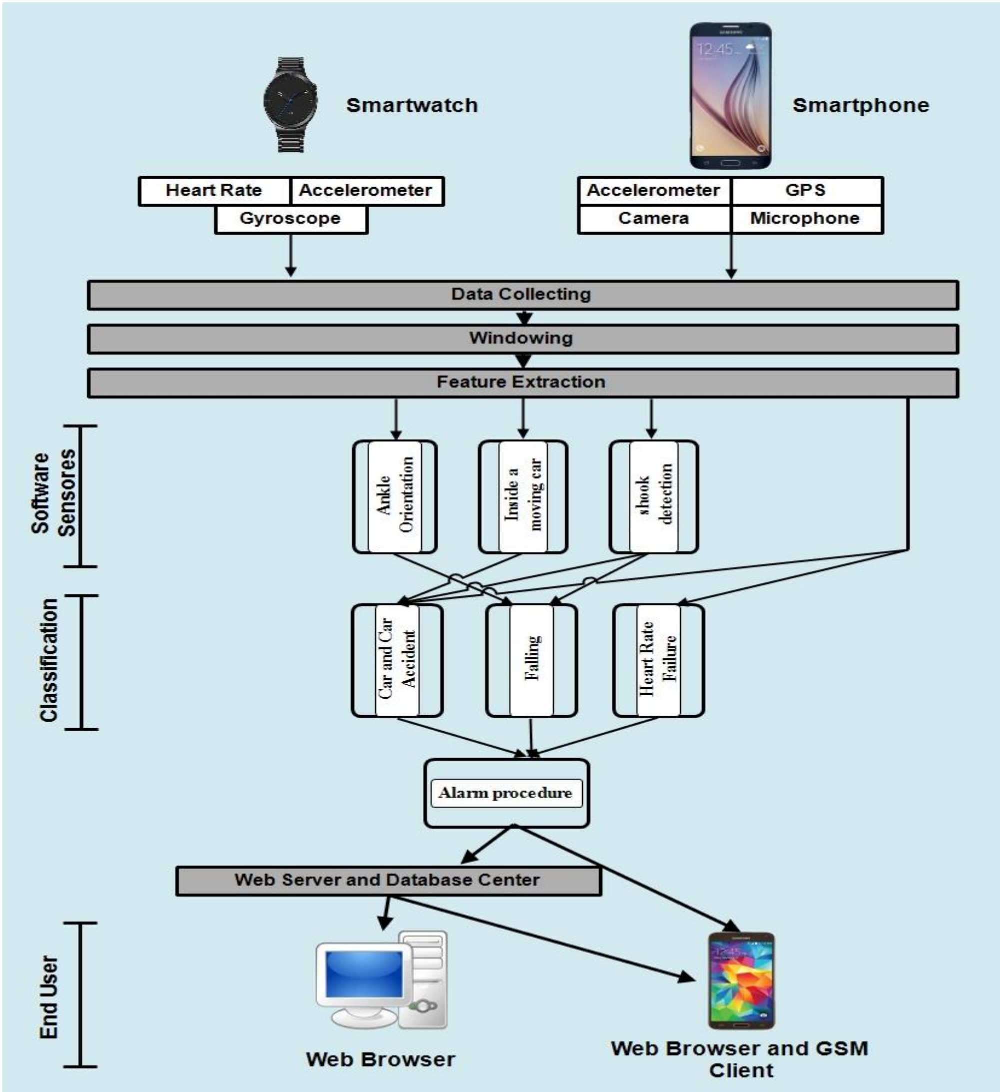

Figure 2 Overall system design mechanism

A1-Data collecting

The smartphone and the smartwatch collect data from their sensors at the same rate (every 20ms), but with different update time for each sensor reading. It should be noted that in android platform there are many types of sensor event listeners that are responsible to update sensor readings like normal every 200ms, user interface every 60ms, game every 20ms and fastest about every 10ms, the latter depends on the sensor hardware specifications. The type of the sensors and the sampling rate for each sensor, chosen for this work, are listed in table 1. Also, it is very important to know that the sensor sampling rates and position of every smartwatch sensor are chosen carefully after conducting many experimental tests with different situations to obtain the best clear features that are suitable for all emergency cases to achieve minimum processing load and separable/generalized features. Figure 3 show the three axes coordinate for smartwatch sensors

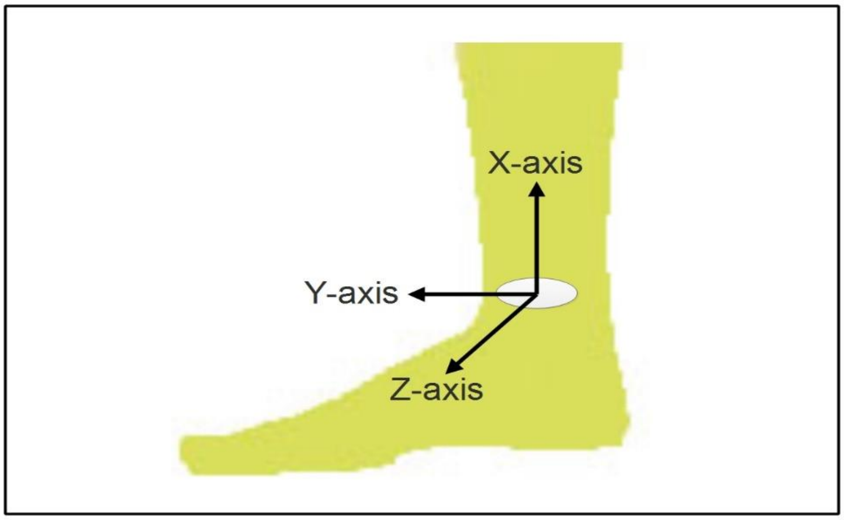

Figure 3 Three axes coordinate for smartwatch sensors

Table 1 Android and android wear platform sensors

No	Type of sensor	location	Type of sensor event listener	Sensor update time
1	Accelerometer	smartwatch	sensor delay game	20ms
2	Gyroscope	smartwatch	sensor delay game	20ms
3	Heart rate	smartwatch	sensor status accuracy high	200ms
4	Accelerometer	smartphone	sensor delay game	20ms

A2- Windowing

The windowing process is used to split the continuous collected data, of each sensor, into small time segments called windows for the purpose of feature extraction. In this work, a window size of 3 seconds is adopted to be adequate for feature extraction. The windowing process is executed continuously in real time simultaneously with other parts of the system such as feature extraction and classification.

A3- Feature extracting

Each sensor window size exemplifies a 150 vectors of raw data; some sensors have 3-axes coordinates. The purpose of feature extraction process is to inspect and measure the properties of the window raw data pattern relative to the required emergency case detection. In other word, to find the best approximate distribution of the raw data to emergency case it belongs. For example, mean, maximum value, and minimum value are valuable candidates for feature extraction process

A4- Classification

Classification is the process of discriminating each featured window and detects each emergency case. Classification process consists of three parts: Car Accident detection, Heart Rate Failure Detection and Falling Detection.

A4.1- Software Sensors

Before discussing and analyzing the rest of the emergency case detection, it is found necessary to explain the software sensors, illustrated previously in figure 2, that are used in the forthcoming emergency case detection. It is important to know that there are two types of sensors; software and hardware sensors in android platforms. In this work, three software sensors have been built for the purpose of extracting features that are used in the emergency case detection.

The three software sensors are called Ankle Orientation, Shock Detection, and Inside a Moving Car. The purpose and the functions of each software sensor are explained as follows:

A4.1.1- Ankle Orientation

The purpose of the Ankle Orientation sensor is to measure the ankle orientation of the human body. This sensor, on each 3 seconds window size, takes the three axes of the smartwatch accelerometer sensor and calculates the mean of each x, y, and z axes coordinates. Then it arranges, the three means, according to which axis coordinate is mostly vertical to the earth to obtain user ankle orientation. This sensor is used to detect falling incident.

A4.1.2- Shock Detection

The purpose of Shock Detection sensor is to detect and determine if the user has been exposed to a shock such as falling, car accident, or any other sort of collisions. This sensor, for each sampling of a window size, reads the three axes x, y, and z coordinates of the smartwatch and smartphone accelerometer sensors and check if the absolute reading of each the three axes x, y and z of each accelerometer sensoris greater than 4 G-force [2], then it indicates that the user has exposed to a shock which is used by car accident detection to indicate car accident. On the other hand, it also provides another type of shock detection concerning the fall incident. In falling detection, equation 1[3] is used to calculate the G-force, where $G_{X,}$ G_Y, G_Z are the values of the accelerometer three access X, Y and Z, then the value of the G-force is checked to indicate a fall incident. The threshold of 2.5 G-force[3]is used to indicates that the user has exposed to a shock incident which is used by falling detection classifier.

$$G - force = \frac{\sqrt{G_X^2+G_Y^2+G_Z^2}}{9.8} \qquad (1)$$

A4.1.3- Inside a Moving Car

The purpose of Inside a Moving Car software sensor is to discover the speed on which the user is moving which in turn assist to find out whether the user is inside a car or not. The speed, which is obtained from the smartphone GPS receiver, is not enough indicators to detect whether the user is currently moving or not. As in certain circumstances, the GPS data is prone to error that is produced when the user is moving between locations that contain obstacles preventing the GPS receiver from properly connecting and obtaining correct data. To recover from such error, a software sensor is created to determine that the user is currently inside a moving car by ignoring incorrect GPS readings. This recovery is accomplished by incorporating the GPS receiver parameters: GPS speed and GPS accuracy which are already available in underlying GPS receiver API. Accordingly, this software sensor determines whether the user speed is fairly to be inside a moving car according to the following procedure:

1- The GPS accuracy parameter of the proposed system is set to be less than 7m and also is made acquiring GPS data every 7m passed by the user. Hence, the movement is detected when the GPS accuracy (less than 7m) and 7m (passed by the user) are achieved. This 7m distance is found reasonable and suitable for detection whether that the user inside the car or not.

2- The GPS speed parameter is set to be more than or equal to 3 m/s. The reason behind that is as long as the window size is 3 seconds, then there will be at least one GPS reading inside the current window size giving that the GPS acquisition reading is made when the user has passed 7m, as mentioned in step 1 above.

The above procedure steps are applied because the GPS reading errors occur when the GPS accuracy parameter is altered due to the change in the number of the satellites that are received by the smartphone GPS receiver.

A4.2- Car Accident Detection

The first step in the car accident detection is to find out whether the user is inside a car or not. For example, while the user inside a car and the car exposed to an accident then it is necessary to detect car accident and notify about such event. Hence, this section is divided in two parts; the first part explains the procedure of recognizing the user inside or outside the car, the second part explains the car accident detection.

1- Inside the Car Detection

When the user is in static state (that was detected by using smartwatch gyroscope sensor) and her/his location is changing continuously then it indicates that the user is inside a car. The smartphone GPS receiver is used to find the change in user location by continuously extracting GPS data to measure the car speed (as well as the smartphone) by using the software sensor (inside a moving car) that was explained in details in the previous section. Due to the computation cost of frequently acquisition of the GPS data, the proposed system is made to acquire GPS data every seven meter passed by the car. This distance could be traveled in different period of time which depends on the car speed that is traveling in crowded traffic or not. It is found that this distance is reasonable for continuously recognition whether if the used inside the car or not. If during this distance the car is stopped and the user is still in static state, then the previous distances will be taken into account to assure that the user is still in the car. Otherwise, if the user gets out of the car and perform any activity (moving) then the smartwatch gyroscope sensor will discover any user movement.

2- Car Accident Detection

While the user is inside the car, the system continuously reads the accelerometer data for both the smartphone and the smartwatch. Then for each window size the software sensor (shock detection) is checked for any smartphone and smartwatch shock occurrence. When a sign of accident is detected by the smartphone and smartwatch, then the system activates the alarm procedure as explained later in notification phase in section B.

A4.3-FallingDetection

The other important emergency case is the detection of user falling incident. While the user meanwhile practicing any daily human activity the falling incident could occur that necessitate the detection of such falling incident and notify for emergency response. The procedure that is used in detecting such incident is listed below:

1- The accelerometers of the smartphone and smartwatch are used in such incident. For each window size, the software sensor (shock detection) checks for a shock incident in both smartphone and smartwatch accelerometer sensors, if shock is detected then the following step 2 is activated.

2- In the two subsequent windows if the orientation (the x-axis of the smartwatch accelerometer) of the ankle is not vertical (that is read from the software sensor, ankle orientation) then it is concluded that the falling incident has occurred.

Immediately, after detecting a falling incident, the system activates the notification procedure as explained later in section II-B.

A4.4-Heart Rate Failure Detection

A real time detection for the heart rate failure is too important in the healthcare services. Because there are many diseases are linked directly to the heart rate. This procedure, on each 3 seconds window size, checks the mean of the heart rate of the smartwatch sensor. In case the heart rate is found in abnormal condition then an alarm will be set and a notification message is sent to emergency centerfor the following case:

a. Increasing in the heart rate (greater than 100 beats a minute for static activities) [4] while the user was static for the last minute.
b. Decreasing in the heart (lower than 40 beats a minute) [4].

B- Notification Phase

In addition to the recognition of the mentioned emergency case, the system is constructed to provide extra information related to the emergency casewhich are explained below:

- **Alarm Procedure**

When one of the emergency events is detected during each window size then the alarm set procedure is activated to perform the following actions:

1- Playing an alarm sound and displays a conformation message, on user smartphone, asking the user to confirm the massage whether she/he is well or not.

2- The system waits 30 seconds to receive confirmation message from the user and during this period the smartphone will be automatically recording a video by using both front and back camera for a 14 sec for each camera. If the user does not confirm, the message or answer negatively then the alarm procedure will send an emergency notification to the emergency center together with the type of the emergency case, videos and location.

3- Sending GSM notification message, and also make an automatically GSM phone call from the victim phone to the emergency contact for listening to the victim voice to predict the type of help she/he needs and take a first impression about the victim case.

Results and Performance

The three services of emergency notifications heart rate failure, falling, and car accidents are tested and produced quite excellent results. as explained below:

Falling: As it is hard to test real falling incidence, hence this test is conducted by imitating the action of the falling incidence which is accomplished by dropping the smartphone on the ground and then the subject falling to the ground. The reason from that is to generate a G-force of greater than $2.5 m/s^2$ for the purpose of falling detection. The result obtained from this test was correct as indicated by the confirmation message displayed on the user smartphone as it was shown in figure 4. After negative answer or no confirmation from the user, the web server inspected and found the video recording of falling incidence was transferred and stored at the web server together with emergency location used to display minimum path between monitoring center and emergency location as it was shown in figure 5. Also the user smartphone sends message via GSM network to the emergency contact and makes an automatic emergency call.

Car accident detection: As it is impossible to conduct this test practically, instead, the smartphone was forcefully hit inside the car and the user foot also shocked hard to produce 4 or greater than 4 G-force at both the smartwatch and smartphone accelerometer sensors as car accident indicator. The result obtained from this test was correct, in a similar manner to the falling test procedure; all the related information is stored at the web server in the same manner as in falling detection as in figure 5.

Heart rate failure: it is too difficult to test the proposed system in a real patient with a heartbeat less than 40 beat per minute or greater than 100 beat per minute during static activities. The detection of the heart rate failure is foregone conclusion because the accuracy of detection of this case depends on the smartwatch heart rate hardware sensor.

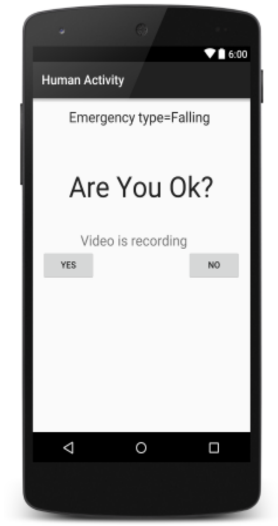

Figure 4. Emergency conformation message interface for the smartphone application

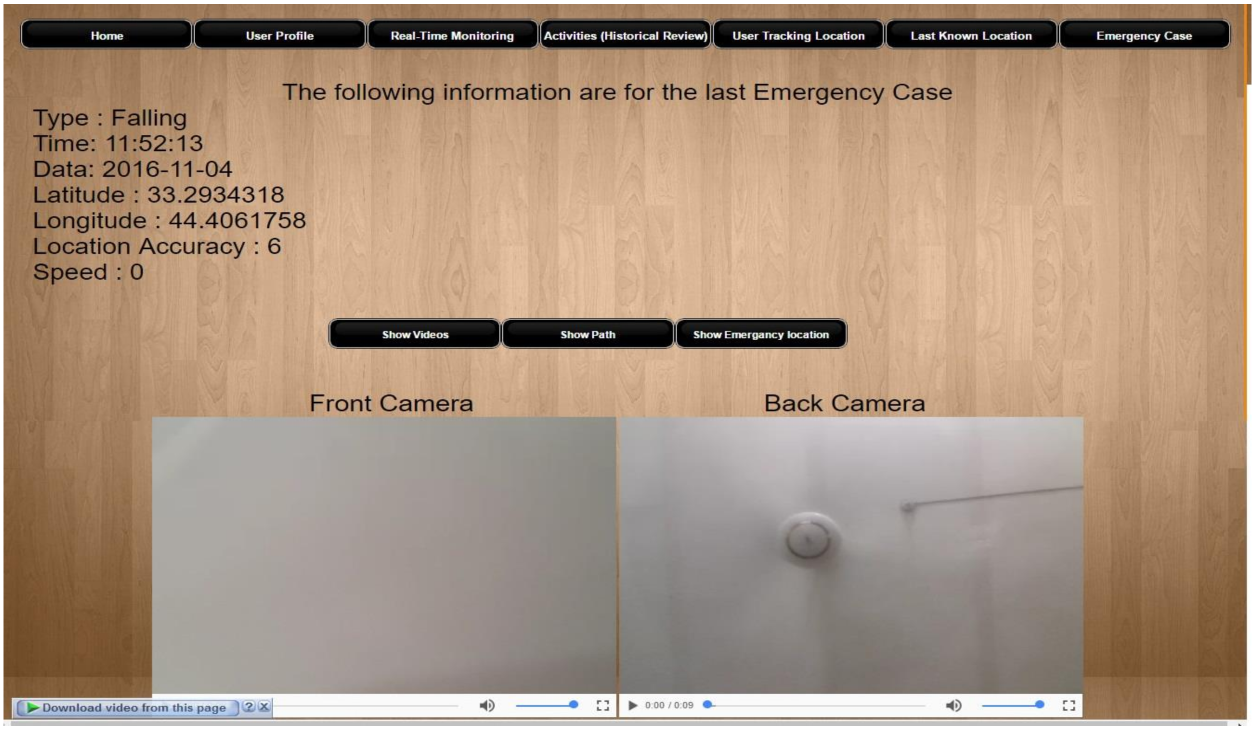

Figure 5-A Emergency notification page

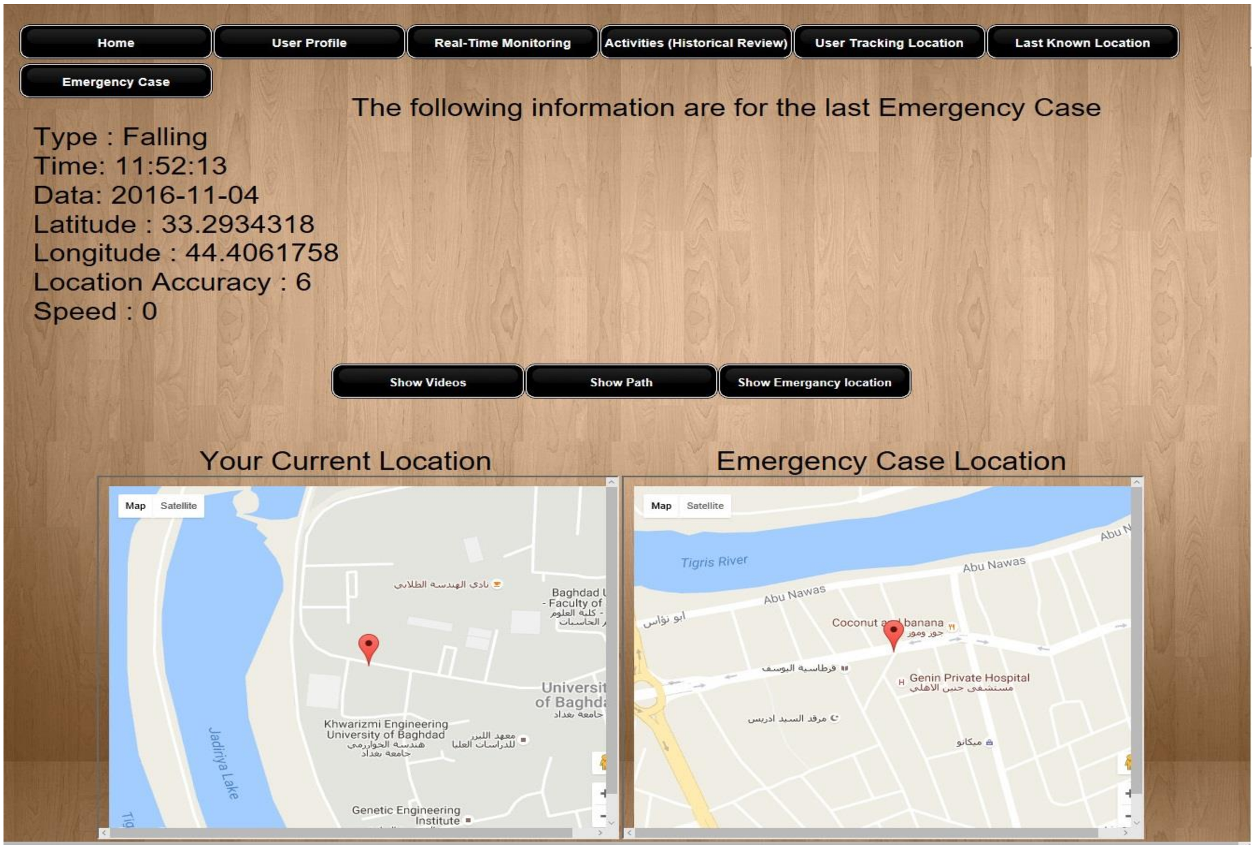

Figure 6-B Emergency notification page

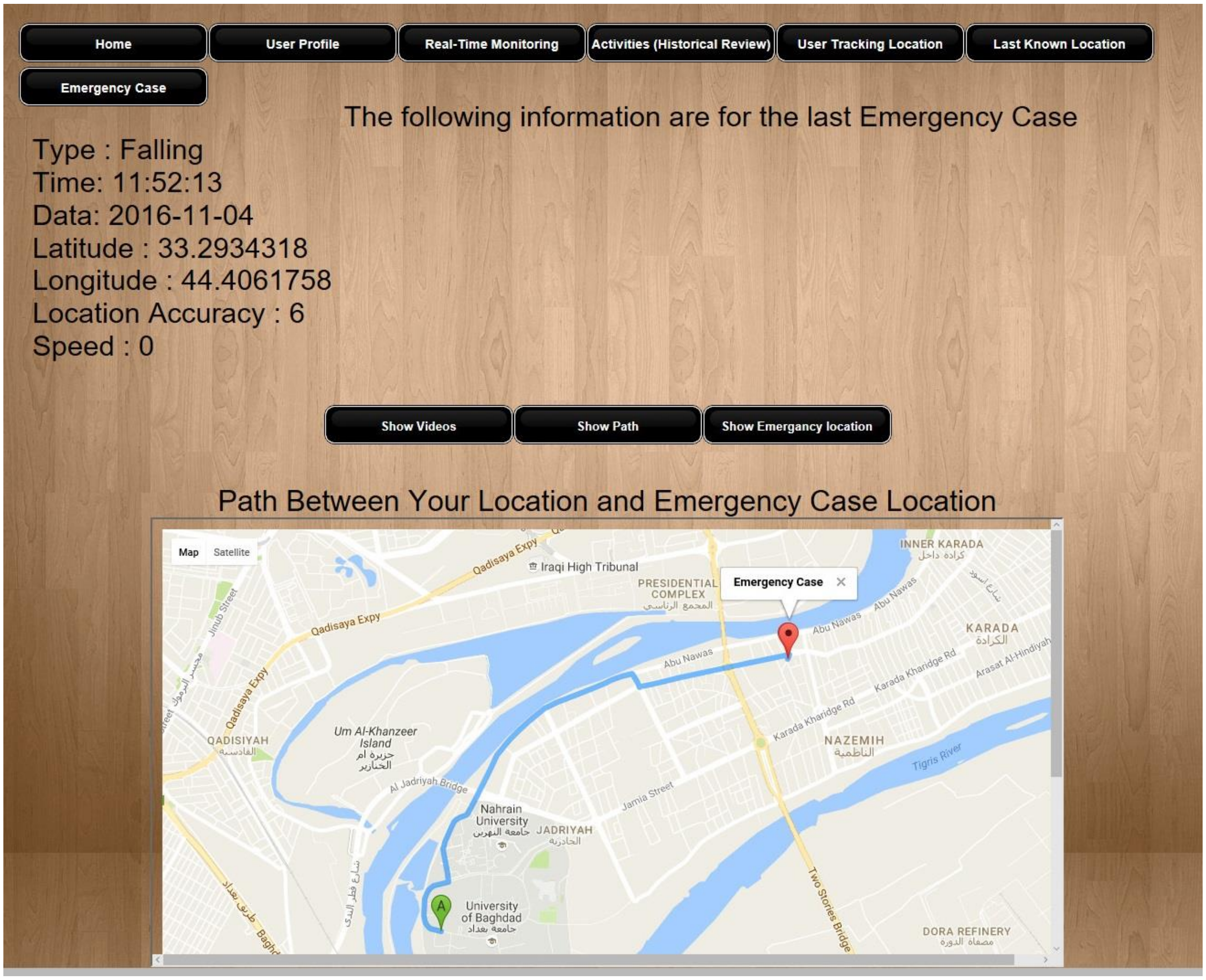

Figure 7-C Emergency notification page

Conclusion

The smartphone based falling and car accident detection system is not an easy task to handle. It is really surrounded with many obstacles that prevent the researchers from achieving high accurate detection system. One of the main obstacles; is determining that the occupant is inside or outside the vehicle while the vehicle is travelling at a low speed and restriction of fixed smartphone on the human body to detect falling instance. The proposed system minimizes the impact of this obstacles which is proved in the practical results conducted in this work.During the study and development of emergency notification system, several points observed and noticed

1- Integrating the smartwatch (steady fixed on the human ankle) with smartphone is due to the main reason of obtaining generalized and separable features to detect emergency cases with high accuracy.

2- Every smartphone based emergency notification system is exposed to false alarm. In the proposed system, helpful supporting features were added to the system to increase the accuracy of detection process and reduce the probability of false positives. These features are briefly listed below:

a. The proposed system presents a confirmation message for emergency notification which gives the user the opportunity to confirm the emergency case. Thus in case false alarm occurs the user can cancel the alarm then the notification is aborted.

b. The proposed system allows the smartphone to automatically capture videos from both front and back smartphone camera and send it to the emergency center to help them for better inspection and analysis of the emergency situation.

c. When the user doesn’t confirm that he/she is okay then the system will make an emergency call from the user phone to the emergency contact. Also emergency information and videos are sent to the emergency center for better diagnostics of the emergency situation.

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