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RESEARCH ARTICLE

Car Accident Detection and Notification System Using Smartphone

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Abstract------ **Every day around the world, a large percentage of people die from traffic accident injuries. An effective approach for reducing traffic fatalities is: first building automatic traffic accident detection system, second, reducing the time between when an accident occurs and when first emergency responders are dispatched to the scene of the accident. Recent approaches are using built-in vehicle automatic accident detection and notification system. While these approaches work fine, they are expensive, maintenance complex task, and are not available in all cars. On the other hand, the ability to detect traffic accidents using smartphones has only recently become possible because of the advances in the processing power and sensors deployed on smartphones. Most of the smartphone based accident detection systems rely 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 an accident. As many references assure that 90% of road-traffic accidents occur at low speed of the vehicle. Hence, in addition to the high speed accident detection, this paper concentrated on low speed car accident detection. The main obstacle that encounters the low speed accident is how to differentiate whether the user is inside the vehicle or outside the vehicle, walking or slowly running. The effect of this obstacle is minimized, in this work, by a proposed mechanism that distinguishes between the speed variation of low speed vehicle and walking or slowly running person. The proposed system consists of two phases; the detection phase which is used to detect car accident in low and high speeds. The notification phase, and immediately after an accident is indicated, is used to send detailed information such as images, video, accident location, etc. to the emergency responder for fast recovery. The system was practically tested in real simulated environment and achieved quite very good performance results.**

Keywords**: Smartphones, Car Accident Detection, Accelerometer Sensor, GPS, Microphone**

I. Introduction

Traffic accidents are a major public issue worldwide. The huge number of injuries and death as a result of road traffic accident uncovers the story of global crisis of road safety. Road collisions are the second leading cause of death for people between the ages of 5 and 29 and third leading cause for people between 30 and 44. According to statistical projection of traffic fatalities, the two-year comparison of total driver participation in mortal crashes presented a three percent increase from

43,840 in 2011 to 45,337 in 2012.Additionally 184,000 young drivers (15 to 20 years old) were injured in vehicle crashes, in 2012, an increase of two percent from 180,000 in 2011 [1].

The most obvious reason for a person's death during accidents is unavailability of the first aid provision, which is due to the delay in the information of the accident being reached to the ambulance or to the hospital. Thus, in the case of incidents involving vehicular accidents, response time is crucial for the timely delivery of emergency medical services to accident victims and is expected to have an impact on fatalities. Moreover, each minute is passed while an injured crash victims do not receive emergency medical care can make a large difference in their survival rate, for example, analysis shows that decreasing accident response time by 1 minute correlates to a six percent difference in the number of lives saved [2].

Thus, the reduction in response time would occur with widespread implementation of enhanced traffic technologies that are used to reduce the response time and thus reducing traffic fatalities. The early experiences with these technologies are concerned with development Advance traffic management system (ATMS) and development automatic car accident detection and notification system built-in vehicles in United States (U.S). The ATMS is based on traffic sensors that are used to monitor the traffic and detect the accidents. These traffic sensors are installed in main highway; some of them are installed under the surface of the road such as loop detectors [3]. However, in this system, finding the traffic sensors in every roads process is impossible, since the traffic sensors are installed in main highways only, besides, the installation cost of these sensors are high. Apart from that, these traffic sensors are affected by the environment. For example some of traffic sensors are not perform well in the snow environment.

Other systems, the automatic accident detection and notification systems are equipped with the most recent manufactures vehicles, such as BMW and General Motor (GM), which depend on the vehicle on-board sensors to detect the accident and utilize the built-in radio cellular to notify the emergency responders [4]. However, the fast evolution of the technology requires the upgrading the software or even some hardware features of the vehicles in order to install the automatic accident detection and notification system, while the installation cost of these system inside the vehicles are expensive. Also, these systems are not considered as a standard option for all vehicles in U.S and other countries, these systems are just equipped with specific type of the vehicles in U.S such as BMW and GM.

These facts are the ones that motivated the researchers to proof the advantages of using the smartphone in development car accident detection and notification systems. The benefits of the smartphone that can be exploited to develop these systems are:

- Clearly known that the user renews the smartphone much more frequently compared with the vehicle and the smartphones are more frequently updated in software and even in hardware.
- Likewise, institution of smartphones gave birth to a lot of innovative technology and exchanging information globally has become more prominent. Smartphones gave a new dimension to the usage of mobile phones for the users.
- Regardless, the use of a smartphone gives the possibility of having additional sensors, advance power processor and communication interfaces, which permits to develop traffic accident detection and notification system that predicts when an accident has occurred based on sensor inputs to the smartphone without need to interaction with a car or changing anything in the car.
- On the other hand, the low cost of the smartphones compared to the existing traffic technologies.
- Moreover, smartphones travel with their owners, providing accident detection regardless of whether or not the vehicle is equipped with an accident detection and notification system, and whether there is a traffic sensor installed on the road or not.

The rest of the paper is organized as follows: section II presents the related works in the field, section III describes the architecture of the proposed system, section IV presents the implementation of the proposed system, section V describes the practical tests and performance results of the proposed system, and the last section VI is the conclusion and future work.

II. Related Work

The early experiments with smartphone based accident detection systems are discussed as follows:

- In [5], the authors develop car accident detection and notification system that combines smartphones with vehicles through a second generation of On-Board-Unit (OBD-II) interface to achieve smart vehicle modeling, offering the user new emergency services. The authors have developed an Android application that in case of accident detection sends an SMS to a pre-specified address with relevant data about the accident and an emergency call is automatically made to the emergency services. The only requirement to achieve the goal of this system is that the vehicle supports the OBD-II standard. The OBD-II standard is mandatory since 2001 in U.S and there is also a European version of this standard, thus this solution is applicable to all vehicles in U.S and European countries and is not available in all vehicles in other countries. Besides that, the maintenance or upgrading process of this system is expensive operation.

- In [4], the authors have developed a smartphone based accident detection and notification system. In this system, a prototype smartphone based client/server application was developed and called WreckWatch that implements a mechanism to provide accident detection and notification by using the embedded smartphone sensors and communication interfaces. The main issue related with WreckWatch system is the deactivation of the system when the speed is below speed threshold since the detection process of WreckWatch begins to recording the accelerometer information and looking for potential accidents only if the speed of the vehicle (as well as the smartphone) is greater than speed threshold and thus, this filtering will shut off the detection process in case of low speed condition and cannot detect the accident in low speed. But it is important to mention that the vehicle is also subject to an accident in case it is continuously travelling at low speed as mention in [6].

- In [7], the E-call system explores the possibility of implementing an automatic crash detection and notification service for portable devices (smartphone). This system uses the cellular network to communicate between the portable device and the Server Center. The main issue with this system is the E-call system uses smartphone built-in accelerometer sensor as a crash sensor, and in this case the E-call system subjects to high rates of false positives emerging while the user is outside the vehicle.

- In [8], the authors have developed an android application that is used to sense the accident using only the accelerometer sensors in the Android Smartphone. After sensing the accident, application automatically generates the geographical information by GPS and sends location information via pre-recorder voice message to 108 ambulance emergency response service that is running in India. The key assumption of this application is that the mobile phone should not be kept along with the person who is driving the vehicle; it must be docked inside the vehicle and the validation of the accelerometer sensor is performed by tilting the mobile left or right or free fall motion. The main issue with system is the smartphone may tilt or fall in any time inside the vehicle accidentally without having a real accident and thus, the probability of false positive will be increased and false alarm will be reported.

III. Proposed System Architecture

This section logically illustrates the mechanism of the proposed system structure together with each module that constructs the overall system architecture. The proposed system, called car accident detection and notification system (**CADANS**), consists of two phases; the detection phase, explained in the next section III-A, is used to identify the occurrence of an accident, and notification phase, explained later in the section III-B, is used to inform an emergency center for fast response and recovery.

A. Detection Phase

Fig.2 shows the main components used in the detection phase. This phase constitutes the main objective of this work which is responsible for discovering the existence of car accident. The detection phase relies on the information extracted from smartphone accelerometer sensor, GPS receiver and built-in microphone to determine the occurrence of car accident. The following steps illustrate the operation of different interoperated components shown in Fig.2:

- Smartphone Accelerometer sensor: The detection phase continuously extracts accelerometer sensor information to record the G-force (acceleration force) experienced by the occupant.
- Smartphone GPS receiver: The detection phase continuously extracts GPS data for the purpose of determining vehicle speed. Vehicle speed is used to increase the probability of detecting an accident based on accelerometer sensor information.

- Smartphone microphone: The microphone is used to detect high-decibel acoustic events such as sound of an airbag deploying. The microphone is used to increase the probability of detecting an accident based on accelerometer sensor information together with GPS data.
- Smartphone camera: The smartphone camera is used to increase the probability of detecting car accident procedure mentioned in the above three steps. The smartphone camera, of the occupant as well as of the bystanders, are used to record and send video to the emergency response centre for further analysis.

Fig 2 Detection Phase Components

1) ***Detection Phase Specification:*** The most important factor that is used, by car accident detection systems, to detect car accident is the G-Force value, of above 4G [4], experienced by smartphone accelerometer sensor. Also, [9] mentioned that, several studies have been performed rear-ended impacts with volunteers; the data used in these studies mean a unique opportunity to analyze how acceleration influences the risk of injury. The results are shown that most occupants suffer from neurological signs, had a mean acceleration above 4G. Actually G-Force value is not enough evidence, to detect car accident, which would lead to false positive sign. The proposed detection phase, running inside the smartphone, continuously sampling and reading the smartphone accelerometer sensor to detect the collision. In the case of an accident, the smartphone experiences the same acceleration force experienced by the occupants of the vehicle, because smartphones are frequently carried in a pocket attached to the occupants [4]. In fact, there are several issues that have to be considered during the accident detection phase. These issues are listed and analysed as follows:

- To filter out acceleration values caused by **dropping the phone inside the vehicle** or **sudden stop**, whose acceleration values could be interpreted as car accident, the empirical results mentioned in [4] showed when the smartphone is dropped inside the vehicle, it experiences approximately 2G's on the y-axis and z-axis with nearly 3G's on the x-axis before it is reset. Also in case of sudden stop (emergency braking) that does not result in a crash, the acceleration experienced by the smartphone is less than that experienced during the fall, it experiences approximately less than 1G's in each direction. Therefore, 4G is chosen as acceleration threshold value to suppress any false positives occurs inside the vehicle.
- The most important system done in this field is activated when the vehicle is at **high speed** of above 24 km/h [4] and the smartphone acceleration experiences greater than 4G. This system didn't take into account accident detection when the vehicle is travelling at a **low speed**, below 24 km/h, which is also subject to an accident. Thus, one of the main contributions of this paper is the detection of car accident at a **low speed**, below 24 km/h, and the smartphone acceleration experiences greater than 4G.
- Also it is worthwhile to take into account some cases that cause false positives like **accidental dropping the smartphone while the user is outside the car and other false positives whose acceleration values are unknown**. So to address these issues and to minimize the false positives presented from these cases, other parameters are investigated and adopted to determine whether the phone is inside the vehicle or outside the vehicle.

The following steps illustrate and analyze the use of the system parameters utilized in detection phase:

i. High speed Accident

The **first parameter** used to make sure that the user is inside the vehicle is the **high speed** of the vehicle (as well as the smartphone). For example if the speed of the vehicle (as well as the smartphone) is greater than the speed threshold value (24 km/h) it would indicate that the user (as well as the smartphone) is inside the car. At the same time, any acceleration event experienced by the smartphone is greater than an acceleration threshold value (4G); it is interpreted as sign of an accident.

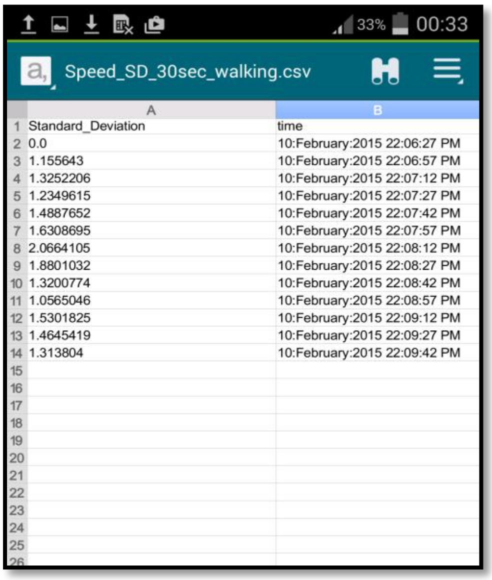
ii. Low Speed Accident

Since, among all road-traffic accidents, 90% occur at speed less than 14mph (22.53km/h), which cause severe injuries to the occupant [6]. Hence, the following two states illustrate the use of the proposed low speed parameters in the **CADANS**:

a. The **second parameter** used to make sure that the user is inside the car is when the car is continuously travelling at a **low speed**, less than the speed threshold 24km/h, which is also subject to an accident. This parameter is called **speed variation period** which is used to measure the speed variation values in certain period of time while the whole speed is below the speed threshold (24 km/h). The idea behind that is when the traffic is oscillating, while it is below 24 km/h, the car won't last for such a long time at steady speed. Actually from practical tests, the **speed variation period** is chosen to be **30 seconds** to indicate the user is still inside the car.

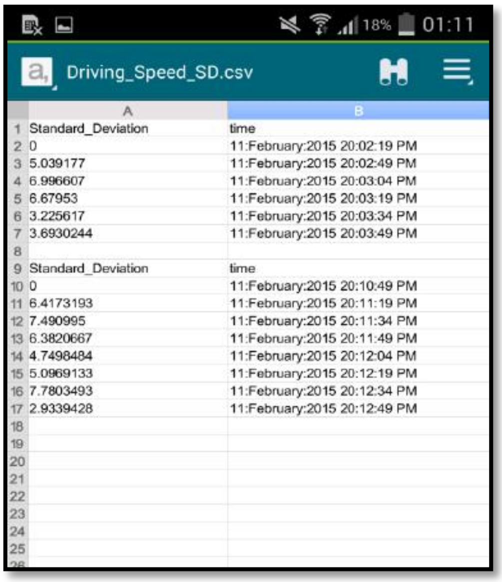
In other hand, if the user is walking or slowly running while carrying a smartphone, then its speed variation is mostly different than when he is inside the car which is moving at a variation of a low speed mentioned above. To differentiate between the two states, the **standard deviation** is calculated of different speed values measured for each period of 30 seconds interleaved of 15 seconds from previous and successive **speed variation period**. From the practical experiments it is found that the standard deviation of different speed values, for the person who is walking, for the **speed variation period,** is ranging between **1.056** and **1.88,** and the standard deviation, for the person who is slowly running is **2.06** as shown in Fig. 3. Other experiments are conducted for the car travelling at various speeds under the threshold 24 km/h; it is found that the standard deviation for these experiments is ranging between **2.9** and **7.7** as shown in Fig.4.

Hence, if acceleration event experienced by the smartphone is greater than 4G and the standard deviation of the **speed variation period** parameter is greater than the threshold **(2.06),** then it indicates a sign of accident.



	A	B
1	Standard_Deviation	time
2	0.0	10:February:2015 22:06:27 PM
3	1.155643	10:February:2015 22:06:57 PM
4	1.3252206	10:February:2015 22:07:12 PM
5	1.2349615	10:February:2015 22:07:27 PM
6	1.4887652	10:February:2015 22:07:42 PM
7	1.6308695	10:February:2015 22:07:57 PM
8	2.0664105	10:February:2015 22:08:12 PM
9	1.8801032	10:February:2015 22:08:27 PM
10	1.3200774	10:February:2015 22:08:42 PM
11	1.0565046	10:February:2015 22:08:57 PM
12	1.5301825	10:February:2015 22:09:12 PM
13	1.4645419	10:February:2015 22:09:27 PM
14	1.313804	10:February:2015 22:09:42 PM

Fig 3 Speed Standard Deviation for a Walking Person for Period of 30 Seconds



	A	B
1	Standard_Deviation	time
2	0	11:February:2015 20:02:19 PM
3	5.039177	11:February:2015 20:02:49 PM
4	6.996607	11:February:2015 20:03:04 PM
5	6.67953	11:February:2015 20:03:19 PM
6	3.225617	11:February:2015 20:03:34 PM
7	3.6930244	11:February:2015 20:03:49 PM
8		
9	Standard_Deviation	time
10	0	11:February:2015 20:10:49 PM
11	6.4173193	11:February:2015 20:11:19 PM
12	7.490995	11:February:2015 20:11:34 PM
13	6.3820667	11:February:2015 20:11:49 PM
14	4.7498484	11:February:2015 20:12:04 PM
15	5.0969133	11:February:2015 20:12:19 PM
16	7.7803493	11:February:2015 20:12:34 PM
17	2.9339428	11:February:2015 20:12:49 PM

Fig 4 Vehicle Low Speed Standard Deviation for Period of 30 Seconds

b. More frequently occurs that the vehicle is traveling at a high speed and suddenly or gradually reduced its speed below speed threshold 24 km/h. Hence, in this case, the **second parameter** mentioned in step **(a)** above is used to handle this phenomenon. Actually the **second parameter** cannot be activated unless a certain period of time has been passing to allow for the standard deviation to be calculated. Therefore, the **third parameter** used to make sure that the user is inside the car (while the car is at a high speed and reduced to low speed) is the **maximum period** of time that the vehicle is travelling from the last location where the speed was reduced below the speed threshold 24 km/h. From the practical result, it is found that a **maximum period** of elapsed **30 seconds** is quite sufficient to make sure that the user is unable to exit the car during the **maximum period**.

This parameter, in particular, is used in case the speed of the car was exceeding the threshold and then was reduced to stop at intersections, traffic lights or due other unexpected events. Hence, if acceleration event experienced by the smartphone while the car speed reduced below 24 km/h is greater than 4G and the elapsed time is less than the above mentioned **maximum period** is occurred, then it is interpreted as a sign of an accident. Clearly, if the above mentioned **maximum period** is passed with no sign of accident, then this situation is handled by the **second parameter** explained in the step **(a)** above. Also the elapsed **maximum period** is taken into account in calculating the standard deviation of the interleaved **speed variation period** parameter mentioned in step **(a)** above.

Fig. 5 shows how the parameters, mentioned in steps **(a)** and **(b)** above, are interleaved and activated.

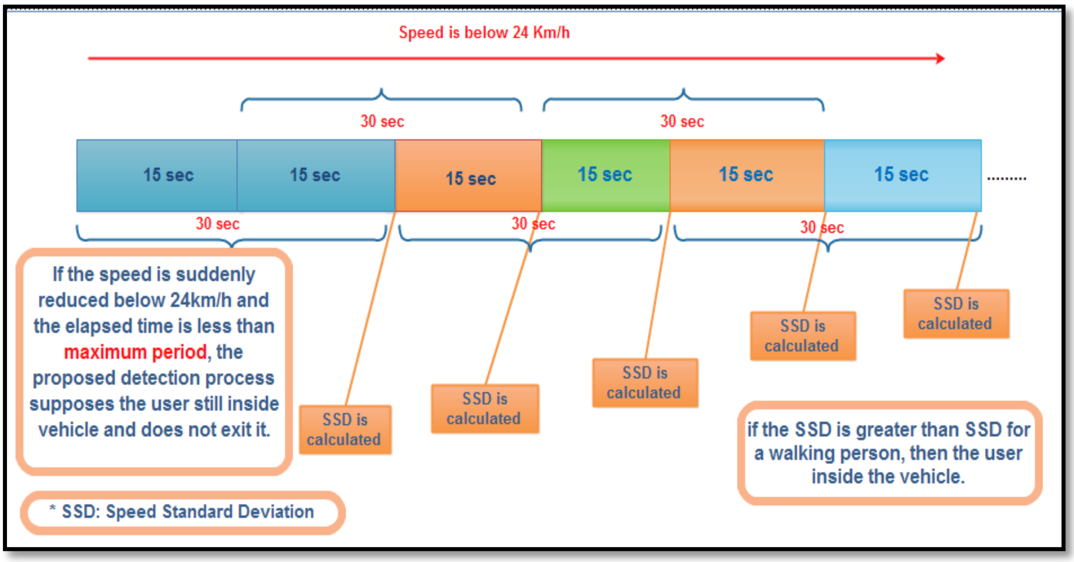


Fig 5: Timing Diagram illustrates how the Low Speed Parameters are activated

iii. Supporting features

To improve the detection process and to reduce the probability of false positives that result from any cases which their acceleration values are unknown, the following features are adopted:

- The built-in microphone is used to listen for the high decibel acoustics event to detect an accident such as airbag deployment, impact noise and car horns. However, driver, passengers can produce a loud of noises that can be interpreted by the device as sound of airbag deployment, they are called benign noises activities, such as phone drops, shouting, laughing, loud music and driven with windows down. According to empirical results mentioned in [4], none of these noises activities would reach the 160db range of an airbag deployment. But because of some smartphone microphones infrastructure suffer signal clipping above 140db, it makes hard to differentiate between the sounds, such as playing the radio at maximum volume from an airbag deployment. For this reason, it is hard to use the sound alone to detect the accident but it is used as a secondary filter with acceleration threshold value to improve the detection process and reduce false positives. And because of signal clipping process, the sound threshold value selected to be 140db in the **CADANS**.

- To increase the likelihood of an accident, increase the accuracy of detection and reduce the false positives, the smartphone camera is instructed by the proposed detection system to record a video, showing what is happening at the instance of an accident, immediately after the detection process indicates a sign of accident. The video is then sent to the emergency responder to be inspected for further certainty of an accident. Also the system is designed to allow the bystanders taking video and send them to emergency responder for further analysis.

2) Detection Phase Mechanism: The proposed detection phase mechanism can be expressed in the following formula, where **I** is accident detection indicator flag:

$$\mathbf{I}= \begin{cases} 1 \text{ if } ((\frac{Acc}{4G} + \frac{\mathbf{SU}}{140db}) \geq \text{Accident-threshold}) \textbf{ AND } (\text{SP} > 24\text{km/h}) \text{..................} & (1) \\ 1 \text{ if } (\frac{\mathbf{Acc}}{4G} + \frac{\mathbf{SU}}{140db} + \frac{\mathbf{SSD}}{2.06}) \geq \text{LowSpeed-threshold} \text{..............................} & (2) \\ 1 \text{ if } ((\frac{\mathbf{Acc}}{4G} + \frac{\mathbf{SU}}{140db}) \geq \text{Accident-threshold}) \textbf{ AND } (\text{elapsed time} < \text{MP}) \text{..........} & (3) \\ 0 \quad \text{Otherwise} & \end{cases}$$

Where:

- **Acc** is an acceleration variable that indicates the maximum acceleration experienced in any direction by the smartphone.
- **SP** is a speed event variable**.**
- **SU** is a sound event variable.
- **SVP** is the speed variation period measured at low speed and it is chosen to be **30 seconds**.
- **SSD** is the speed standard deviation measured for successive speeds while the whole speed below the 24km/h over **SVP** period.
- **MP** is a maximum period of time variable set at low speed with value of 30 seconds.
- **Accident-threshold** is an accident detection threshold, and it is chosen to be **1**.
- **LowSpeed-threshold** is an accident detection threshold at low speed and it is chosen to be **2**.

Thus, there are three **scenarios** (1, 2 and 3), shown above, to trigger accident detection indicator flag as shown in the above formula, otherwise there is no sign of accident.

B. Notification Phase

Car accident detection phase without notification phase is like doing nothing. Logically the most important task of the detection phase is the accuracy of the detection process, while the most important task of the notification phase is the speed and the type of information that are supplied to the emergency responders to respond for an accident. Fig.6 shows the architecture of the proposed notification phase.

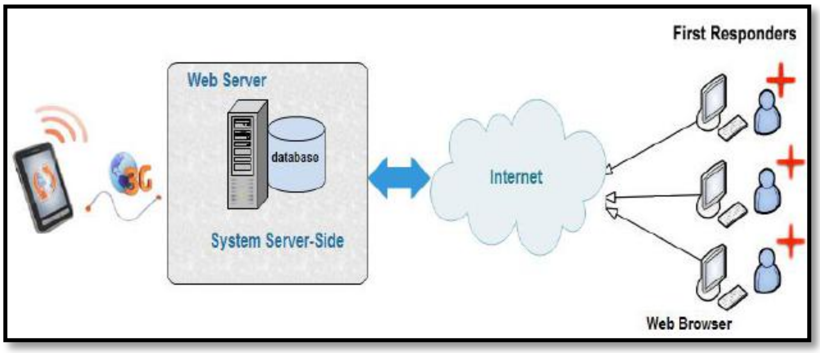


Fig 6 Notification Phase Components

Actually there are three types of notification that can be sent by the smartphone:

1. Driver and /or Passenger Notification

When detection phase confirms that an accident has taken place then a smartphone GPS receiver is required to find the geographical location of the accident and then utilizes the built-in 3G data connection to send accident information such as: G-force (acceleration force) experienced by the occupants during an accident, speed of the vehicle, the GPS location, airbag deployment state, time of the accident, and a recording video (showing what happened immediately after the accident is detected) are sent to emergency responders for fast recovery as shown in Fig. 7.

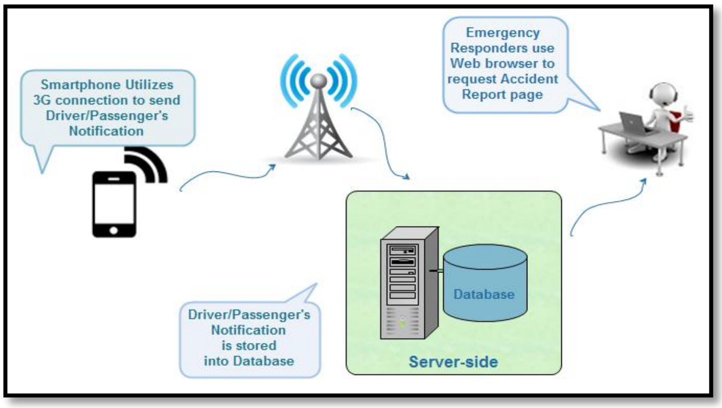


Fig 7 Smartphone sends Driver and/or Passenger Notification to the Emergency Responders

2. Bystander's Notifications

Fig.8 shows how the **CADANS** allows for uninjured people and bystanders to send multiple streams of videos and images from an accident location. Also smartphone GPS receiver is required to find the precise accident location and then transmits this notification to emergency responders.

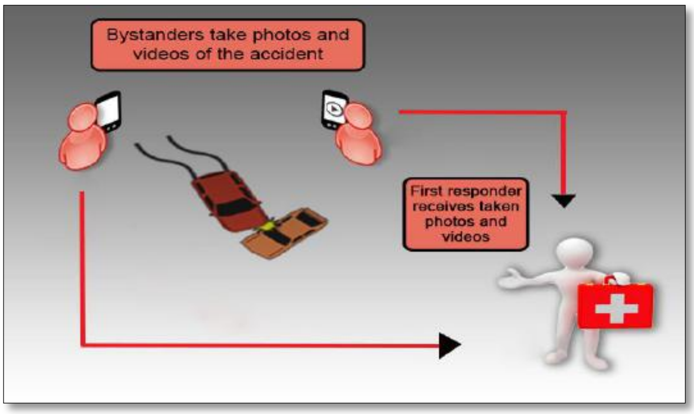


Fig 8 Bystanders upload Videos and Images of the Accident

3. SMS Notification

To strengthen the notification phase, it is found a good idea to notify the contacts of the driver/passenger, such as family member, about the accident through sending SMS message that comprises the location where the accident is happened**.**

IV. CADANS Implementation

As previously mentioned **CADANS** consists of detection phase and notification phase. The detection phase is fully implemented as an application running on smartphone while notification phase is implemented on two sides, the smartphone side and the system server side respectively.

A. *Smartphone Side Implementation*

The all about smartphone side is developing Android application, using Eclipse IDE, which runs on the smartphone. The highest version of Android system with which the application has been tested is **KitKat** with API level is 19. UI screen that represents the home screen for the proposed application is shown in Fig. 9.

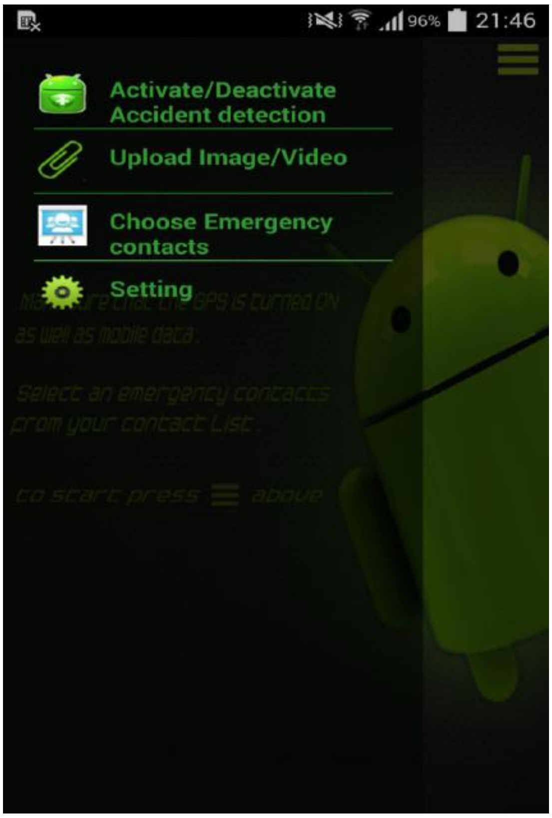


Fig 9 UI Screen for CADANS Application

The **CADANS** application consists of the following Activities which are listed as follows:

- Activate/Deactivate Accident Detection Activity
- Upload Image/video Activity
- Choose Emergency Contact Activity
- Setting Activity

Figs 10, 11, 12 and 13 show the UI screen of each **CADANS** Activities, respectively.

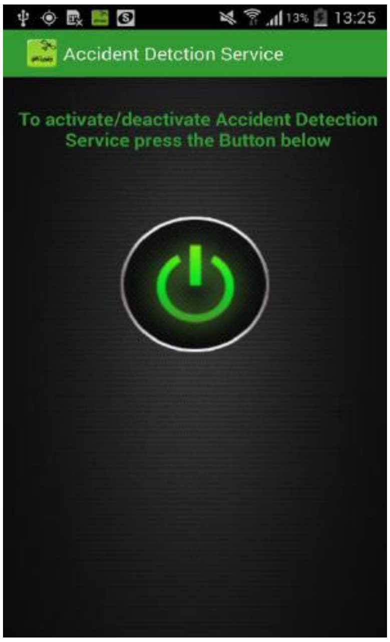


Fig 10 UI Screen of Activate/Deactivate Accident Detection Activity

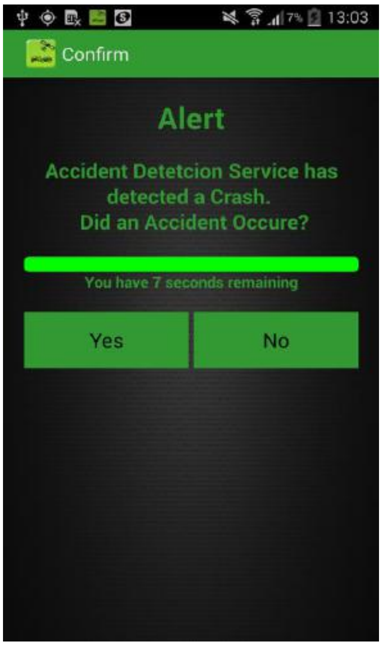


Fig11 UI Screen of Confirmation Activity

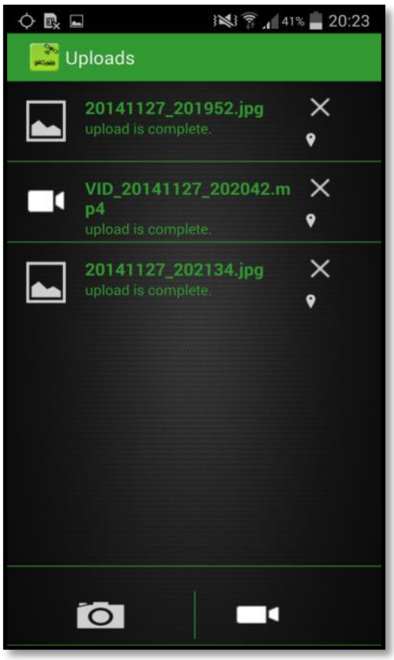


Fig 12 UI screen of Uploads Activity

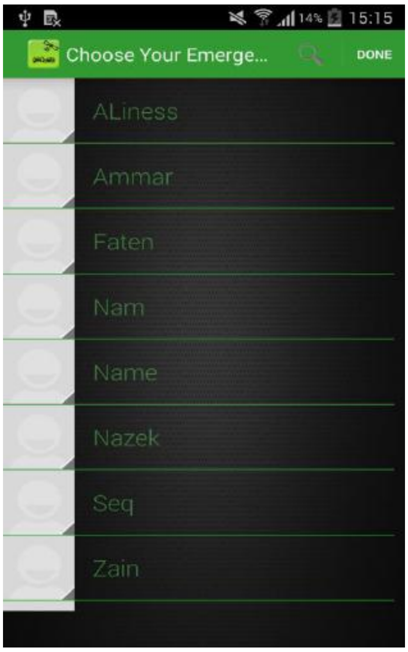


Fig 13 UI screen of Choose Emergency Contact Activity

B. System Server Side Implementation

According to the proposed notification phase, presented in section III-B, the system allows to send two types of notifications to report the accident, which are Driver, and/or Passenger notification and Bystander's notification. These notifications are sent, via utilizing smartphone built-in 3G connection, to the system server-side and finally resided into the database. Thus, to find out about an accident, the authorized emergency responders in the emergency center needs to access to the whole accident notifications that are resided into the database. Therefore, according to notification phase architecture, the emergency responders should contact the web server, through the internet, for requesting the notification web page. The emergency responders use web browser to retrieve and display the accident notifications, as shown in Fig.14.

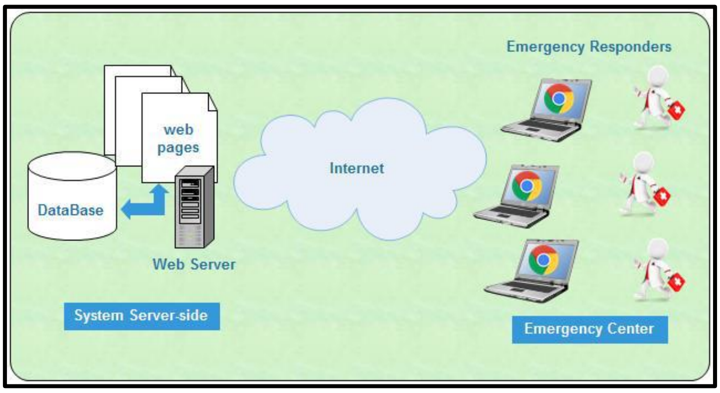


Fig 14 Communication between System Server-Side and Emergency Responders.

The all useful, new web technologies, are used to develop the system server side, are listed as follows:

1. Apache is chosen as a web server.
2. MYSQL is chosen to be the main database.
3. HTML5, PHP, JavaScript and CSS to develop the web pages.
4. Google Map JavaScript API v3 is used to bring the power and convenience of Google Maps to the Web Pages.
5. Server Sent Event API[10], which is new web technology that is used to push fresh data from server to client (web browser) instantly, without needing to wait for them to request that data as shown in Fig. 15. Consequently, the most significant advantage of SSE is lower latency and there are no more consumed resources (such as bandwidth, CPU cycles, etc.) and no more wasted requests if there are no available new fresh data. Thus, Because of its main speed advantage to deliver accident notifications, received by system server-side, quickly without delay the data push (SSE) technology is used. The SSE is supported in all major browsers, except Internet Explorer such as Google chrome, Opera, Firefox and safari.

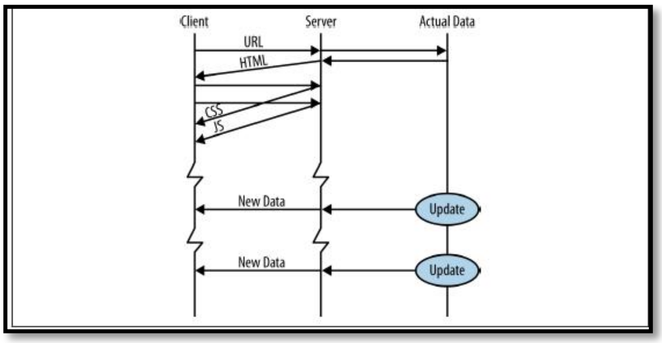


Fig 15 Server-Sent Event Diagram [10]

Figs 16, 17, and 18 show the main web pages that are requested by the emergency responders.

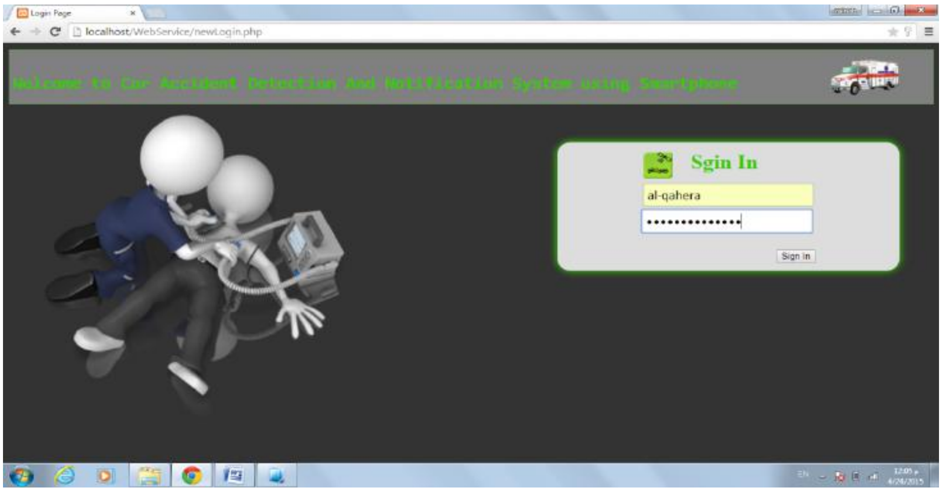


Fig 16 Login Page.

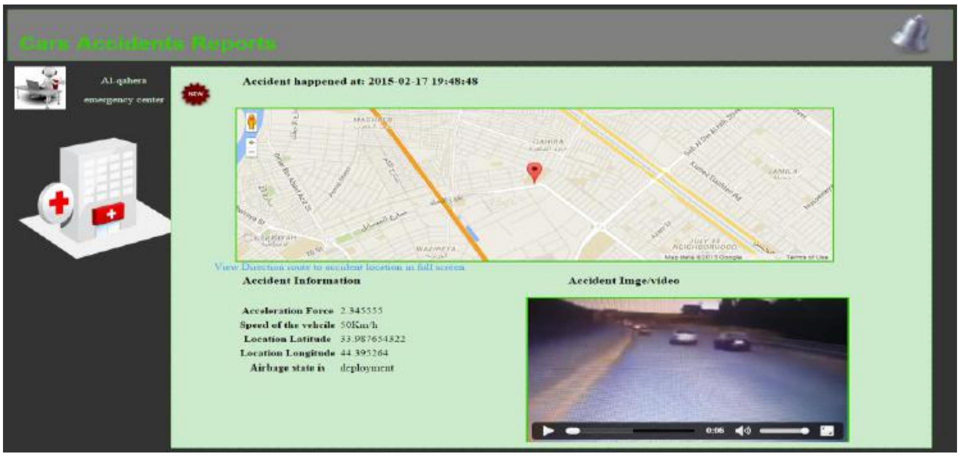


Fig 17 Accident Report page.

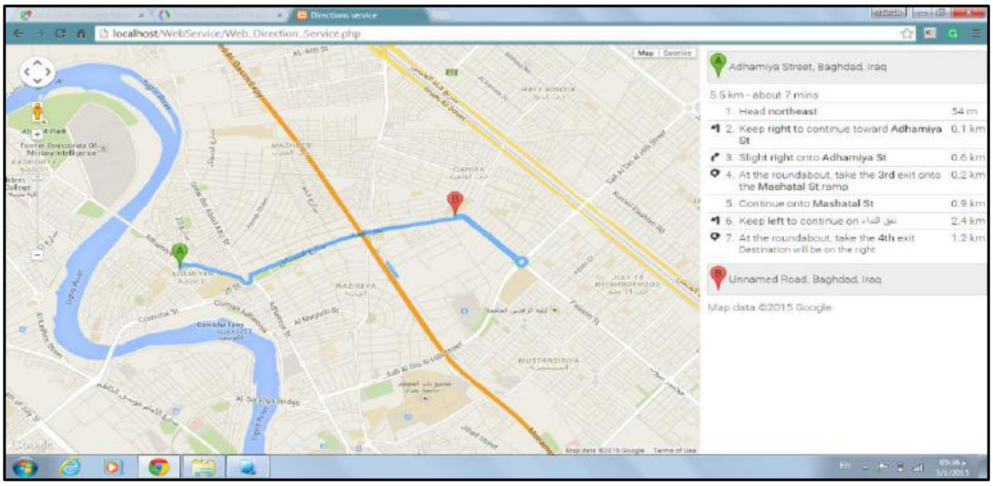


Fig 18 Map Showing Direction Route between Emergency Center and Accident Location

V. Performance Results

Due to safety matter and the significant damage concerned, crash testing of the **CADANS** in real environments (real car accident) is not realistic and practical. Also the lack of the availability of laboratories that can be used to simulate the crash environment is making the crash testing difficult to achieve. However, constructing some cases that simulate the scenarios of the proposed detection phase mechanism and testing the **CADANS** against these cases would yield a high confidence that supports the reliability and certainty of **CADANS**.

These tests are performed on the **CADANS** in real environment; by having the driver drives the vehicle in different speeds, so the speed of the vehicle is not steady all the time. Also the other factors, like G-Force and sound decibel are imitated inside the car while the car is moving at different speeds. The idea is to create an environment that mimics the real environment as these mimic environments are required to test the **CADANS** under different speed conditions (low speed and high speed). Before going to demonstrate the tests on **CADANS**, the following important issues that must be taken into account are listed below:

- As mentioned and analyzed in detection phase specification, the smartphone must experience a forcible acceleration event, which is greater than 4G, to be interpreted as indication of an accident. So to achieve this issue, during these tests, the smartphone is dropped forcefully inside the vehicle to obtain acceleration event greater than 4G. Actually this case has repeated many times but the acceleration value experienced by the smartphone is approximately reached to 3.5G as shown in Fig.19. Also another experiment is conducted inside the vehicle, which is shaking the smartphone very vigorously, to try obtaining acceleration event greater than 4G. In fact the maximum acceleration force experienced by the smartphone, in this case, is 3.9971G as shown in Fig.20.
  Since it is difficult to obtain forcible acceleration value greater than 4G from the simulated test, a threshold value of 3G is used to test the **CADANS** for the value of the G-force experiences by the smartphone accelerometer sensor to indicate a sign of an accident.

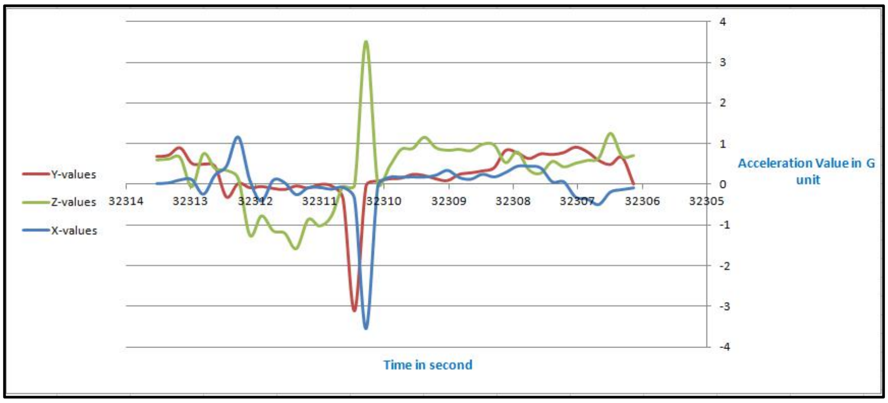


Fig 19 Acceleration Values during Dropping the Smartphone Forcefully

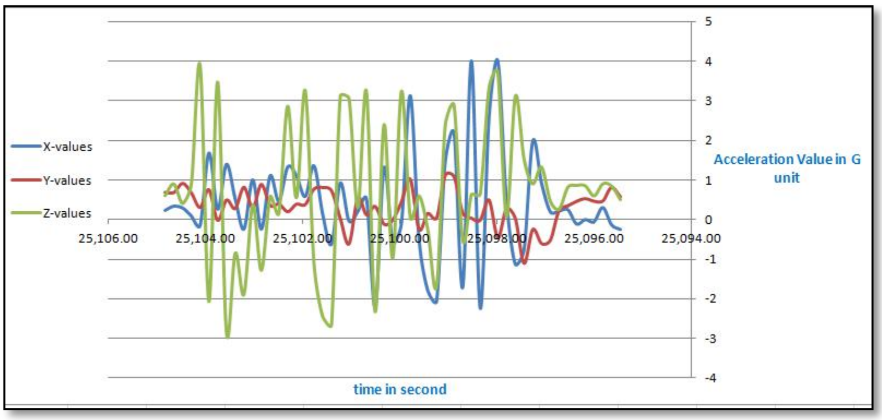


Fig 20 Acceleration Values during Shaking the Smartphone Forcefully.

- Since it is difficult to test the **CADANS** in real accident to achieve a high decibel level of sound event (greater than 140db) without existence of airbag deployment, the radio inside the vehicle is played with high volume and all windows of the vehicle are closed.

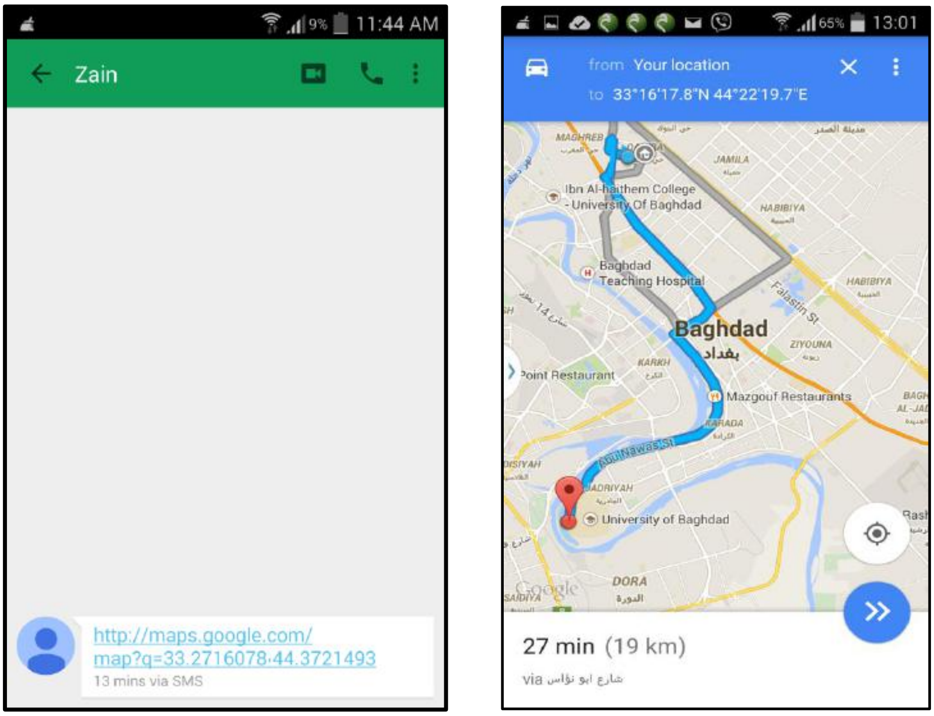
A. First Practical Test

This practical test is performed while the smartphone inside the vehicle, which is running at speed of approximately (70 km/h), to test the **CADANS** in high speed condition. Besides that, to achieve all conditions that trigger the first scenario of detection phase mechanism the smartphone is forcefully dropped into the vehicle and the radio is played with all windows are closed to accomplish the high decibel level of sound event. After the Accident is confirmed, the **CADANS** immediately began recoding the video, for 10 seconds, and uploaded to the web server. Then the **CADANS** began executing two operations asynchronously which are: sending driver/passenger's notification to the web server via built-in 3G connection, and sending SMS notification to emergency contacts. The database at the server is examined and it is found filled with a new record related to this practical test as shown in Fig. 21.

Acceleration_Value	latitude	longitude	speed	elapsed_time	SSD	airbag_fla	Video_Url	accident_time
3.5G	33.379092	44.391465	70 km/h	NULL	NULL	true	http://192.168.2.101/WebService/uploads/VID_20	2015-02-17 19:45:48

Fig 21 database record shows the accident information that was inserted during first practical test.

Also, the smartphone of emergency contact (whose number is chosen before the test is performed) received a new SMS message as shown Fig. 22.



(a): UI Screen for Message Application

(b): Map shows the Red Marker on the Accident Location

Fig 22 UI Screens for SMS and Map Applications

B. Second Practical Test

The second practical test is performed to test the **CADANS** when the vehicle (as well as the smartphone) continuously travelling at a low speed (approximately reaching a maximum of 23km/h). At the beginning of the trip the driver was driving the vehicle at a low speed, which was ranged from 1km/h to 23km/h, which is below speed threshold 24 km/h. Thus, this practical test is reflecting the reality of either the traffic is oscillating and the driver is at the traffic tail so that it reflects the likelihood of rear ended crash, or when the driver is continuously driving in low speed and suddenly collides with other opposite direction speeding vehicle which causes severe damage. Thus, this situation is appropriate to test the **CADANS** against the second scenarios of detection phase mechanism. Also, to satisfy all other conditions the (smartphone is dropped forcefully to achieve high acceleration event and the radio inside the vehicle is played with high volume so that the sound level that is sensed by smartphone built-in microphone is greater than 140 db.

To make sure the smartphone (as well as the user) still inside the vehicle while the speed is below 24km/h, the speed standard deviation (SSD) is calculated over **speed variation period** of 30 seconds and compared with predefined SSD for a walking person. As in the first practical test, after the accident is confirmed, the same procedure mentioned in first practical test is repeated here but the database is found filled with a new record related to this test as shown in Fig. 23.

Acceleration_Value	latitude	longitude	speed	elapsed_time	SSD	airbag_flag	Video_Url	accident_time
3.5G	33.379092	44.391465	23 km/h	NULL	7.7	true	http://192.168.2.101/WebService/uploads/VID_20150217_1802042	2015-02-17 19:48:48

Fig 23 Database Record shows the Accident Information that was inserted during Second Practical Test.

C. *Third Practical Test*

This practical test is concerned with third scenario of detection phase mechanism which is also conducted in real vehicle. At the beginning of the trip the vehicle is driven with high speed reached to approximately (70km/h) and then, the driver begun to reduce the speed to stop at intersection or due unexpected event so that the speed of the vehicle reached to 15km/h. In this test, at the instance of reducing the speed below 24km/h, the smartphone is dropped forcefully inside the vehicle and as in previous practical tests a forcible acceleration event of greater than 3G is achieved, which is acceptable during the test.

In this test, the elapsed time from the instance of reducing the speed below 24km/h and dropping the smartphone forcefully inside the vehicle is less than **maximum period** (30 seconds), so that the proposed detection process supposes the user is still inside the vehicle and does not exit it. Also during this test, the radio inside the vehicle is played with high volume so that the sound level is greater than 140 db. After the accident is confirmed the same procedure mentioned in first practical test is repeated, but the database is found filled with a new record related to this test as shown in Fig.24.

Acceleration_Value	latitude	longitude	speed	elapsed_time	SSD	airbag_flag	Video_Url	accident_time
3.5G	33.377018	44.395451	15 km/h	10 sec	NULL	true	http://192.168.2.101/WebService/uploads/VID_2015	2015-02-17 19:56:48

Fig 24 Database Record shows the Accident Information that was inserted during Third Practical Test.

VI. Conclusion and Future Work

- It has been realized that the smartphone based car accident detection system is not an easy task to handle. It is really surrounded with many obstacles that prevent the researchers from achieving 100% 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. The proposed system minimizes the impact of this obstacle which is proved in the practical results conducted in this work.

- Every smartphone based accident detection and notification system is exposed to false positives. 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, which are briefly listed below:
  a. CADANS presents a confirmation screen which gives the user the opportunity to confirm the accident, thus in case of false positive occurs the user can cancel the alarm and notification is aborted.
  b. CADANS allows for uninjured peoples or bystanders to take images/videos and send them to emergency responders, for reporting the accident.
  c. CADANS utilizes smartphone camera to record a video, showing what is happening at the instance of an accident immediately after the detection process indicates that there is an accident. This video is sent to the emergency responders for further inspection and analysis.
- To notify the family or friends quickly about the accident, the proposed system sends SMS message which contains accident location coordinates to predefined emergency contacts.

As a future work, a further analysis can be tried to improve the accuracy of detection phase and reduces the probability of false positive signs that are generated from being the user is inside or outside the car when the vehicle is travelling at a low speed. Therefore, it is suggested that the researchers investigate in the field of "Activity Recognition" based on smartphone sensors, which is used to detect the current activity of the user whether he is driving, walking, running. Also, a voice recognition module can be constructed and added to the proposed system to differentiate between airbag deployment and benign noise. Achieving this enhancement would increase the proposed system reliability and decrease false positive signs.

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