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Vehicular impact analysis of driving for accidents using on board diagnostic II

Siddhanta Kumar Singh, Ajay Kumar Singh
Department of Computer Science and Engineering, School of Engineering and Technology, Mody University, Laxmangarh, India

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ABSTRACT

A large number of people meet with an accident everyday around the world. One of the leading causes of death is traffic accidents. The reasons behind India's rising number of road accidents contribute to bad driving behavior, poor road design and infrastructure, lack of enforcement of traffic laws. The post accidental investigation report is very important to know the actual reason of collision for the concerned parties and the insurance company and the police. The proposed work effectively extracts interpretable features describing complex driving patterns. It will provide analytical report of the accidents to various parties involved in process. This work analyzes the type and cause of accident. The experiment has been simulated using on board diagnostic II (OBD II) and smart phone accelerometer for post accidental analysis of collision. As the electronic control unit (ECU) does not provide accelerometer sensor, so the smart phone accelerometer has been utilized in conjunction with another parameter of OBD II device. The gravitational force (G-force) values observed from accelerometer sensor along the different axes and speed, acceleration, fuel consumption rate, and are retrieved from OBD II device. The result shows that the parameters recorded are very helpful in finding the actual accidental status of the vehicle.

Corresponding Author:

Siddhanta Kumar Singh
Department of Computer Science and Engineering, School of Engineering and Technology
Mody University
Sikar Rd, Laxmangarh, Rajasthan 332311, India
Email: singhsiddhant@yahoo.com

1. INTRODUCTION

Due to huge growth in population and the rapid urbanization of the areas, there is a tremendous growth in the motor vehicles in the recent years. Eventually it has led to the various traffic management systems namely traffic congestion, accidents, fuel consumption, and pollution of air. Sometimes even after accidents, the vehicular profile of accident is not known properly. To overcome this, the work uses the accelerometer sensor and on-board diagnostic II (OBD II) speed parameter from the electronic control unit (ECU). The iSaddle [1] OBD II scanner shown in the Figure 1 is used to read the various OBD II real time parameters and also reads the diagnostic trouble code (DTC) code from the phase-change memory (PCM) memory. The application of accelerometers extends to multiple disciplines such as academic, research, and consumer-driven fields. The three axes of the accelerometer determine its acceleration along the three axes as shown in the Figure 2. Accelerometer is used in cars as a device of detecting car crashes and deploying airbags almost instantaneously. The accelerometer sensors are integrated circuits (ICs) that measure the accelerations, which is the rate of change in velocity. Measuring acceleration makes it possible to obtain information such as object inclination, vibration and gravitational force (G-force). The g is also used as a unit for acceleration, relative to standard gravity (1 g=9.80665 m/s^2).

Figure 1. iSaddle OBD II scanner

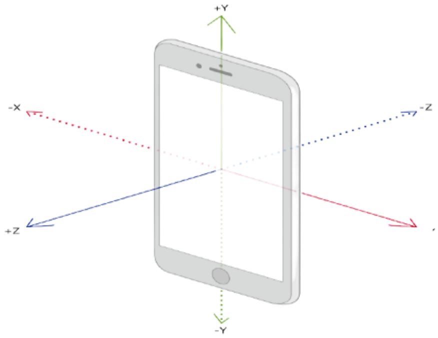

Figure 2. Accelerometer axes

OBD I: itis Theon-board diagnostics interface used to control the emission [2] of vehicles manufactured in California in 1991. It was mandated by the state that the vehicles sold after this time had to be equipped with OBD I to detect emission issues report the diagnostic codes. But OBD I was not generic. It means that the protocol varies from manufacturer to manufacturer. And the OBD II port was also not the same and one had to use different adapters to read ECU data and diagnostic code using cable. To avoid this disadvantage, a new protocol standard came up as OBD II.

OBD II: there are five communication protocols used by the OBD-II compliant vehicles. These protocols are society of automotive engineers (ISO15765-4/SAE) J2480 controller area network (CAN protocol), J1850PWM, J1850 VPW, ISO9141-2, and ISO14230-4. The CAN protocol was used by US manufacturer after year 2003 only, but nowadays after year 2008, the CAN protocols are being used by almost all the vehicles. All the cars manufactured after 2013 in India are equipped with OBD II data link connector (DLC) port.

The SAE defined two types of DLC [3]. These are known as type A and type brushless data link connector's (BDLC's) as shown in the following Figures 3 and 4 respectively. The main difference between the two types of DLC lies in their shape and their positions in dashboard. The driver's compartment region is equipped with type A connector which is bounded by the driver's end instrument panel to about one foot beyond the vehicle center line and easily accessible from the driver's seat and passenger side in J1962. The most favorable location of this type A connector is between the steering columns and the vehicle centerline.

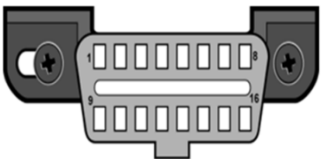

Figure 3. DLC type A

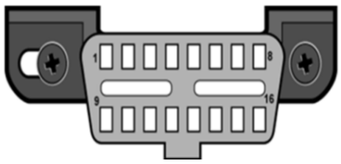

Figure 4. DLC type B

The driver's compartment area is defined by the driver's end of the instrument panel and an imaginary line about 2.5 feet beyond the vehicle center line or the passenger side. Type B connector is mounted on the instrument panel and accessible from either the driver's or co-driver's seat. All cars and light weighted trucks manufactured in the US after 1996 are mandated to be OBD II compliant. The EU OBD legislation is somewhat more complicated. OBD II a diagnostic interface mandated by the US government and later by many countries. The OBD II interface provides us real time engine and other information including DTC codes [4]. A DTC code corresponding to that fault is immediately stored in its memory whenever the engine control module (ECM) encounters a problem. These codes are used by the technician to determine the nature and the root cause of engine failure or any other problems. The DTC code is a string of five alphanumeric characters "XXXXX". The meaning of each character is given in the Figure 5. The OBD I protocol used manufactured specific code and therefore, to understand the code, one had to refer to the company engine manual but today's OBD II protocol uses mostly generic DTC code and the interface is also generic unlike OBD I which was different for different manufacturers. The DTC code PXXXX is the OBD II emissions related code for the powertrain related issues. POXXX is for generic DTC code and P1XXX refer to manufacturer specific codes whose meaning will be supplied by the manufacture of the vehicle. The third character tells us where the fault has occurred like whether is in the fuel system or metering system.

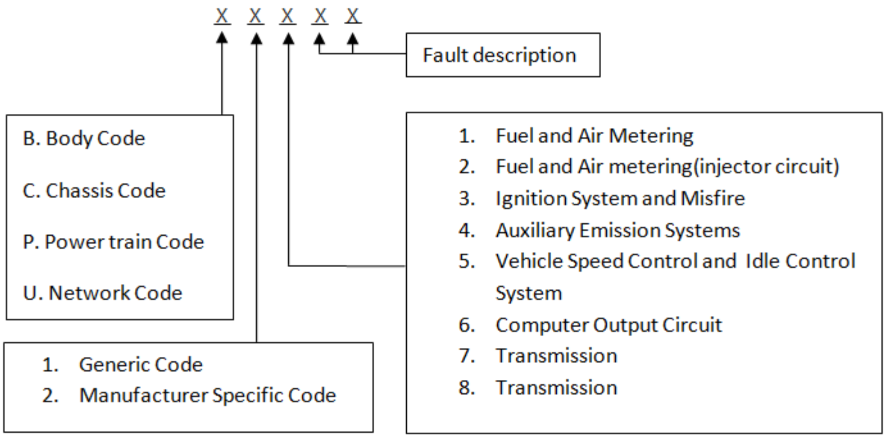

Figure 5. DTC code format meaning

In some cases, the check engine light is not commanded to glow despite having DTC code in memory. These types of DTC codes are known as pending codes. These codes are caused by intermittent faults or faults that the ECM needs to see happen in two consecutive warm-up cycles to set the code. The freeze frame data is also captured by the system when a pending code is stored in the memory, which gives the technicians the actual operating conditions when the fault was triggered. A warp up cycle means driving a vehicle so that the engine coolant temperature (ECT) rises by at least 40 degrees Fahrenheit after the engine is started and reaches at least 160 degrees Fahrenheit. If the fault does not reappear again in the next 40 warm up cycles, the code will automatically be deleted from memory. If the fault code reappears again in the memory for the specified number of times, the code will then mature into a DTC and the check engine light will be commanded by the PCM of the vehicle to illuminate so that the user knows about the fault. The US government did not mandate the manufacturers to standardize the communication interface to the engine computer when OBD II was rolled out. Initially OBD II had about a half dozen communication protocols but later mandated that the ECU must support the CAN communication protocol. The CAN communication protocol is supported under OBD II. The scanner will automatically detect the available protocol. In this research paper, the literature survey is done in section 2, the model and theories are shown in section 3, the experiment and results are discussed in section 4 and finally the conclusion is made in section 5.

2. RELATED WORKS

There was a comparison made between OBD II and CAN bus in the research paper by Sik *et al*. [5]. The novel tool collects various data using OBD II and displays on the smart phone and developed interface for social driving. Rimpas *et al*. [6] determined fuel consumption on the basis of engine data and then compared with the standard one to find the driving behavior. The work helps how OBD II data can be used in finding driving behaviour. Dong *et al*. [7] proposed a novel deep learning solution for driving behavior analysis by extracting features describing complex driving patterns from global positioning system (GPS) data. The android app for this work is also available in play store for free download. There are many causes which lead to transportation accident. To get rid of this Moniaga *et al*. [8] created a diagnostic approach to read OBD II data using scanner by connecting to the DLC connector and sending this real time information to Raspberry Pi for further processing of vehicular data. The purpose of this research work is to diagnose his own vehicle. Ameen *et al*. [9] in his research work identified the different types of driving behaviors like normal, safe, aggressive, and dangerous using statistical methods. Carignani *et al*. [10] in her research work proposed a system of in vehicle CAN/OBD and IoT network. Bdaway *et al*. [11] conceived smart education system using IoT system with OBD/CAN and conveys message to central servers on cellular data using message queuing telemetry transport (MQTT) protocol. Husni *et al*. [12] applied IoT in cars for monitoring and maintenance. The supervised driving behavior would increase the efficiency of the car thereby reducing fuel consumption and emissions. Hsieh *et al*. [13] developed a vehicle monitoring system using IoT which can monitor different weather parameters like temperature and humidity. For vehicle tracking and analysis, Malekian *et al*. [14] used wireless onboard diagnostic system using OBD II to read different engine parameters. Kirthika *et al*. [15] developed a system to connect to ECU using OBD II and Raspberry Pi, Arduino Uno, using WiFi to monitor the vehicle. Andrews and Rajavarman [16] research work, it focuses on migrating the current CAN bus based network to IP based network. Zualkernan *et al*. [17] designed and implemented a social internet of vehicles which enables the drivers and the vehicle about the surroundings so that they can act on time. Husni [18] developed VISCar system to monitor the fuel consumption for android application to solve the problems related to fuel consumption and efficiency using IoT. Abukhalil *et al*. [19] proposed a model for to calculate the fuel consumption using the onboard diagnostic information from OBD-II using support vector machine and Langrange interpolation. In the research work by Khosravinia *et al*. [20], electric vehicle (EV) system was developed which uses OBD II to communicate with CAN bus to communicate and integrate the various EV parts for monitoring vehicles. Shetty *et al*. [21] proposed an automatic IoT based car maintenance system to assist a person from minor gliches in the vehicle. Srinivasan [22] in his research work improved the quality and safety of the vehicle by monitoring vehicle in real time, using Raspberry Pi and machine learning algorithms. Afosono *et al*. [23] proposed a system which will allow us to monitor and control vehicles from anywhere anytime using IoT systems which uses Bluetooth, wireless sensor network, human machine interface, and online database firebase. Ali and Alwan [24] proposed a model for accident detection at high and low speed on the basis of G-force [25] measured using accelerometer and sending the message to the local authority.

3. THE WORKING METHOD

The model is based on experiencing G-force for driver and passengers inside the car either in high speed i.e., 24km/hr or at low speed (<24km/hr). This paper is based on driving analysis at low speed and high speed vehicle driving. The workflow of this research paper is shown in Figure 6 in the flowchart.

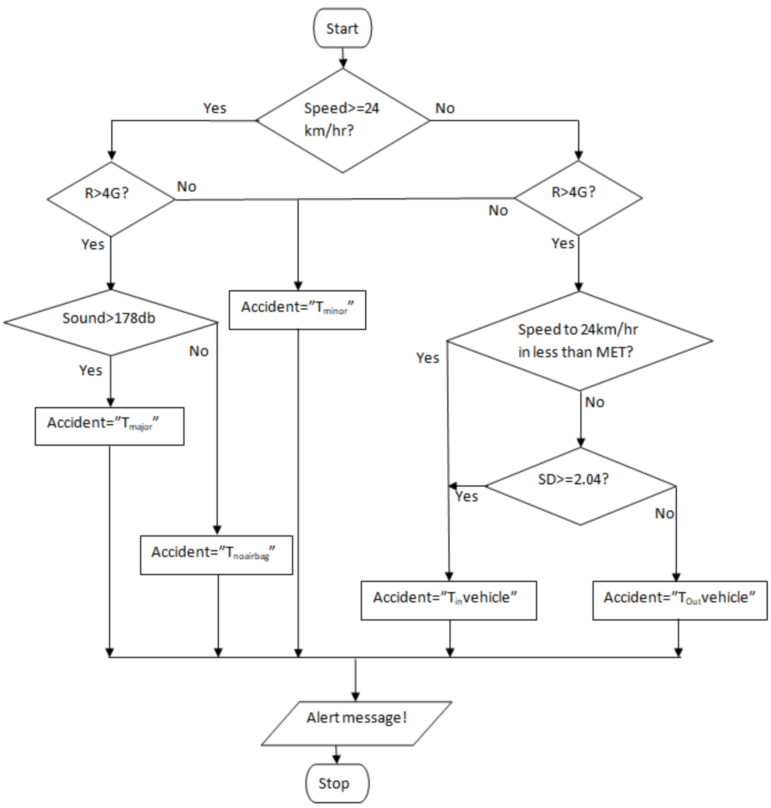

Figure 6. Flowchart of the workflow

An acceleration of 4G is considered as an accident. Because to avoid false positives accidents like the accelerometer inside the interior of the vehicle is hit by some object or the smart phone dropped accidently which generates G-force less than 4G only or in the event of sudden retardation of the vehicle. A diagnostic trouble code B1942 can result in the airbag [26] not deploying in a collision from OBD II and this information is registered in ECU memory after detecting a discrepancy in the voltages to two terminals in the airbag circuit in case there is no sound more than 178 dB [27] is produced with airbag facility in the car. Any noise including that of firecrackers (up to 150 dB) which is less than 178 dB is not airbag inflation noise. This is how we can avoid false positive sound about airbag deployment due to other noises.

When the vehicle is moving at slow speed, there may be two cases. It may reduce to this slow speed in a very short time or it may attain this speed so that it finds maximum elapsed time (MET) of 10 secs to facilitate calculation of standard deviation (SD) of varying speeds at slow speed to ensure whether the person is inside the vehicle. If the speed was not reduced abruptly then it would calculate the SD and it is seen experimentally that SD higher than 2.06 signifies that the person is inside the vehicle because there is a lot of chance that the speed would vary a lot when inside the car even at low speed.

To calculate the G-force, we use the accelerometer of the smart phone which is firmly placed on dashboard or at any location attached firmly to the car and calibrated accordingly. The software to retrieve these G-force values is the torque pro [28] and the speed is determined from the ECU using OBD-II protocol attached to the OBD-II port underneath the dashboard of the vehicle. We can imagine the car to part of 3D co ordinate system with running the axes along different directions perpendicular to each other as show in Figure 7 and the android app developed to read the real time data is shown in the Figure 8.

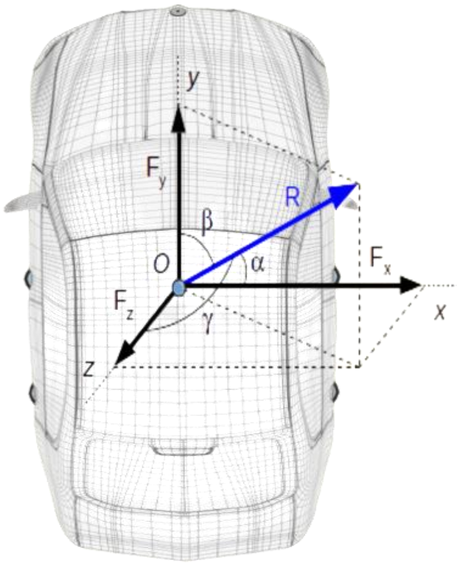

Figure 7. G force resolution

Figure 8. Android G-force data readings

R is the G force vector with which collision takes place which gives rise to the G-forces recorded from the G-force sensor accelerometer long the 3D axes in m/sec^2 given by the parameters F_x, F_y, and F_z along x-axis, y-axis and z-axis respectively. The F_z is the acceleration due to gravity which is the only force acting on it in default condition whose value is 9.8 m/sec^2 acting vertically of the vehicle. The F_x is the G force acting sideways and Fy is the G-force experienced along the road. This is achieved by setting $curr_X$, $curr_Y$, and $curr_Z$ parameters with the event values of sensor event object for x-axis, y-axis, and z-axis accelerations respectively. The changes in x-axis, y-axis and z-axis are calculated as δ_X, δ_Y and δ_Z respectively as in. The $last_X$, $last_Y$ and $last_Z$ are the last changes.

$$\delta X = | lastX - currX |$$

$$\delta Y = | lastY - currY |$$

$$\delta Z = | lastZ - currZ |$$

The parameters δ_X, δ_Y, and δ_Z are the changes in the accelerated values. Given these G-forces we can determine the resultant G-force R by using the following (1).

$$R = \sqrt{Fx2 + Fy2 + Fz2} \quad (1)$$

We can also determine whether the collision is sideways, from behind or it is a head on collision by determining the angle of collision with respect to the three axes. Let α be the angle of collision with respect to the x-axis, β be the angle of collision with respect to the y-axis, and γ be the angle of collision with respect to the z-axis on 3D plane. Therefore, the angles can be measured using the following in (2)-(4).

$$\text{the angle} \propto = \cos^{-1}\left(\frac{F_x}{R}\right) \quad (2)$$

$$\beta = \cos^{-1}\left(\frac{F_y}{R}\right) \quad (3)$$

$$\text{and } \gamma = \cos^{-1}\left(\frac{F_z}{R}\right) \quad (4)$$

Hence using the values of angles, we can easily determine from which side the collision occurred. For example, the more the values of angles of α and the less the values of β, is the sign of head on collision. And conversely the less the values of angles of α and more the values of β, is the sign of sideways collision. An equal value of these angles gives rise to cornered collision. The γ angle might be affected to some extent due to vibration and jerk along z-axis as well. But this angle basically can be used in this experiment to determine potholes and other kind of on road physical irregularities which gives rise to different driving experience and analysis. The side of the impact can be determined by the following algorithm:

```
If α+β=90 OR γ=90
 If Fx>0
 Impact="Perfect Right Sideways"
 Else
 Impact="Perfect Left Sideways"
Else if β+γ=90 OR α=90.
 If Fy>0
 Impact="Perfect head on"
 Else
 Impact="Perfect back on"
 Else
 Impact="Cornered "
```

The F_z has very negligible change in its values due to impact as this is dependent of gravity component unless there is a roll in the vehicle due to major accident.

4. RESULTS AND DISCUSSION

To detect the accident at low speed, speed band of 10 sec is chosen interleaved of 5 sec between previous speed band and the next speed band. The speed band is used to determine the standard deviation in the varying speeds of the vehicle in the time period to ensure that the person is inside the car. The Speed while waking is retrieved from the GPS speed while the speed while in the vehicle is taken from the OBD II reader using torque pro as shown in Table 1 and Table 2. The standard deviations calculated for walking (the GPS speed and standard deviation of speeds being in y axis and time along x-axis) and driving (the OBD II speed and standard deviation of speeds being in y-axis and time along x-axis) are shown in Figure 9 and Figure 10. As the maximum standard deviation from the experiment is 2.04 and hence this can be chosen as threshold to determine whether the person is walking. Because the standard deviation of the cars speed yield higher values as can been seen from the test.

Table 1. Standard deviation(walking)

Time (Sec)	Device time (hh:mm:ss)	GPS speed (km/hr)	Standard deviation
40	4:56:08AM	4.572	1.043433307
45	4:56:13AM	4.7052	1.131782434
50	4:56:18AM	3.9816	0.268357403
55	4:56:23AM	7.2336	1.132336745
60	4:56:28AM	3.9456	1.809362123
65	4:56:33AM	3.6252	2.048796514
70	4:56:38AM	3.6036	0.097473689
75	4:56:43AM	3.8952	0.136547662
80	4:56:48AM	4.1904	0.114754765

Table 2. Standard deviation (driving)

Time (Sec)	Device time (hh:mm:ss)	OBDII speed (km/hr)	Standard deviation
240	9:03:50AM	9	3.425395354
245	9:03:55AM	14	1.87379591
250	9:04:00AM	20	4.817791103
255	9:04:05AM	11	4.37289632
260	9:04:10AM	10	1.87379591
265	9:04:15AM	8	0.918936583
270	9:04:20AM	1	3.212821536
275	9:04:25AM	5	2.321398046
280	9:04:30AM	6	3.056868405

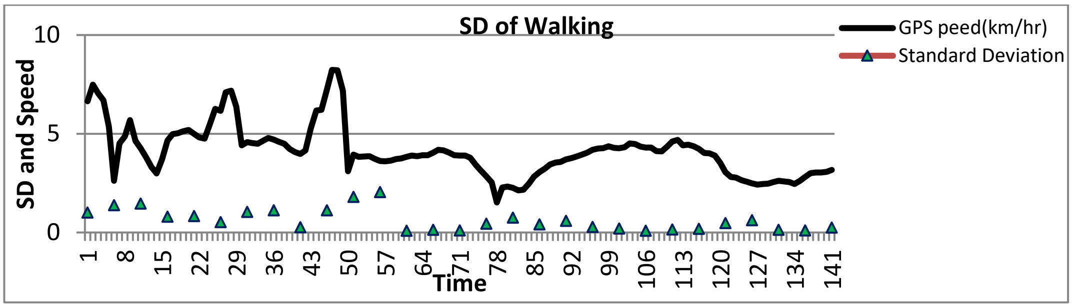

Figure 9. Walking speed and SD

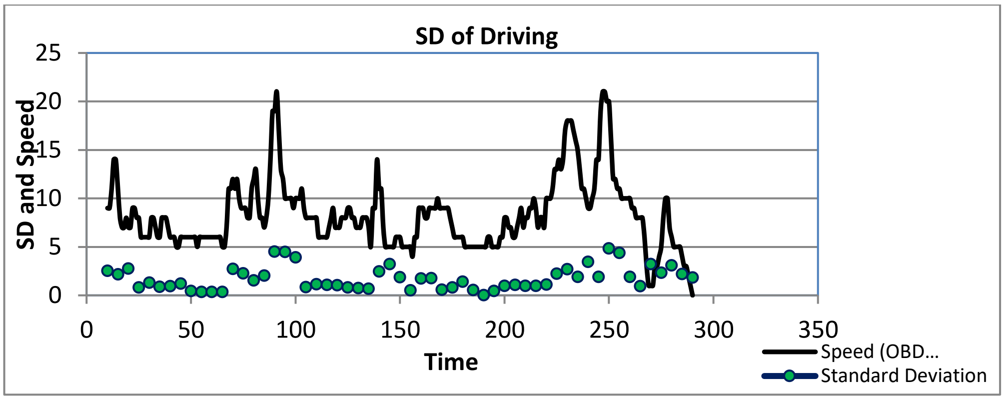

Figure 10. Driving speed and SD

To determine the G forces with angle of collision, we place the smart phone firmly on dashboard or any other place with properly calibrating the sensor data. We start out android program which will read the instantaneous accelerometer values along all the three axes. The OBD II speed is also being read in real time. The car was driven at low speed 24 km/hr on a road and keeping in mind the safety of the in and out vehicle people, instead of the real collision of the vehicle with another vehicle or any hard object, the device is manually impacted inside the lab with hard surface with high G-force to simulate the real event of collision to record data. The logged comma separated value (CSV) data file was created by the android application as shown in Table 3 where part of 12 sec journey time is extracted which is the relevant event in this work. This is a comma separated file where the first attribute is the running time in 1 sec interval, the second parameter is the actual device time, and G(x), G(y) and G(z) are the accelerations occurred along x-axis, y-axis and z-axis respectively.

Table 3. CSV logged data file

Time (Sec)	Device time	G(x)	G(y)	G(z)
1	11:40:59 AM	-0.41	0.14	9.85
2	11:41:00 AM	0.01	0.4	10.03
3	11:41:01 AM	-0.45	-0.36	9.93
4	11:41:02 AM	-0.35	0.43	9.93
5	11:41:03 AM	-0.01	0.33	10.08
6	11:41:04 AM	-0.1	-0.17	9.82
7	11:41:05 AM	36.7913	31.4171	10.37
8	11:41:06 AM	-0.35	0.2	10
9	11:41:07 AM	-0.6	-1.05	9.95
10	11:41:08 AM	-0.24	0.06	9.91
11	11:41:09 AM	-0.23	0.1	9.94
12	11:41:10 AM	-3.19	3.15	9.83

In the CSV logged data file at 7 sec, we can notice the maximum acceleration occurred along the x-axis and y-axis which eventually lead to a major accident with resultant G-force>4G. The calculation and the angles of the impact are calculated using different mentioned in this paper. In the Figure 11, the progress of device time is taken along x-axis and the acceleration is shown along the y-axis.

From the graph it can be seen that the impact of G-force 3.8 and 3.2 applied along x-axis and z-axis though there was a little noise in z-axis due to this collision. The values 36.7913, 31.4171, and 10.37 were recorded by the application for F_x, F_y and F_z respectively. So the total resultant G-Force will be calculated using (1). R=49.48 m/sec^2 which gives rise to about 5G Force with the following impact angle parameters α=41.96, β=50.58 and γ=80 and as the values of the F_x and F_y are all +ve means the impact is from front front-right side of the vehicle. Therefore, from analyzing the parameters, we can easily detect the impact amount and the side of the impact which will be used by the local authority for further decision in the accident.

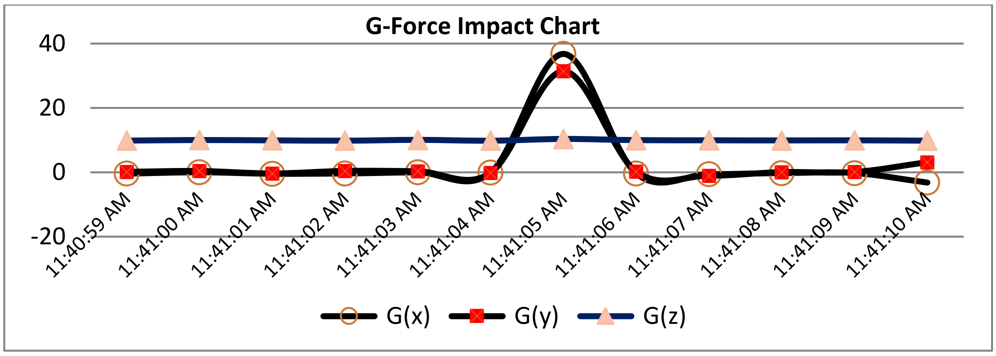

Figure 11. Real time collision data

5. CONCLUSION

As in almost all the cases the impact might be horizontal to the ground, therefore the G-force vector's magnitude along z-axis is fairly negligible and may be avoided as was seen in this experiment where for 5G force of accident, there was only a unit change in its acceleration value which is in turn less than 0.1 G-force. But an accident which leads to the roll of the vehicle or falling to a chasm or ditch, this parameter would play significant roll which may be considered for the future work. As there might be the case of non-deployment of airbag in some cases in an accident, so the airbag inflation sound cannot always be the criteria to detect impact. Hence the diagnostic error code generated in the engine control unit memory module should be immediately retrieved by OBD II and along with other details this deciphered error code should be made available to the local authority. And instead of using smart phone, one can use accelerometer sensor separately fixed it in the vehicle permanently which will avoid calibration of the device will give more accurate data.

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BIOGRAPHIES OF AUTHORS

Siddhanta Kumar Singh has 20 years of work experience in the area of software training in engineering colleges, university and multinational company in IT technologies in India and China. He works as an assistant professor in Mody University with B.E. (Computer Sc. and Engg.) and M.Tech.(Computer Sc. and Engg). He is also a research scholar and currently pursuing Ph.D. in Computer Science and Engineering. The areas of scientific interest are on board diagnostic, AI, IoT, study and analysis of obd data, diagnostic trouble codes, and driving behavior. He can be contacted at email: singhsiddhant@yahoo.com.

Dr. Ajay Kumar Singh is a Professor in the Department of Computer Science and Engineering and Coordinator of IQAC Cell at the School of Engineering and Technology, Mody University of Science and Technology, India. He holds bachelor and master’s and Ph.D in Computer Science and Engineering. He has more than 19 years of teaching, research, and industrial experience. He has guided 50 research projects at under graduate level, 9 atpost graduate level, and guiding 2 Ph.D scholar. His major research interests include Image analysis, pattern recognition, and machine learning. He has published 37 research papers and articles in national and international journals and conferences. He can be contacted at email: ajay.kr.singh07@gmail.com.