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A Novel IoT Based Gps Tracking System With Black box

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***Abstract*—**Road accidents have always been a major cause of mass fatalities all over the world specially in India, where the conditions of the roads and the whole traffic infrastructure in general are less than ideal, and collisions in roads tend to occur more often. The influx in road accidents over the past few years has led the researchers to analyze the cause of the accident. In this regard, a smart system integrating recorded information like velocity, acceleration, rotation, position of the vehicle can play a significant role in detecting the occurrence of the accident and can send prompt alerts to first responders. This study aims to introduce an approach with a 'Black box' module that serves two purposes simultaneously to reduce the number of accidents. The mentioned module equipped with different sensors can record important parameters of road as well as the overall condition of the road while simultaneously being capable of properly detecting the occurrence of a road collision. The 'Black Box' module can map and record the data of a certain road's condition which can be matched with the available accident data of that particular location saved on a database. Based onthe data, alert can be provided to the concerned for accident prone locations. In this way, the number of road conditions taking place each year can be reduced up to 80%.

Keywords—Sensor, Data Science, Big Data Analysis, Accident Detection, Road Surface Mapping, Driving Pattern Detection

I. INTRODUCTION

Road accidents or traffic collisions have always been a matter of concern all over the world. In India, between 1982 and 2000, the number of traffic accidents climbed by 43%, while the number of fatalities caused by these incidents increased by roughly 400% [1], making it a national issue. In the first five months of the year 2019 alone, at least 7,855 people got deceased and 13,330 people were injured in 5,516 traffic accidents across the country [2]. Apart from unprecedented losses of innocent lives, these frequent road accidents also take a toll on the economy of the country aswell. According to a statistic found on the "Together for Safer Roads" website [3], road accidents each year come at the hefty cost of 518 billion USD to the global economy. Traffic collision fatalities act as a massive hindrance in the way of sustainable development in middle income countries like India. In developing countries, the rate of mortality from these incidents is substantially higherthan in developed countries. Middle income countries like India tend to lose as much as 3% of the GDP each year die to road accidents [3]. According to *The Guardian* [4] India loses an estimated 1.2 billion pounds per year due to traffic collisions, which is equal to 2% of GDP and all of India's yearly foreign aid. The primary culprits behind the alarming rise in the frequency of traffic collisions can be stated as the poor and hazardous road conditions of the sub-urban areas where most of these accidents take place as well as the incompetency of the driver of the vehicle. The rash and incautious nature of vehicle drivers exemplified by impetuous driving, over- speeding, overloading, overtaking, infringing traffic laws, and consumption of illicit substances play a huge part.

Another very significant reason is the general lack of awareness among people when it comes to very basic and rudimentary traffic laws. These entire issues combined make for a scenario allows for the frequent occurrences of road accidents that take thousands of lives each year [5]. In countries like India, where most of these accidents take place in inter-city highways and narrower roads in sub-urban areas, the first response to the victims of such events have always been a big issue. It could be argued that the rate of fatalities would not be as high as it currently is if the casualties were dealt with proper and prompt response. According the "Golden Hour Principle" [6], people falling victim to road collisions stand a much higher chance of surviving if life saving measures are taken immediately inform of quality medical care. While immediate on-the-scene rescue and first-aid are imperative, the victims stand the best chance of survival if they are treated by the emergency service in the fastest possible time. As a result, the timely arrival of emergency services to the scene of the disaster is critical to the survivors' lives. Detection of road collisions as soon as they take place and sending an alert to the appropriate first responders for fast response to the scenecan go a long way to reduce the number of fatalities caused every year. Even though there has been vast research in this regard, an adequate solution is yet to be implemented, especially in developing countries where people often are subjected to driving vehicles that are not as technologically advanced as they are in the more developed countries.

Worldwide researchers are researching to improve the detection technique precisely and automatically in health care [7-12] as well as notify emergency services immediately to take actions. In this regards, ML [13-18] and AI [19-25] are utilized. The majority of practical solutions were explored for this literature review study, with an emphasis on software and hardware-based systems [26-31]. The strategies for detecting accidents that use various sensory inputs were given special attention. Iqbal et al [32] approaches the problem by creating a device module equipped with different sensors to detect the event of the accident and basic communication devices such as GSM module to send data such as the location of the event to first responders. In [33], the authors review various approaches and methods different researchers have resorted to in order to address the same issue. However, Chris et al. [34] developed Wreck Watch, a smart phone-based client/server program. The main drawback of this system is that it stops recording accelerometer values when the car is moving below the threshold speed which means in low-speed conditions, it is not very reliable in detecting collisions. Moreover, Sneha et al. suggested an E-call system that uses the built-in sensors in smartphones as a collision sensor in[35]. The main drawback of this arrangement was that even when the user is not actively driving the car, the E-call system is prone to high rates of false positives. Furthermore, Zhao et al. [36] have proposed a crash notification system based on mobile devices that detect accidents using accelerometer and GPS data. On the other hand, Patel et al. [37] created an Android application that identifies accidents using only accelerometer values. The accelerometer was also highlighted by Aloul et al. [38] as the primary sensor for detecting a traffic collision. This is accomplished byreceiving data from the accelerometer on a continual basis and analyzing it to assess the severity of an accident. The fundamental disadvantage of both of these arrangements is that they rely on a single sensor data, which opens the door to false reporting because no other information is available to confirm the existence of a suspected mishap. Zaldivar etal. [39] created a smartphone application that makes use of an on-board unit.

Faiz et al. [40] also presented a smartphone-based car accident detection and alert system. This is accomplished by utilizing the phone's pressure sensor. The GPS sensor is used to determine the vehicle's speed, and the accelerometer values are used to determine the vehicle's tilt. On the road condition monitoring front, notable work has been done by El-Hariri et al. [16] where anomalies such as speed bumps are detected by sensors, namely accelerometer and gyroscope, built within the smart phone itself. Ito et al. [17] developed a much advanced version of this called SODiCS (Spatial and temporal Omni directional sensor data Distribution and Collection System). Aside from detecting anomalies in roads that might cause traffic hazard, this particular arrangement also allows for interchanging information between drivers via a web-application. This particular system developed by Ghose et al. [18] closely resembles this project as it combines the road condition monitoring mechanism with a smart alert system with the aid of Internet of Things (IOT). In this particular arrangement, much emphasis is put on energy efficient transmission of data in form of road condition parameters asit involves phone-oriented-agnostic accelerometer analytics in smart phones that reduces the volume of data that needs be communicated between the phone and the back-end over Internet. It is to mention that most of the research done on this fields of a roughly limited to various detection techniques and efficient transmission of necessary data to the first responders.

This study intends to address the problem by developinga 'Blackbox' module that serves multiple objectives at the same time in order to reduce the number of accidents and casualties in the case of a road collision. Not only will the module be equipped with the necessary sensors (RTC, GPS Sensor, Digital Compass Sensor, Accelerometer Sensor and Gyroscope Sensor) and essential communication tools suchas GSM to efficiently spot a traffic collision and send data to first responders, the associated vehicle data recording system (VDRS) can record important parameters of the condition of the road as well. This module can record the condition of the road based on different parameters (hazardous condition can be exemplified by bumps and dangerous turns) and the recorded data will be compared with the data saved on a database to deduce the level of hazardousness. Based on this, an alert will be sent to the driver to govern the state of his driving accordingly. A successful implementation of such module in vehicles inday-to-day use can not only reduce the number of accidents taking place every day but also help bring down the number of fatalities and injuries caused by those accidents. Section II of the paper consists of methodology with a workflowdiagram. Hence, the results are portrayed in Section III. Lastly, the benefits, challenges and conclusion are shown in Section IV and V.

II. METHODOLOGY

In order to record the data, the Black box "module is composed of different analog-digital sensors and modules which work based on protocols such as UART, I2C and SPI.A GPS module is integrated in the system to record the geographical data such as latitude and longitude. Sensors that have been used in the module to collect necessary data include Accelerometer, Gyroscope, Magnetometer, Temperature-Humidity sensor and Vehicle ON/OFF detector. All these sensors have been interfaced with a Raspberry Pi ZERO (R-Pi Zero) board that acts as the heart of this system. Data that are recorded using these sensors include time and date, speed, 3-axis acceleration, 3-axis rotation, 3-axis compass, temperature, humidity, vehicle ON/OFF and event notifications information. Moreover, the system also contains wireless communication devices such as GSM, Wi-Fi and Bluetooth modules for seamless transmission of data for necessitating prompt first response in case of an accident. Table I contains necessary descriptions of the operating voltages, currents and communication protocols of the sensors that have been used and Table II depicts the features of the sensor modules.

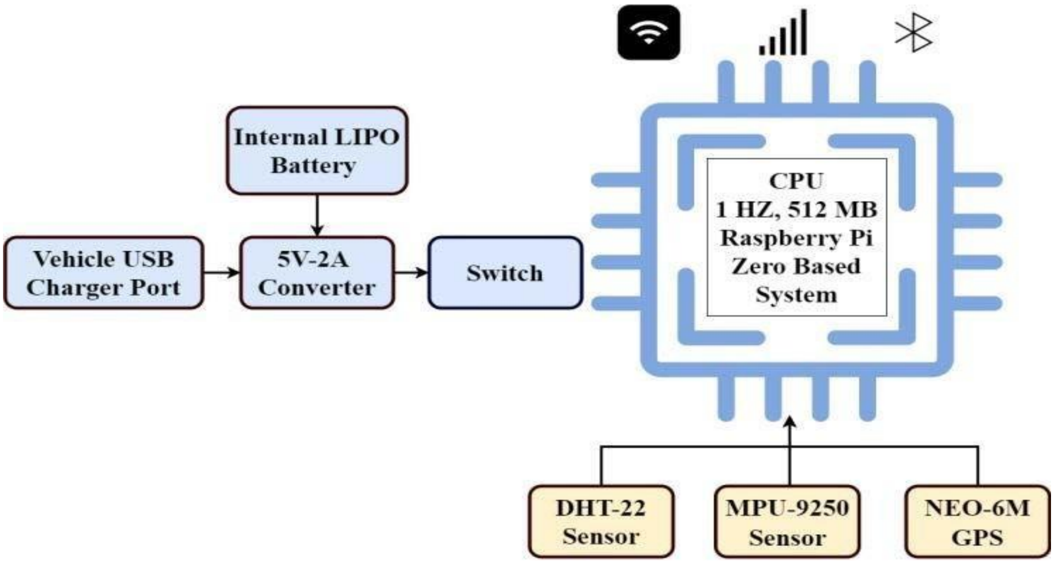

Fig.1. System Architecture

TABLE I. OPERATING VOLTAGES, CURRENT AND COMMUNICATION PROTOCOL OFSENSOR MODULES

SensorModule	**Operating**		**CommunicationProtocol**
	Voltage	**Current**	
NEO-6MGPS Module	3.3~5V	45mA	UART
MPU92509DOF IMUModule	3.3~5V	3.5mA	I2C
DHT22	3.3~5V	2.5mA	DigitalSingleBus

TABLEII. FEATURESOFSENSORMODULES

SensorModule	**Features**
NEO-6MGPS	Interface: NMEA, Receiver Type: 50 channels, GPSL1(1575.42Mhz), Navigation Update Rate: 1-5Hz,NavigationSensitivity:161dBm
MPU92509DOF IMU	User-programmable, gyroscoperangeof±250,±500, ±1000,and ±2000°/sec,accelerometerrangeof±2g, ±4g,±8g, and±16g,andamagnetometerrangeof ±4800µT.
DHT22	Measuringrange:humidity0-100%,RHTemperature: -40-125° Celsius, Accuracy: humidity ±2%,temperature±0.2°C,Sensingfrequency:~0.5Hz

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C. Tripper Performance from Acceleration, Rotation and Compass:

The 3-axis acceleration, rotation and compass data have been collected using the MPU-9250 (9DOF) MEMS Module in order to portray a trip quality. The acceleration value is in m/s^2 whereas; the rotation and compass value are in rad/s and T/s respectively. Moreover, the positive X axis data represents the forward acceleration and rotation. The positive Z axis data represents the upward acceleration and Processing unit that has been used in the study. Fig.1 demonstrates an overview of the whole system architecture

TABLEIII. SPECIFICATIONS OF THE PROCESSING UNIT (RASPBERRYPI-ZERO)

Specifications	**Values**
CPU	1-GHZ,BroadcomBCM2835
RAM	512 MB
OperatingVoltage	3.3V(Processor)
OperatingCurrent	~250mA
I/O	40GPIOPinswithUART, I2CandSPI
Wireless	802.11n/Bluetooth4.1/LE

A. Data Acquisition:

The Black box "module can efficiently collect motion and weather data using the above mentioned sensors. The system can also process the collected data and notify about various anomalous events such as over-speed, speed breaker, bumpy roads and hard breaks. The data collection frequency is about 15-22 Hz. Data collection process with the Raspberry Pi based system has been discussed.

B. Time, Position and Velocity:

The positional data containing latitude and longitude information has been collected by the NEO-6MGPS Module. This module provides information using the NMEA protocol which is further communicated as NMEA message strings. For the requirement of the system, GPRMC string has been collected from the NMEA message strings which indicate time, position and velocity. The sting has the following format:

*"$GPRMC,hhmmss:ss,Status,LatitudeN,LongitudeE,SOG,COG,ddmmyy,MV,MVE,Mode*CS<CR><LF>"*

From which using the location 1, 3, 4 and 7 of the string,the Time, Date, Latitude, Longitude and Speed over ground data has been collected respectively. The speed is later rotation. On the other hand, the negative axes for both X and Z represents exactly the opposite. Collected data then have been filtered by implementing a Kalman filter to reducenoise. Next, the collected data are used for road condition and vehicle driving pattern studies. Several test drives have been conducted across Dhaka and adjacent areas where speed breakers, bumpy roads and forced hard brakes had been in effect. Next, the collected data were analyzed and based on the mapping of the locations where the speed breakers, bumpy roads and forced hard brakes were in effect, several patterns were recognized. Based on the detected patterns different thresholds were set for X and Zaxis acceleration and rotation. Finally, after detecting such patterns and setting numerous thresholds, a trip quality graph was generated and posted on the web server.

D. Temperature and Humidity:

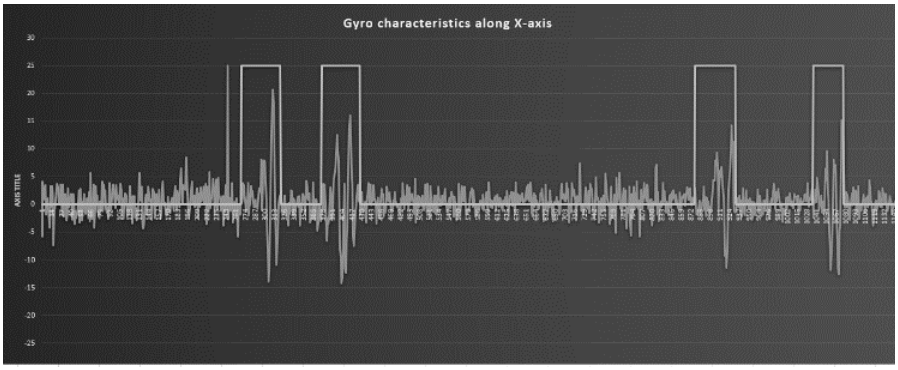
The DHT22 sensor has been used to collect the current location"s temperature and humidity data. The temperature at a is in degree Celsius, and the humidity is in percentage.

E. Vehicle ON/OFF Detector:

The Vehicle on/off detector was implemented using a USB wire connected to the vehicle's dash board power supply which is connected as input to the GPIO pins of theR-Pi Zero. As soon as the vehicle is powered up it detects event.

F. Data Logging:

A text file is generated containing all the sensor and moduledata. The document has header as follows: *"Time and date, AcclX, AcclY, AcclZ, GyroX, GyroY, GyroZ, MagX, MagY, MagZ, latitude, longitude, temp, hum, speed, speed_breaker, Vehicle_start"*. Moreover, a Json is also generated to post the data on the server. Data is logged into a cloud server using MQTT Protocol after each journey.



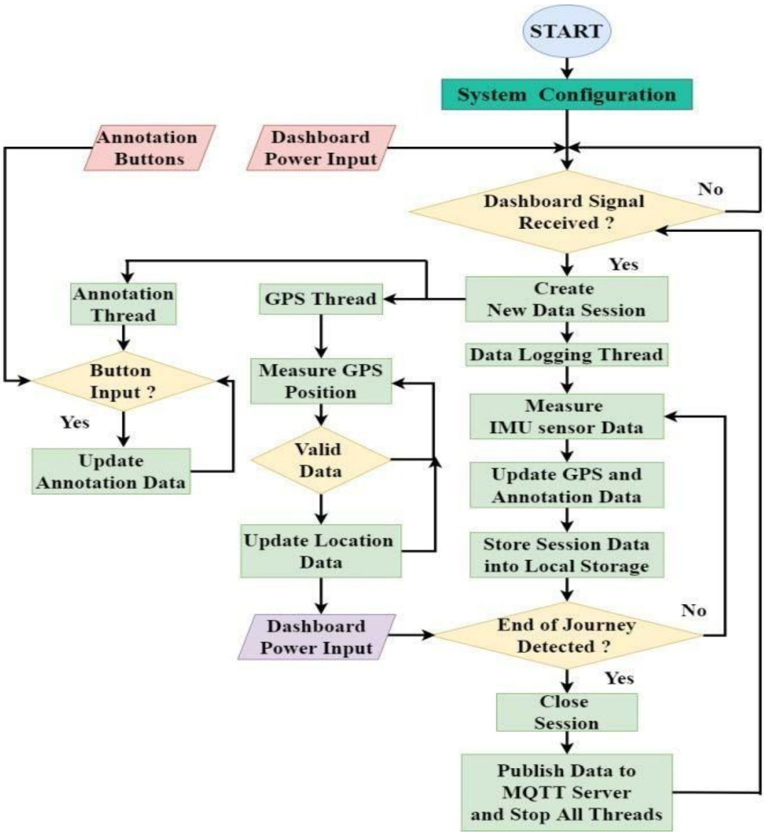


Fig.2.SystemOperationFlowchart

G. Connectivity:

The "Blackbox" is equipped with Bluetooth, Wi-fi and GSM connectivity as already mentioned. Bluetooth is used for device-to-device communication. Moreover, Wi-fi and GSM are used for internet connectivity.

H. Posting Data Online:

A web page has been created where separate boxes show the collected data in real-time. The web page will incorporate more demonstrative features such as graphs in the future.

I. Threading:

Separate threads were created to speed up the data acquisition process. Threading allows you to run more than one operation simultaneously. In our system, the GPS module, DHT22 temperature and humidity sensor and the Motion data collection device MPU-9250 were run on three separate threads so that each device could not disturb and slow up the data collection process. The data were synchronized with the time value. It is to be mentioned that the "Black box" module, in its current form is confined within an enclosure and is to be used as a separate entity to avail its functionalities. Fig. 2 provides an overview of the entire system operation.

III. RESULTS&DISCUSSION

The device collects GPS Coordinates, speed, acceleration in x, y, z axes, Gyro meter value along x, y and z axes and internal temperature and humidity inside vehicles at a rate of 15 samples per second.

Fig. 3. Time domain representation of gyro meter values along X-axis (back-front direction of the vehicle) with respective annotation for speed-breakers(the square waves in the graph).

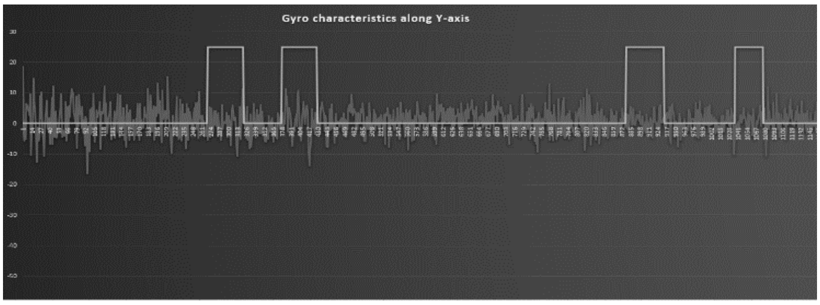


Fig. 4: Time domain representation of gyro meter values along Y-axis (left-right direction of the vehicle) with respective annotation for speed-breakers (the square waves in the graph).

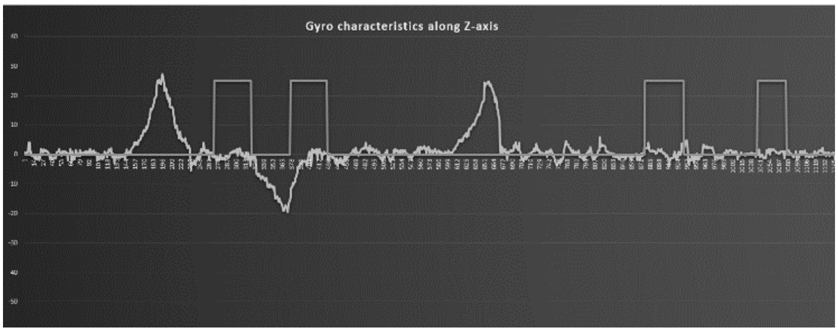


Fig. 5: Time domain representation of gyro meter values along Z-axis (axisvertical to the direction of vehicle movement) with respective annotation for speed-breakers (the square waves in the graph).

The collected dataset is plotted against time and checked for correlations with the annotation flags to determine patterns generated for specific events. It is found that the gyro meter value along the direction of vehicle movement show a certain deviation pattern when the speed breaker and pot holes are found. Fig. 3 to Fig. 5 gives a depictive show-casing of the collected gyro meter values in time domain. Visual inspection on the time domain graphical representation of gyro meter values confirms a potential correlation between acquired values along the direction of vehicle movement, and presence of speed breakers.

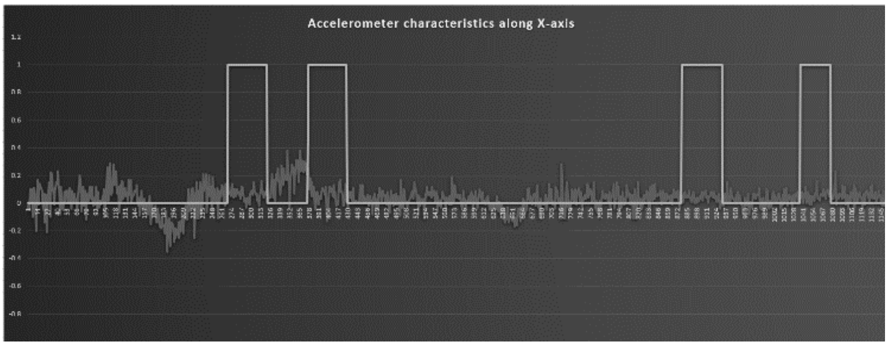


Fig. 6: Time domain representation of accelerometer values along X-axis (back-front direction of the vehicle) with respective annotation for speed-breakers(the square waves in the graph).

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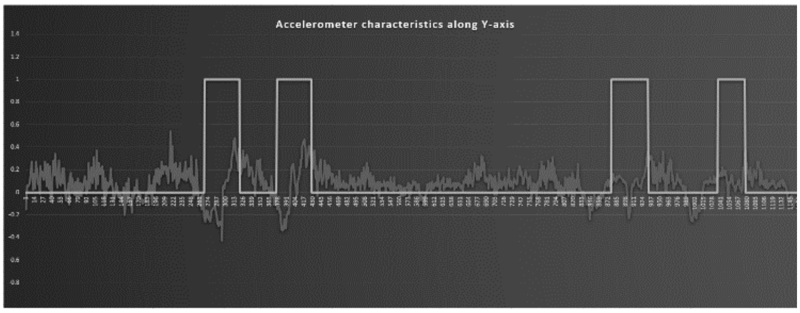

Fig. 7: Time domain representation of accelerometer values along Y-axis (left-right direction of the vehicle) with respective annotation for speed-breakers(the square waves in the graph).

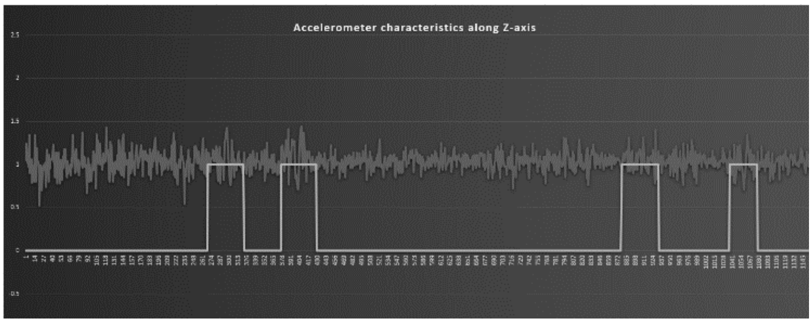

Fig. 8: Time domain representation of accelerometer values along Z-axis (axis vertical to the direction of vehicle movement) with respective annotation for speed-breakers (the square waves in the graph).

Gyro meter values alongside wise and vertical direction shows arbitrary characteristics regardless of presence or absence of bumpy conditions. Fig.6 to Fig.8 gives a depictive show-casing of the collected accelerometer values in time domain.

IV. BENEFITS, IMPACTS AND CHALLENGES

The live “Black box” project aims to contribute to acciGone plan of 80% less accidents within 5 years. Not only live “Black box” collects road surface and other vehicle data to reduce road accidents and improve journey quality and experience, in case of any unfortunate accidents, the device will allow the system to deploy fast responder teams for quickest rescue and medical support.

A. Better and Safe Journey Experience for the Drivers and Passengers:
- Early notifications on potential risky road conditions ahead
- Driving assistance alerts on speed limits, sharp turners, blind corners etc.
- Quickest support in case of any accidents

B. Insured and Economic Management for the Owners:
- Complete control over vehicle data.
- Driver behavior Monitoring and Driving.
- Performance Evaluation.
- Better acceptability for vehicle insurance.
- Predictive Maintenance Service [Based on vehicle usage and vital monitoring].
- Cargo security for fleet owners.
- Real Time vehicle information and location update

C. Benefits for Government and Private Organizations:
- Stored data can be used by police and forensics for post-accident analysis.

Generated road surface condition updates can help the government to monitor the country's road conditions and create and implement better road safety policy
The application of the live “Blackbox” device has thepotential to impact the overall road safety scenario.

V. CONCLUSION

The extent of work that has been done so far involves creating the “Black box” module and doing several test runson different streets inside the city to collect data for varying road conditions. The collected data provides a rough idea of the varying road conditions of different parts of the city. For example, usage of appropriate machine learning algorithms to train the collected data will go a long way for the research to reach its ultimate aim. Different appropriately chosen data science techniques must be implemented to come up with conclusive measures. Moreover, several test runs for more varying road conditions are to be carried out and a fully accessible database with an alert system is to be developed with the intent of aiding drivers around the country in the form of alerting them about hazardous road conditions. At its current stage the module can successfully detect accidents and send alerts to first responders in the fastest possible time. Moreover, while in operation, it can also read and record several vital parameters of the condition of a road.

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