Low Cost Black Box for Cars

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Automotive electronics plays a significant role in the automobile industry and provides luxurious features and more importantly addresses the safety and security concerns. The work presented in this paper aims at providing a cost effective solution to the design and development of an event data recorder which has been basically adopted from the aviation sector considering the need and the correlated benefits. The paper presents an integrated design of the black box with the basic features of the data recorder which could be very useful for domestic vehicles and at the same time it also hosts several additional features that could assist in mitigating the number of accidents, or at bare minimum, will serve as an analysis tool to prevent future accidents by analyzing the previous accidents. The black box also provides automatic accident notification system which helps in informing the nearest hospital and the traffic authority by providing not only the coordinates of the accident but also the exact physical address for immediate medical attention which can save numerous lives every day. The black box also hosts several other features like CAN compatibility, attractive user console and advanced web tracking anytime and from anywhere. Thus the overall cost is highly optimized by integrating such multiple features.

1. Introduction

Nowadays, automobiles have become an integral part of our daily lives. In India, the numbers of vehicles have grown exponentially, making people's lives easier and better. However, the number of road accidents have also kept in pace with this number. According to the WHO, India suffered from the highest number of road accidents in 2011, the death toll being 105,000. The Low Cost Black Box for cars presented in this paper is aimed primarily at reducing this huge number.

The Black Box comprises of the following important features –

- Accident detection
- Automatic accident notification
- Advanced web tracking
- Innovative event data recorder
- CAN compatibility
- Attractive user console
- Cost effective

Accident detection

The black box situated in the car is capable of detecting an impact with an obstacle and identify as accident. There are several parameters to categorize an impact as an accident, the designed black box utilizes Principle Direction of Force and Crash Delta Velocity as the primary criteria to categorize whether an event is accident or not.

Automatic Accident Notification System

Each minute that an injured victim in a crash does not receive emergency medical care makes a large difference in their survival rate – Analysis shows that reducing the accident response time by one minute correlates to a six percent difference in the number of lives saved. In order to reduce the time to notification and response, Automatic Accident Notification System (AANS) is incorporated in the black box. As soon as the Black Box detects an accident, the AANS immediately notifies the nearest Emergency Service Provide\r (ESP), thereby enabling the immediate dispatch of the medical and responsible personnel.

Advanced web tracking

The Black Box allows the owner of the vehicle to track his vehicle. An attractive user-friendly web interface, explicitly designed for the Black Box allows the user to login to his account and track his vehicle at any time and from anywhere. This provides an anti- theft mechanism.

Innovative event data recorder

Event Data Recorders serve as tools to objectively analyze the severity and the sequence of events that occur before and during the accident. The EDR onboard records relevant data before and during the crash, in order to enable the crash investigators to reconstruct the scenario seconds before the crash. The relevant data includes the time of the accident, acceleration, crash delta velocity, and principal direction of force (PDOF). Conventional data recorders store the data in a local storage device which is then extracted after an accident but it is very likely that the memory device might be damaged in the event of an accident thus destroying the data. To overcome this problem, the black box has been designed to upload the relevant data to a cloud storage in real time using GPRS protocols which is made possible by the GSM modem present in the system. This makes recovery of the data very easy and convenient.

CAN compatibility

Controller Area Network (CAN) is the most widely used protocol used in the automobile industry. The entire black box has been made flexible by incorporating CAN functionality. The central processing unit (CPU) of the black box is CAN compatible and hence any other CAN device, usually present in the automobile, can be easily integrated with this CPU. For instance the secondary processor LM3S2110 present in the black box is interfaced with CPU using CAN protocol.

Attractive user console & cost effective

The black box also provides an attractive front end to the user which provides a velocity display unit and an acceleration display unit. This avoids the need for any additional dashboard for speed etc. since they are already computed and displayed by the black box. Thus it reduces the overall cost by extracting multiple features by exploiting the same hardware. Hence the black box is cost effective.

Technical Background

General Motors (GM) introduced EDRs in select vehicle models in 1974, in order to control the airbag modules. The modules had limited storage capability and the data from the module could be downloaded only by the OEMs. The NHTSA sponsored Automated Collision Notification (ACN) system could detect and characterize crashes and then automatically send a data message to a Public Safety Answering Point (PSAP). The WreckWatch is a prototype smartphone – based client/server application which provides functionality similar to Event Data Recorder by recording the path, speed and forces of acceleration leading up to and during an accident. It can notify emergency responders of accidents and send pre-recorded text/audio messages to emergency contacts in the event of an accident.

The solution we propose is also based on Client – Server architecture. The Client is a dedicated electronic system on the vehicle which is equipped to send necessary information about the vehicle to the server, detect an accident, and report the characteristics of the accident to the server. Our implementation differs from the previous implementations in the following respect –

- Use of Google Maps JavaScript API v3 to provide a mapped location of the accident.
- Presence of a web – tracking interface to track the vehicle.
- Reliability – Use of a dedicated electronic system and an online Event Data Recorder (EDR) increases reliability of the crash data.
- Flexibility – Online Event Data Recorder eliminates the need of crash data retrieval systems, and makes download of the crash data easier.

2. Black Box Design

The top-level block diagram of the Black Box as shown in Fig.1 represents the primary functions of the Black Box: Event data recording and automatic accident detection and notification.

The 4 parameters that are being recorded by the Black Box are:

- Acceleration
- GPS coordinates
- Velocity value
- Time stamp

The CPU is receiving these parameters at regular intervals and these values are

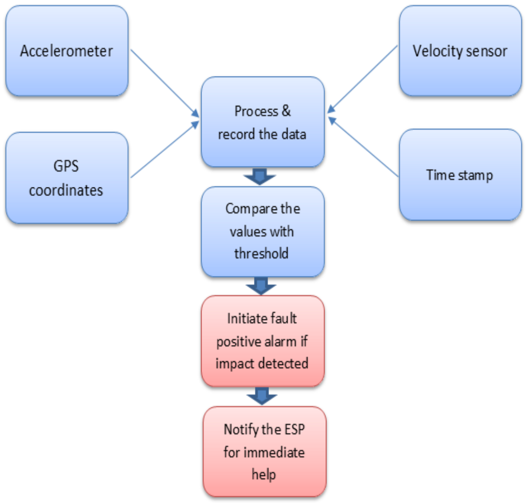

Fig.1 Top-level block diagram of Black Box

initially stored in the volatile memory of the CPU. It then combines a block of data together and uploads the data to the cloud storage via GPRS. Soon after receiving all the parameters, the CPU processes these values to check if an accident has occurred. According to the statistics and trials, thresholds are set for the parameters to detect an accident. Whenever the parameter exceeds the threshold, a fault positive alarm is set, which notifies the driver that the Black Box has detected a collision which has been classified as an accident. In cases where the driver is safe, and accident has not occurred, the driver is able to reset the alarm within 5 seconds of being set. In case an accident has actually occurred, the driver will not be able to reset the alarm and hence it is considered as a case of confirmed accident. This is done in order to eliminate the chances of false detection, which is indeed a rare scenario. Once the Black Box detects the collision as a confirmed accident, it immediately notifies the nearest ESP and seeks for help. This is done by sending the location of the crash site to the concerned authority via SMS. The SMS doesn't contain the GPS coordinates of the crash site but the exact address extracted using the GPS coordinates. This helps the officials to reach the place quickly.

3. Hardware Implementation

The Black Box has been divided into different sub systems, each dedicated for a set of processes. All these sub-systems are centrally coordinated by the CPU. The division of the system helps in providing dedicated hardware to each process and also reduces the processing load on the CPU. The entire architecture of the Black Box is shown in Fig.3

The Launchpad G2231 sub-system forms an entity to handle the acceleration detection and display, and also to detect the collision of the vehicle and transmit the interrupt signal to the CPU in case of an accident. Freescale MMA7260QT accelerometer provides the acceleration values, along the 3 axes, in analog domain.

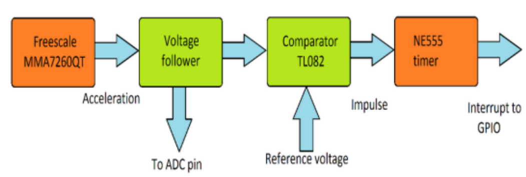

Fig.2 Acceleration pre-processing unit

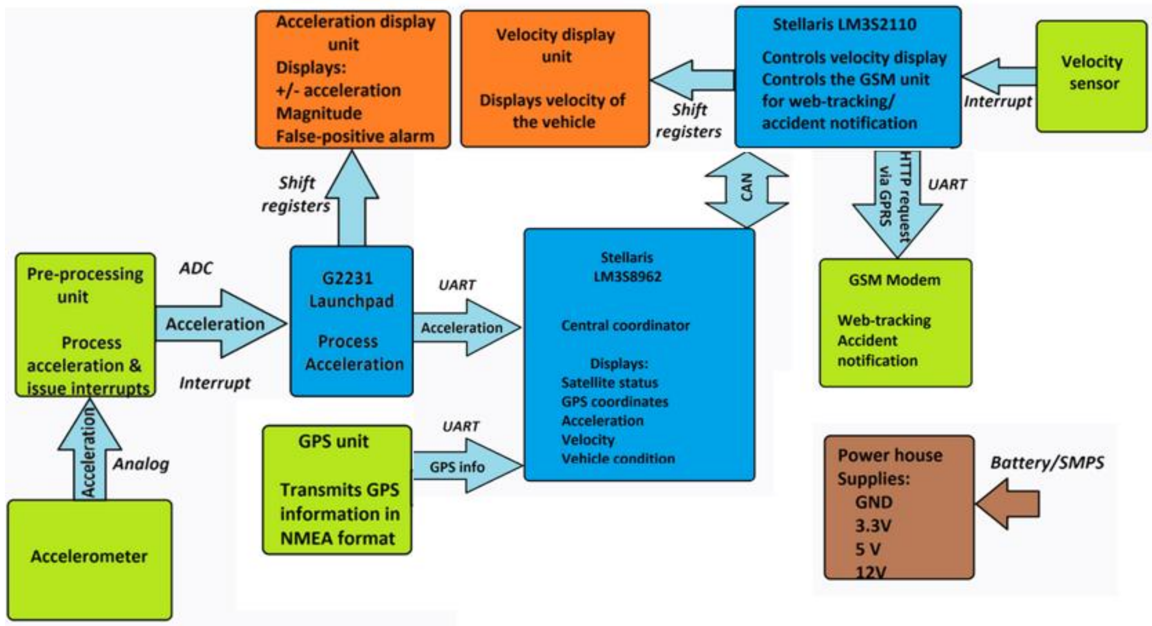

Fig. 3 Black Box architecture

As shown in Fig.2 the signal from the accelerometer is processed in the pre-processing unit so that G2231 can measure it using ADC. The signal is isolated using a voltage buffer as shown in Fig. The pre-processing unit also checks if the acceleration value crosses the reference voltage which is set as the threshold for accident detection. Whenever the value exceeds the threshold, an impulse is generated which triggers the NE555 timer, which in turn is connected to the interrupt pin of G2231 and an interrupt on this pin indicates that a probable accident has been detected. The G2231 is also connected to the acceleration display unit which provides a visual display of the acceleration value in real time. The display also has an indicator of false positive alarm which when set, alarms the driver that a probable accident has been detected. G2231 is connected to the Stellaris LM3S8962 (CPU) via UART and transmits the acceleration and accident status regularly.

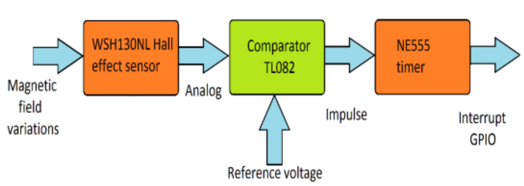

Fig. 4 Velocity sensor sub-system

The velocity of the vehicle is calculated and displayed by the Stellaris LM3S2110 using the velocity sensor sub-system shown in Fig. 4. The Hall Effect sensor WSH130NL measures the magnetic field variations around it created by the magnet mounted on the rim of the wheel. These variations in analog domain are compared with a reference voltage to create an impulse each time the magnetic pole passes the sensor. The impulse triggers the NE555 timer which in turn is connected to the interrupt pin of LM3S2110.

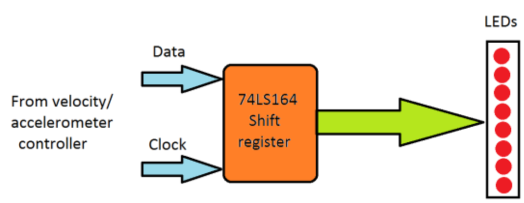

Fig. 5 LED display array

The LM3S2110 is also responsible for displaying the velocity via velocity display unit, as shown in Fig. 5, which is composed of LED array controlled via 74LS164 shift register which receives its Data and Clock inputs from the LM3S2110. Similar display sub-system is used in the acceleration display unit and it receives its inputs from G2231. The LM3S2110 is also solely responsible for controlling the GSM modem via UART. The GSM modem is used for accident notification, web tracking, and also to upload the data to the cloud server. The LM3S2110 is interfaced with the LM3S8962 via CAN and receives all the data that needs to be transmitted through the GSM modem.

The CC4000GPSEM GPS unit transmits the GPS data to the CPU. The data includes parameters such as latitude, longitude, time stamp etc. The data is in NMEA format and is transferred to the CPU via UART.

The Stellaris LM3S8962 (CPU) serves as a central coordinator of all activities and it is connected to multiple sub-systems via different protocols. It has an on-board display which displays all the essential parameters such as satellite status, satellite lock, latitude, longitude, acceleration, velocity and condition of the vehicle. Hence the Black Box can be visualized as conglomeration of several sub-systems each with an independent processor and corresponding protocol. The CAN compatibility of the system helps in future addition of other CAN compatible systems thus adding to the feature set.

4. Software Implementation

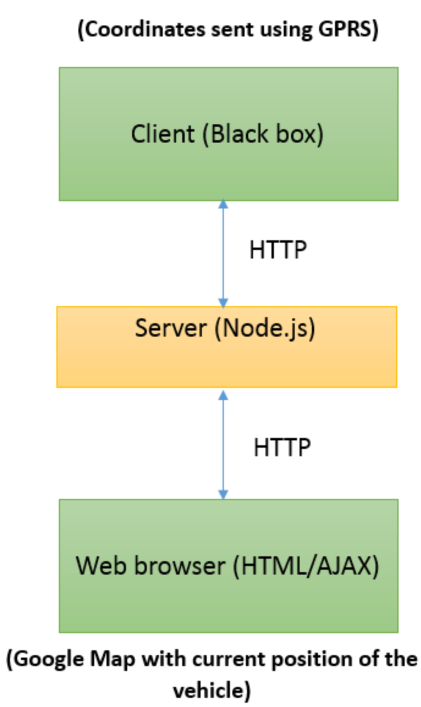

Fig. 6 Client-Server architecture of the Black Box

The software implementation of the Black Box mainly consists of a server. The server is developed using Server Side JavaScript/MongoDB database with node.js framework. The basic function of the server is to aggregate the data received from the vehicle over time, and act as communication channel to the Emergency Service Providers (ESP) such as the medical personnel, the police and the relatives. The server presents a web – tracking interface to enable tracking of the vehicle using Google Maps JavaScript API v3. It plays host to an online Event Data Recorder (EDR) which records essential information like acceleration, velocity and geographical coordinates of the vehicle. It also hosts an Automatic Accident Notification subsystem, which sends notifications in the form of an SMS to the intended recipients.

Web – tracking interface

The user interface for web – tracking is provided by means of Google Maps JavaScript API v3. It is made available over HTTP through a standard browser and is built with AJAX and HTML. When the geographical coordinates/ velocity/ acceleration of a vehicle with a valid VID (Vehicle ID) becomes available, the server stores it in the database. When a user logs into his account, a HTTP request for tracking is made. The geographical coordinates/ velocity/ acceleration of the vehicle corresponding to the user are fetched from the database, and a Google map with a marker overlaid at the center, indicating the position of the vehicle, is displayed to the user. The web – tracking interface supports dynamic updates of the geographical coordinates, velocity and acceleration of vehicle.

Online Event Data Recorder

The online Event Data Recorder performs the task of storing essential information about the vehicle over time. Since the vehicle (client) sends out data periodically, it becomes unfeasible to store data in a linear fashion. Moreover, in the event of an accident, information stored during last few seconds before the accident is significant. Therefore, when the geographical coordinates/velocity/acceleration of a vehicle with a valid VID (Vehicle ID) becomes available, the server stores it in the database in a circular fashion. For instance, in our implementation, we have 30 locations in a circular buffer to which the data can be written to. Therefore, the server can store 30 most recent values of geographical coordinates/ velocity/ acceleration of the vehicle.

Automatic Accident Notification subsystem

The AAN subsystem performs the task of sending out notifications to the intended recipients in the event of an accident.

When an accident occurs, the client reports an accident to the server. Certain characteristics of the accident such as - geographical coordinates of the vehicle, Crash Delta Velocity (CDV) and Principal Direction of Force (PDOF) etc. are also reported. The server first stores information related to the accident in the database. It then sends an HTTP request to the Google server to perform Reverse Geocoding on the reported geographical coordinates. The Google server returns data using custom JSON. The server injects this data into a JSON parser, and extracts the address corresponding to the geographical coordinates. It then sends an email which contains the address of the accident location to a SMS gateway using *emailjs* module in node.js. The SMS gateway sends the notification in the form of an SMS to the intended recipients, i.e. the medical personnel, the police and the relatives.

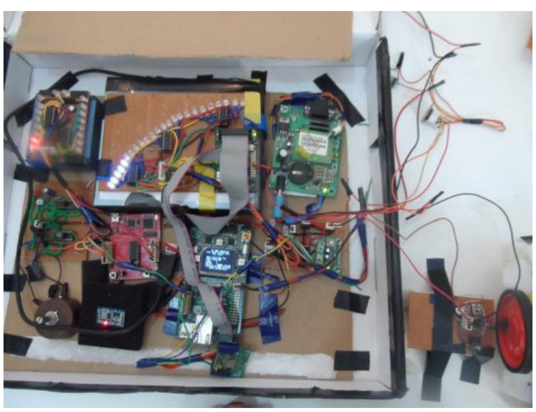

Fig. 7 Actual implementation

5. Results

Fig.7 shows the actual implementation of the Black Box discussed in this paper. For experimentation purpose the magnet is mounted on a toy wheel to simulate the

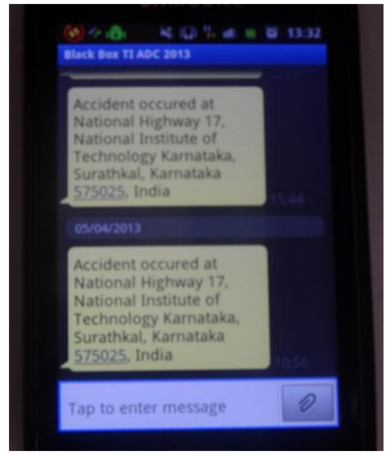

Fig. 8 SMS received by recipient

functioning of the velocity sensor sub-system. The velocity is updated and displayed on the velocity display unit. The accelerometer is present in the Black Box and any tilt in the Black Box is detected and displayed on the acceleration display unit. Tilting the Black Box beyond a certain angle causes the acceleration value to exceed the threshold thus setting the false positive alarm. The user can press the switch in order to reset the status, else the Black Box detects it as an accident and sends a message to the listed recipient as shown in Fig. 8.

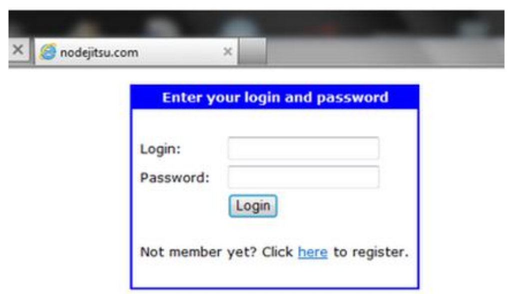

Fig. 9 Web interface for Black Box

The web interface explicitly created for the Black Box is shown in Fig. 9.The user can register the details of his vehicle and the list of recipients who are supposed to receive the SMS in case of an accident, after which he can login to his account and perform tasks like web-tracking from any part of the world, thus enabling him to keep an eye on his vehicle when he has lent it to someone. Fig. 10 shows the web tracking in action, the location of the vehicle is plotted on the map in real time.

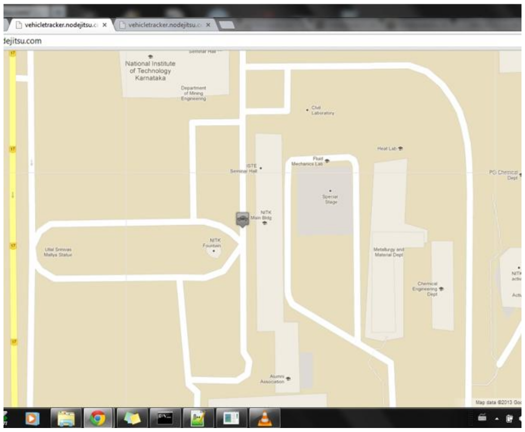

Fig. 10 Web tracking in real time

5. Conclusions

Introduction of the Black Box would be the best and cost-effective solution for automatic accident detection and notification, navigation, security, web-tracking and control of peripherals in all passenger vehicles. The black-box is expected to substantially reduce the road fatalities in all passenger vehicle occupant fatalities, due to reduced crash-to-Emergency Medical Service time. It has the greatest potential to prevent road fatalities in rural areas, given that the remoteness of the crash location leads to longer crash notification times in comparison to urban areas. Compatibility with the CAN devices provides an added feature to the Black Box since most of the devices in vehicles are CAN compatible. A cost effective Black Box has been designed and developed and the same has been presented in this paper. We hope that in the near day this work will help in making travel by car a better and safer experience.

6. References

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