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IQRAR: AN INTELLIGENT, QUICK AND RAPID ACCIDENT RESPONSE SYSTEM

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ABSTRACT

It is an open secret that deaths due to road accidents are growing exponentially. Every day the Police Control Room (PCR) receives many calls and all such seems to be actionable. On the contrary, the fact is that minor mishaps do not warrant the presence of the police, thereby causing loss of precious time and money and thus, we need to discriminate between accidents based on their impact sounds and level of damages done. This paper attempts to propose an automated accident response system fitted with advanced technologies comprising sensors, communication devices, GPS, GSM module etc. that would be fitted into the vehicle and would raise an alarm and/or alert the PCR immediately about the occurrence of a major road accident, so that necessary actions can be taken instantly and precious lives could be saved. Moreover, the system utilizes seven different Machine Learning-based classification techniques for predicting the situations leading to a major accident at the region of interest using different readings from sensors along with the combination of impact sounds. The best accuracy of 85.71% was obtained for Naive Bayes and Decision Table classifiers.

KEYWORDS

Audio Fingerprinting; Audio Cross-correlation, Peak Identification, Fingerprint Hashing, Machine Learning.

1. INTRODUCTION

As per The Global Status Report on Road Safety 2018, launched by World Health Organization (WHO) in December 2018, the number of annual road traffic deaths has reached 1.35 million. The escalating rate of fatalities caused by road accidents is a growing concern for us because road traffic injuries are becoming the leading killer of people who are aged between 5 to 29 years. In fact, WHO has estimated that the number of fatalities caused by road accidents for the year 2016 in India alone is 2,99,091 at the rate of 22.6 deaths per 1,00,000 population. Thus, it is quite alarming that if proper cognizance is not taken as soon as possible, then the world is going to observe an even more gloomy state of affairs due to the increasing road mishaps. Currently, the traditional way of informing the PCR about any road accident or dealing with it is neither foolproof nor reliable. Moreover, it becomes intractable to save the life of victims if the accident takes place very far away from town; especially in network-less areas, thus resulting in death due to excess bleeding.

This paper attempts to design a fully automated, quick and rapid accident response system to alert the nearest PCR van and ambulance. The proposed system senses the possible occurrence of the road accident through impact sound with the help of sensors attached to the vehicle, which will be immediately communicated to the concerned authority, so that further action can be taken without much delay and medical attention can be availed immediately, thereby saving a lot many lives.

The expected outcomes of this research work is to provide facility of a PCR van and/or an ambulance by raising a security alert and by sending

enough information to take some action before reaching the accident spot. IQRAR is a hybridized system where various events pass through two levels i.e. processing is done from hardware level to software level for better accuracy and a brief prediction report is generated which will help others to take action before reaching the target place. The most unique selling point of this system is that diagnosis is done at different scale, type and dimension to prevent any fault event generation.

The rest of the paper is organized as follows: Section 2 discusses about previous related works in the domain of accident detection and notification systems. Section 3 explains the terminologies associated in designing the proposed system at both the hardware-level and the software-level. Moreover, this section presents the architecture of the proposed system along with its working principle. Section 4 shows the system implementation using an indigenously created Kaggle dataset and self-built Audio Fingerprinting Generator. Different case studies and performance of various classifiers are also discussed in this section. The paper ends with conclusion and scope of improvements that can be taken up as future work.

2. PREVIOUS RELATED WORK

Many accident detection and notification systems have been proposed till now. Such systems are very expensive, complex and difficult to maintain. The details of some of the existing systems and/or approaches are discussed in this section.

Kattukkaran et al., 2017 have proposed a system to alert the nearby

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medical center about the accident for providing immediate medical support. The vehicle has an attached accelerometer which senses the tilt of the vehicle. Furthermore, there is a heartbeat sensor attached to the user's body that senses the abnormality of the heartbeat to comprehend the seriousness of the accident. Thus, the system will be able to make the decision and can send information to the smartphone, connected to the accelerometer and the heartbeat sensor, through Bluetooth. The Android application in the mobile phone will be able to send text message to the nearest medical center and friends. The disadvantage of such a system is that it is fully hardware monitored, so if the vehicle tilts with an abnormal angle and again goes to the stable state, the system will identify it as an accident as there is no other parameters for accident detection. Additionally, only vehicles with this installed system will be safe in case of any hazard.

Ali and Alwan, 2015 have discussed the fact that 90% of road-traffic accidents occur at low speed of the vehicle. So, rather than focusing only on the high speed accident detection, they have concentrated on accident detection when the car is running in low speed. For understanding whether the user is inside the vehicle or outside it, walking or slowly running, the authors have proposed a mechanism for distinguishing between the speed variations of a low speed vehicle and walking or slowly running person. The proposed system has been tested in a simulated environment and consists of two phases viz. detection phase (for detecting vehicle's speed during an accident) and notification phase (for sending detailed information such as video, images, accident location, etc. to the emergency responder for carrying out the recovery process asap). The loophole of such a system is that it fully concentrates on slow moving vehicles only and also for the purpose of speed detection, computer vision technique is used which will create a delay and is not feasible to implement in every vehicle due to higher costs.

The purpose of the work by Khan et al., 2018 is to reduce the response time of emergency services in situations like traffic accidents or other emergencies through the on-board sensors of a smartphone. The proposed system will be able to detect vehicular accidents and provide real-time location tracking to the nearest available emergency responder for providing immediate medical attention. This system is fully dependent on smartphone and if all the sensors of the smartphone do not give accurate and precise readings to the hardware monitor, the performance and accuracy of the overall system suffers.

The research proposed by Dar et al., 2019 combines the sophisticated features of smartphones and fog computing for developing an Emergency Response and Disaster Management System. An Android application is developed for detecting an accident using sensors fitted on the smartphone and the nearby hospital is located using the Global Positioning System (GPS) and a notification is sent to it. This system too depends on the ability of sensors attached with the smartphones.

Shaik et al., 2018 have proposed a system in which the accelerometer and the GPS sensor attached to the vehicle will send a signal to the cloud. On receiving this signal, an alert message will be received by the person who is subscribed to that car. The signal is meant to represent the severity of the road accident as well as the GPS location. The ambulance will then use the GPS coordinates for reaching the spot of accident as quickly as possible. This system needs a cloud service which will monitor vehicular traffic in real-time, thereby making it a cost ineffective solution.

Fogu et al., 2012 have presented an e-NOTIFY system that allows quick detection of road accidents and offers enhanced aid to the injured people by reducing the response time of availing emergency services. To do so, they have proposed an approach of utilizing a combination of V2V and V2I communications for efficiently transferring the information related to the accident. Their system necessitates installation of OBU in the vehicles meant for detecting accidents and for notifying them to an external CU; that will estimate the accident's extremity and subsequently inform the appropriate emergency services about it. This architecture aims to replace the existing mechanism for accident-related notification based on witnesses as they might provide incomplete or erroneous information after a long delay or time. The disadvantage of this system is similar to that discussed by Kattukkaran et al., 2017.

A customized Android application is developed in the research work by Bhatti et al., 2019 for gathering information such as speed, location, pressure, sound and gravitational force. Furthermore, a navigation system

is also developed for sending information about the incident to the nearest hospital. The proposed approach is validated through simulations and comparisons are drawn using the dataset of road accidents obtained from the Road Safety Open Repository. Similar to the research work by Khan et al., 2018 and Dar et al., 2019, this system's performance and efficiency too depends on the accuracy of the attached sensors.

On analysing the existing systems, it has been observed that systems based on sensors will work only when there is an abnormal movement or tilt of a vehicle, sometimes resulting in inaccurate or unpredictable results. Moreover, most of these systems need 24/7 network connectivity for sending the details after an accident has occurred. It might also happen that GPS may not be connected during an accident and thus, such systems fail to respond in time and the very purpose of their design and development goes in vain.

The IQRAR system proposed in this paper can monitor impact sounds. Sensor monitoring is done to ensure whether or not any road accident has occurred, leading to a precise and accurate accident detection system. Moreover, there is an override button in the front panel of the driver's seat through which any passing vehicle can also generate an alert for location hazard. Additionally, a new solution for locating vehicles that have met with an accident without GPS technology and/or without the aid of Google map has been proposed in this work.

2. PROPOSED METHODOLOGY

Through the proposed IQRAR System, an attempt has been made to overcome the limitations and constraints of systems currently existing in the market, along with achieving maximum efficiency. To do so, two levels of processing have been conceptualized viz. hardware-level and software-level. The hardware-level processing has higher priority in detecting and alarming about any road accident compared to the software-level counterpart. The discussion pertaining to these two levels follows in the next sub-section.

2.1 Hardware-Level

In this level, different sensors and modules have been used for the purpose of detecting and reporting the occurrence of any road mishap to the PCR and for immediate access to ambulance and necessary medical facilities. The hardware components used in the proposed system are as follows:

1. Accelerometer: It is used for detection of abnormal tilt and acceleration of the vehicle. If the inclination at a specific axis is abnormal, then the sensor monitoring phase will interrupt the hazard signal (see Fig. 1(a)).
2. GSM module: This module is used for communicating over SMS and reporting to PCR van and medical facilities. It is also useful for collecting network information like LAC, CID, MNC etc (see Fig. 1(b)).

Figure 1: (a) ADXL345 Accelerometer Module; (b) GSM Module

3. GPS module: Although it is optional in the proposed system, but this module gathers vehicle latitude, longitude and height at a specific moment. When any incident happens, one URL will be sent to the PCR and Health Care Unit for the identification of the incident location (see Fig. 2).

Figure 2: NEO GPS Module

2.2 Software-Level

In the software-level, two techniques have been used viz. Audio Fingerprinting and Audio Cross-correlation, which are discussed as follows.

1. Audio Fingerprinting: An audio fingerprint is also known as an acoustic fingerprint. It is a compact representation of any audio. It encodes information specific to the audio it represents. It is used for capturing the signature of any piece of audio so that it can be distinguished from other audio files. Generally, most audio fingerprinting technology obtains fingerprints from a time-frequency representation of audio, called a spectrogram. A spectrogram is a visual representation of the spectrum of frequencies of a signal as it varies with time. When applied to an audio signal, spectrograms are sometimes called sonographs, voiceprints, or voice-grams. When the data is represented in a 3D plot, they are referred to as waterfalls. The Spectrogram shows frequency information across the vertical axis. Lowest frequency content is displayed at the bottom, while the highest frequency content is displayed at the top. The amplitude of frequency content is indicated by variations of different colours in the Spectrogram. The colour map ruler (to the right of the frequency ruler) shows the colour being used to represent a given amplitude value (Chirp Webpage, 2018).

It is worth mentioning that a spectrogram is not considered very useful as an audio fingerprint in its raw form. This is because spectrograms comprise a lot of redundant information. Moreover, due to noise different spectrograms are created but their peaks are mostly intact.

2. Audio Cross-correlation: Cross-correlation is a measurement for tracking the relative movements of two sets of data or variables. To understand the term better, assume that there is an independent variable X and two dependent variables viz. Y and Z. When the independent variable X influences the dependent variable Y and if both these variables are positively correlated, then any upward change (or increase) in the value of X will result in the increase of Y's value as well. The same thing goes true in case of variables X and Z when they are positively correlated. So, it can be said that the dependent variables Y and Z are cross-correlated as their behaviour is positively correlated due to the relationships each of them maintain with the independent variable X. Cross correlation can also occur in case of sets and time series of data (see Fig. 3) (Kenton, 2018).

Figure 3: Correlation Metrics for Different Sounds

The cross-correlation returns a value from 0 to 1. When the value is 1, it means that the two audio files are same. For other values, it shows how much similar they are to each other. Here, different accident and hazard audio or sound files have been collected and a database of positive and negative impacts has been made. When the system starts running, it collects a 3 seconds of audio chunk and process it during runtime to find out the match in parallel threading environment. The audio fingerprinting is more precise than audio cross-correlation and so it has higher priority

in time detection. The discussion about how peaks are identified from a sound file and how fingerprint hashes are found is as follows.

1. Peak Identification: From a given spectrogram, search is done to find "peaks" in amplitude. A peak can be defined as a (time, frequency) pair equivalent to an amplitude value that is the greatest in a local "neighbourhood" around it. Other types of (time, frequency) pairs are lower in amplitude and their chances of surviving noise are very less. Finding peaks is a difficult problem and so spectrograms are generally considered as images and the image processing toolkit and techniques from SciPy (a well-known open-source Python library that contains modules for optimization, linear algebra, integration, interpolation, FFT, signal and image processing etc) are used for finding out peaks. A combination of a high pass filter; that accentuates high amplitudes and SciPy local maxima structures is normally used for peak identification (see Fig. 4).

Figure 4: Graph for showing the Peak Identification process

Once the noise-resistant peaks are extracted, different points of interest in a sound can be found to identify it. Thus, the two parameters viz. time and frequency are converted into discrete, integer values. This discretization could lead into resemblance and possible collision of peak pairs of different sounds and so, the fingerprint hashing method is used to generate a unique fingerprint value pertaining to each sound.

2. Fingerprint hashing: On observation of spectrogram peaks and by combining peak frequencies along with the time difference between them i.e. by gathering information from identified peak values (see Fig. 5), a hash that represents a unique fingerprint for the sound file is created (Drevo, 2013).

Hash (frequencies of peaks, time difference between peaks) = fingerprint hash value

Figure 5: Graph showing the Relative Information Gathering from identified peaks

2.3 System Architecture

The architecture of the proposed system is given in Figure 6. The audio fingerprinting contains a Knowledge Base (KB) of some accident or hazard sounds or audio files. If each of those sounds is passed through a spectrogram, then we can observe the time, frequency and peak at each points. We can then take different peaks with different time intervals as a

paired structure (peak, time) and create a collection of those for each of the sound file. Due to the noise, there can be many unpredictable and inaccurate matches and so to avoid it, we will send the data to a hash function to create a unique hash for each of the sound which is further saved by the system. This method is termed as audio fingerprinting.

In case of audio cross-correlation, each of the sound present in the Knowledge Base is matched with runtime sound chunk to get the correlation index. If the correlation value passes a specific threshold limit, then that will infer that some event has taken place i.e. road accident has occurred; otherwise not. When any incident of any road mishap occurs and if it is detected by at least one level (either hardware-level or software-level), then both the reports generated from the hardware and software levels will be sent to the Inference Engine which will ultimately generate a detailed report, thereby predicting the occurrence of the road accident. After the report generation phase, if any major road accident is found to occur, then an alert is sent to the Report Dispatcher which is situated in the hardware-level. The Report Dispatcher finally sends the report to the PCR Van and other medical facilities that is pre-specified in the dispatcher system.

Figure 6: Architectural Design of the Proposed IQRAR System

3. IMPLEMENTATION AND RESULTS

The proposed IQRAR system has been tested using seven different Machine Learning-based classifiers viz. AdaBoostM1, Bayes Net, Decision Table, J48, Multilayer Perceptron, Naive Bayes and Random Forest. Moreover, an indigenous Fingerprint Generator has been created where a dataset of different sounds need to be provided that will create a feature set which can be directly fed into any Machine Learning classifier. The feature sets have been extracted and the feature values have been fed into the Weka tool to generate different results for the various classifiers. The results so obtained has been summarized in the form of table (see Table 1) and a ROC curve which shows the most effective classification technique for the audio fingerprinting (see Fig. 7). The Fingerprint Generator software, tutorial and expanded results for each classifier can be found at Perity.site Webpage, 2019.

Table 1: Accuracy Scores of Different Classification Techniques	
Classifier	Accuracy (in %)
AdaBoostM1	80.95
Bayes Net	80.95
Decision Table	85.71
J48	71.43
Multilayer Perceptron	61.90
Naive Bayes	85.71
Random Forest	71.43

Figure 7: ROC Curve depicting the Performance Metrics of Different Classifiers

Naive Bayes and Decision Table classifiers are found to perform best with an accuracy score of 85.71% each followed by both AdaBoostM1 and Bayes Net classifiers with an accuracy score of 80.95% as the second best. Multilayer Perceptron classifier with a score of 61.90% offers the worst performance.

The following figure (see Fig. 8) shows the Fingerprint that is generated for an audio file. For bypassing the Google map and GPS, a dataset has been created in Kaggle (Das, 2019) which works depending upon mobile network connection for retrieving the latitude, longitude and other positional details like landmarks, roads etc.

Figure 8: Screenshot showing the Fingerprint of all audio files tested for audio classification

Figure 9 is collected from Wikipedia.org webpage, 2019 and it shows that there are only three navigation or Global Positional satellites which were detected by the GPS module. Due to the lack of the number of satellites, sometimes the existing systems that depend entirely on the GPS module for location details face higher delays.

TS	RNSS-1C	Navigation Data	Positioning	Altitude	Speed	Direction	Remarks
15	RNSS-1C	Navigation Data	Positioning	1425.4 kg (1.142 kg/m³)	1500 (1.142 kg/m³)	15 October 2011	RNSS-1C is the third satellite in the Indian Regional Navigation Satellite System (IRNSS)
16	RNSS-1F	Navigation Data	Positioning	1425.4 kg (1.142 kg/m³)	1500 (1.142 kg/m³)	10 March 2015	RNSS-1F is the sixth satellite in the Indian Regional Navigation Satellite System (IRNSS)
17	RNSS-1G	Navigation Data	Positioning	1425.4 kg (1.142 kg/m³)	1500 (1.142 kg/m³)	28 April 2015	RNSS-1G is the seventh and final satellite in the Indian Regional Navigation Satellite System (IRNSS)

Figure 9: Screenshot showing 3 Navigation Satellites detected by GPS Module

The proposed system depends on the Kaggle Dataset (Das, 2019) for fetching location of the accident spot and thus achieves to overcome the constraint of limited number of satellites. Figure 10 shows the screenshot of the webpage of the Kaggle India Location Dataset. This dataset contains four tables which can be related using different SQL queries to get the location of the user using LAC, MCC, and MNC. The four tables are as follows:

Tables: NODE_DATA, WAY_DATA, REL_DATA, CELOC

Figure 10: Screenshot of the webpage showing the dataset loaded in the Kaggle database

The Master Controller takes input from different services and sensors and compare the data to understand and analyze the type of the incident. The following examples will explain the working of the IQRAR system in details.

Example 1: One vehicle gets rammed into another vehicle.

In this case, the acceleration value will be suddenly changed. Also if the vehicle is tilted, then an abnormal measurement will be obtained through the Gyro sensor. At the software level, the software service will get a highly accurate impact sound (i.e. over the threshold limit) matched from its database. So, the master controller will send the following demo report:

Incident: Self Accident
Location: MAP URL with latitude and longitude
Timestamp: Time of the incident
Speed: Speed of the vehicle last recorded.

Example 2: One vehicle just passes through the spot where an accident had taken place.

In this case, the acceleration and the inclination value will not change suddenly. But the software service will get a highly accurate impact sound (i.e. over the threshold limit) matched from its database. So, the master controller will send the following demo report:

Incident: Accident
Location: MAP URL with latitude and longitude
Timestamp: Time of the incident

The following table (see Table 2) shows the different case scenarios pertaining to how any road accident is detected based on the status at hardware and software levels.

Table 2: Different Case Scenarios for Accident Occurrence Detection			
Events	Hardware-level	Software-level	Description
1	Yes	Yes	Accident occurred
2	Yes	No	Nothing happened as there is no impact sound., instead the hardware level 'Yes' is due to the temporary tilt of the vehicle which comes back to the normal state
3	No	Yes	Accident occurred but hardware could not detect it
4	No	No	Nothing happened

4. CONCLUSION AND FUTURE WORK

Through this paper, an Intelligent Quick and Rapid Accident Response (IQRAR) System has been developed that works at two levels viz. Hardware-level and Software-level to detect road accidents based on the impact sound when one vehicle gets rammed into another. This system sends automatic signals by sharing the location details of the accident spot through SMS to the nearest PCR and the hospital so that instant medical help is availed and to limit the casualties, traditionally caused due to delay in slower response. Thus, the proposed system can act as an efficient and fast communication system without the need of any human interference

for saving precious lives that have met with a dangerous and impactful road accident.

As only one sensor has been used for audio input and it is well-known that for detection of any road accident, at least 3 seconds recording of audio chunk is essential, so there might be a situation where the recording gets stopped at the 3rd second and during that moment due to re-initiation of audio, a time interval (delay) will occur. During this time interval, no audio is recorded and so if something happens or any road accident occurs further, then it could not be detected by the software-level. So to overcome this problem in future, a set of three sensors needs to be utilized for obtaining higher accuracy and better fault-tolerance.

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