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An Early Detection-Warning System to Identify Speed Breakers and Bumpy Roads using Sensors in Smartphones

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ABSTRACT

Speed breakers and bumpy roads are a major threat to drivers that questions their safety. The mishap happens because of no sign boards indicating the speed breaker, poor visibility at night and road works that are often carried out with no proper signs of road deviations and also the negligence of the driver. All these factors put the life of the persons in vain causing damage to the vehicle as well as life. Bumpy roads have become a problem for cars with less ground clearance. The focus of the paper is on designing an early warning system detecting both speed breakers and bad road conditions. The approach used in this paper is a real-time solution and is developed as an android service that runs in the background and relies on Google Maps application in the smartphone. This service will throw an alert giving early warning if the user is approaching the speed breaker or a bumpy road. Apart from just giving an early alert to the user, it also provides the user with an alternative and a better route. The solution proposed in this work is a form of crowdsourcing where users share and get data, therefore making the system cost effective.

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1. INTRODUCTION

Speed breakers are generally laid for the safety of the pedestrians in residential zones and school zones to control the speed limit of the vehicle, thereby avoiding accidents. But these days, many numbers of unauthorized speed breakers are laid unnecessarily, which do not follow the standard size proposed by National Highway Authorities. Speed breakers are common in developing countries like India, China, Pakistan, etc. because sign boards like “stop”, “yield” and “speed limit” etc. will not work due to lack of traffic enforcement resources. Though there is evidence that speed breakers reduce speed related accidents, there are also situations causing accidents and severe injuries. Driver negligence, the speed of the vehicle, low visibility at nights will result in crossing the speed breaker in greater velocity. There are few incidents reported [1], where motorcycles, scooters, and cars are vulnerable because unnoticed speed breakers may throw them off balance causing severe accidents and damages.

According to the Road Accident Report (2014) published by the Road Transport & Highways ministry, while 4,726 lives were lost in crashes due to humps, 6,672 people died in accidents caused due to potholes & speed breakers [2], this figure is not small and the numbers of deaths due to speed breakers are increasing every year. The statistics of the road accidents collected from the report are shown as a bar chart in Figure 1.

As part of this work, a general survey was conducted to opinions from different people. Many of them have complained that their vehicles are thrown off balance, especially when they are traveling in new routes and in the nights. For example, many have complained that Bangalore is one such city where night traveling is very tedious and dangerous as most of the speed breakers are very huge and there are no proper sign boards installed. Also, the current version of the Google maps will provide data about ongoing repairs on a road but, it will not provide any data about speed breakers and bad road conditions. This provides us an opportunity and motivation to develop a solution that will alert the user about the speed breakers, particularly when he is traveling on new routes.

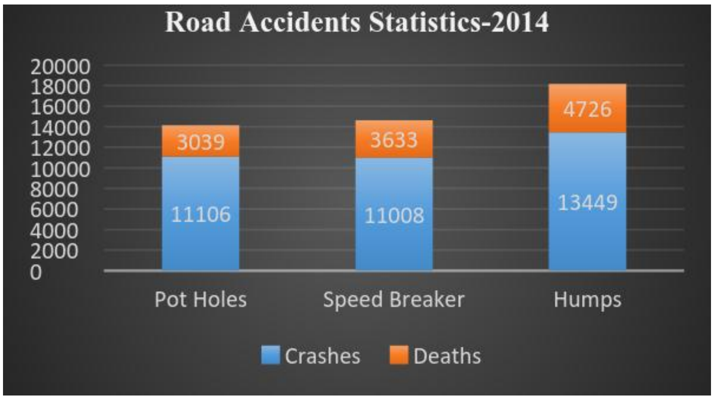

Figure 1. Statistics of Road Accidents-2014

The proposed solution will not make use of any additional hardware equipment rather it uses the data from the sensors like (Accelerometer, Gyro Sensor, Magnetometer etc.). In this Smartphone era, every person possesses a Smartphone that is GPS enabled and always connected to the internet. This enables us to develop an Android application that uses the data generated out of the existing sensors in the Smartphone to alert the user regarding bumps and bad roads. The challenge for this application is in populating data with the speed breaker locations. The same smartphone that takes the data from the server will also provide the data about new speed breakers and bumpy roads to the server, just like the concept of torrents: "if you want something, you need to share something". This paper gives a proof of concept that is being developed as an android service which will run relying on the Google maps application. The rest of this paper is organized as follows: related work in Section 2, proposed system and its architecture in section 3, implementation of the system with detection techniques, classification, datasets and results in section 4 and conclusion in section 5.

2. RELATED WORKS

Most of the existing systems use an additional hardware to detect the Speed breakers, most of which are expensive. Some of the existing approaches are discussed in this section.

Magnetometer and accelerometer are the two smartphone sensors used by the system proposed by Wolverine [3]. This method uses accelerometer sensor of a smartphone to collect the data for the monitoring of traffic and detecting the road bumps.The Magnetometer is used for the reorientation of the axes of the vehicle and device since the device may be placed inside the vehicle at any arbitrary orientation. This can be done in two stages. In the first stage, geometric axes and phone's axes should be aligned. In the second stage, the new device's axes are aligned with vehicle axes. GPS is used to locate the direction of motion of vehicles to find the angle of motion of the vehicle with magnetic north to transform the devices axes towards the vehicle axes. The data from the sensor is classified into two classes using K-means clustering algorithm and they are manually labeled as either smooth or bumpy and break or not. SVM is trained using this labeled data for classification of data points during test face for vehicle state prediction. For bump detection, this system produces 10% false negative rate and for the detection of breaking the system produces 21.6% false negative rate and 2.7% false positive rate. The main drawback of this system is it requires magnetometer for reorientation, but magnetometer is not present in all phones that are under use and increases the battery consumption.

Hull et al. [4] proposed a distributed mobile sensor computing system, which records the data collected by the sensors that are installed on the vehicle. The sensors like camera, GPS, Bluetooth and wifi are used for collecting data during a travel by the vehicle. The collected data is used only for route planning and to calculate the time taken to travel. This application does not detect any bad road or speed breaker during the travel.

P.Mohan et al., [5] proposed a system for detecting speed breakers and breaking events in which the potholes and speed breakers are not differentiated. Microsoft Research India developed Traffic Sense using Windows Mobile OS powered Smartphone as hardware/software platform with an array of accelerometer (sampling rate 310 Hz), and GPS. Their algorithms are based on the simple threshold approach *z-sus* (for speeds <25km/h) and *z-peak* (for speeds ≥ 25 km/h). They also used virtual re-orientation to adjust the orientation of the Smartphone during driving. The overall complexity and battery consumption is increased because of the requirement of GPS for reorientation. The reorientation complexity is avoided by using mobile phone crowdsourcing based pothole detection algorithm developed by J.Eriksson et al [6].

Mednis et al., [7] developed an android based OS system for Smartphone is having an accelerometer sensor for the detection of pothole in real time environment. The collection of data in the system is done for offline post processing and it detects the real time event.3-axis accelerometer sensor which is available in Smartphone is used to collect the data. For the detection of potholes in real time environment the first two algorithms (Z-THRESH and Z-DIFF) are used and the next two algorithms (STDEV (Z) and G-ZERO) are used for offline post processing of data. The analysis of tuple without the information about the position of z-axis is done by G-0 algorithm. This proposed system gives a true positive result of 90%.

R. Ramanathan et al., [8] proposed English font recognition system based on a support vector machine algorithm. In this approach the English text was taken as an image and it was classified based on already trained images of English fonts. Six frequently used English fonts are used for training and the SVM classification of those fonts provides the accuracy of 95%. The SVM classifier is used for classification of speed breaker with bad roads.

Singh et al., [9] proposed a mobile phone application that uses GPS, accelerometer and microphone to collect the data. This application detects road and traffic conditions along with driving behavior. This application is used to detect various events based upon the patterns observed. This application does not use machine learning. It is completely based upon the patterns obtained from the sensor data.

Researchers from University of Jyvaskyla [10] designed an offline data mining technique for pothole detection. They pre-processed raw data collected by accelerometer using band-pass filters, further they used the feature detection algorithms such as mean, peak-to peak ratio, standard deviation, root mean square, variance wavelet packet decomposition and power spectrum density. Further to reduce the features backward and forward selection and genetic algorithms were used. Although this approach shows a good performance in detecting the potholes but this is too complex to be implemented over small devices like Smartphone because of less processing power and small memory size.

3. PROPOSED ARCHITECTURE

The proposed system is an android service that starts in the background when the user is using the Google maps. The system fetches the details i.e. latitude and longitude data of all the speed breakers and bad roads within a radius of 20 kms from the current user position. Initially the database if empty, it is populated when different users are reporting about the speed breakers. The proposed system is designed in such a way that it doesn’t require any human intervention in reporting server about the speed breakers. When a user is coming across a speed breaker the sudden change in the amplitude of accelerometer data from the mobile is noted. This amplitude data along with lat-long data are sent to the server. As we cannot conclude on classifying speed breaker and bad roads from a single user which may result in false positives. When multiple users are reporting the approximately same amplitude data near the same lat-long positions, we build a trust value based on the number of users reporting the same kind of data. This enables us to populate the data in the server. Now, let’s examine the case where the user is travelling in a new route. When he starts the navigation on Google Maps, our application runs in the background, based on his current location, the system fetches the data from the server. This data is about the speed breakers and bad roads is fetched for every 20 kms. When the user is approaching a speed breaker the system will show him an alert on the screen as shown in Figure 10. This alert is shown approximately 200 meters before the car approaches the point, giving sufficient time for the car to slow down. If the user is approaching a bad road, an alert will be thrown before he approaches the road and an alternative route will be suggested. The whole system is depicted in Figure 2 and will be working in two phases as follows:

1. When the applications starts, the server pushes the data about the currently logged markers (both speed breaker and bad roads) and shows an alert when the user is approaching the marker. In case of a bad road it also suggests an alternate route.

2. If the car has encountered a new speed breaker or a bad road which is not yet marked in the database, application pushes that new data to the server. A trust value will be built when multiple users are reporting same data.

For a particular latitude and longitude value, many users may provide the information like it is speed breaker or a bad road. The trust value for a particular latitude and longitude value is calculated based on the number of users mention it as speed breaker/bad road. The attribute which is having the higher trust value decides whether it as speed breaker/bad road. In this application 50 users' suggestions are taken into account and based on the trust value it is classified as a speed breaker or a bad road. The trust value keeps changing when a new user reporting for a particular latitude and longitude value as a speed breaker/bad road. The classification of speed breaker and the bad road are made based on the changes in amplitude values of the accelerometer. The values of the peaks in the accelerometer graph are taken and those values are normalized based on the following normalization Equation x-mean(x)) * SD.

$$Normalized\ value = \left(x - mean(x)\right) * SD \quad (1)$$

From Equation 1, x denotes the set of amplitude values that are collected by crossing a speed breaker or a bad road. Mean denotes the average of the amplitude values for a particular speed breaker or a bad road. SD is the standard deviation that is observed from the amplitude values.

If the sum of all the normalized value for a particular latitude and longitude amplitude is zero, then it is classified as a bad road otherwise it is classified as a speed breaker. The system frequently updates the database with the current latitude and longitude values from the bad road and the speed breakers. In this approach the use of the magnetometer is not required since the application does not need the reorientation of the device axes with the vehicle axes. This overcomes the drawback of the method proposed by Wolverine for the detection of the speed breakers. This method classifies the speed breaker and bad roads, hence it outperforms all the available exiting systems.

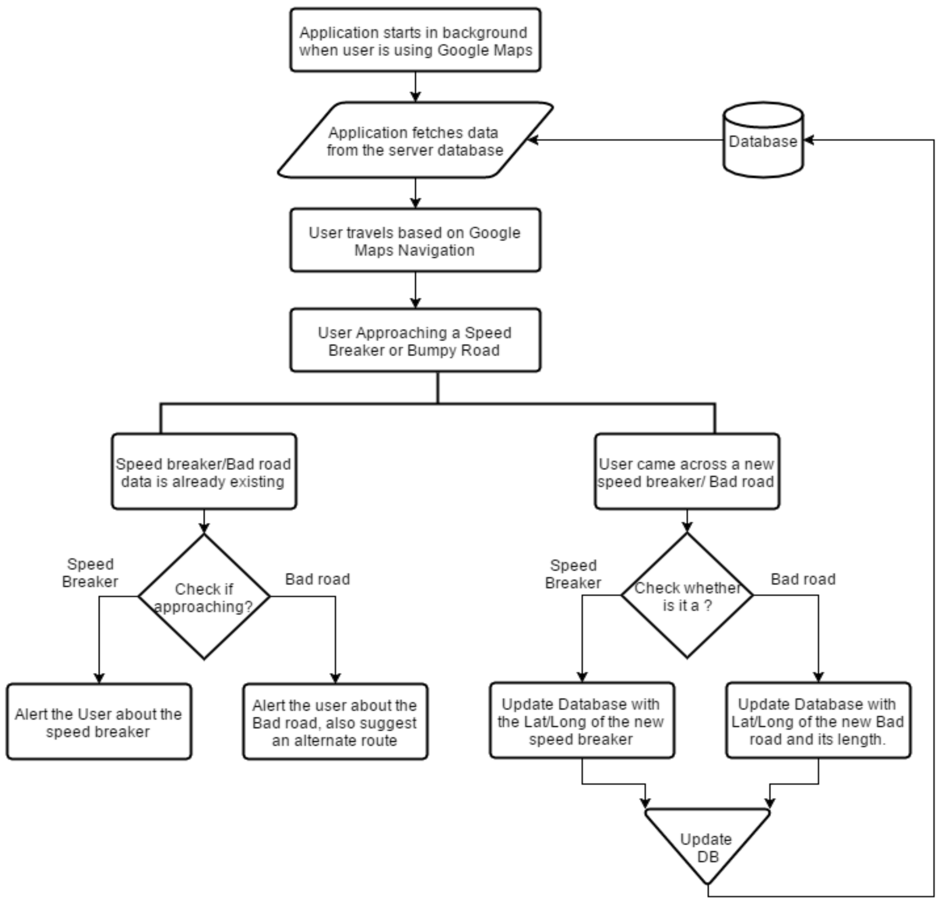

Figure 2. System Architecture

For classification support vector machines are used, since SVM is a simple classifier in machine learning algorithms and the accuracy of the SVM classifier is more for the numerical data set compared to other classifiers. The date used here for classification is a normalized numerical data and the classification is not based on the accurate values. To classify the data that falls near to the margin is classified as one class (speed breaker/bad road) and the values apart from the marginal are classified as another class (speed breaker/bad road). So far we have discussed how to log the data to the server, but we haven't described when we have to discard the data as it becomes invalid over a period of time. The proposed system will keep track of the last updates based on the timestamps, the marker that is having the oldest time stamp will be removed if the difference is more than 1 month for a speed breaker and 1 week for a bad road. It is assumed that the bad road conditions are due to the maintenance work that is carried out and it will not last long, whereas a speed breaker has a larger lifetime, changes to speedbreaker are done very rarely.

4. IMPLEMENTAION

To implement the proposed system a smart mobile handset with internet connection is used. The axes of Smartphone will not be aligned with the vehicles axes since the location [11] of the Smartphone may be in a pant pocket, wallet, dashboard and seat etc., The reorientation of axes is not required in this application for the proposed system concentrates only on the variations of the vehicle's Z axis. The application consists of four modules:

1. Data collection for speed breaker
3. Data collection for bad road condition
4. Dynamic detection of speed breaker and bumps
5. Notification and route recommendation

The developed mobile application works independently on any vehicle and on any Android device. Data collections for speed breaker and bad road condition module gathers data by an accelerometer and location related data are sent to the cloud [12] server where the probable location of speed breakers are identified. Nearby speed breakers are grouped within a single route and that information is fed into a database. When a vehicle travel in a particular route, the latitude and longitude values of speed breaker are recorded and send to the server database and the process is shown in Figure 3.

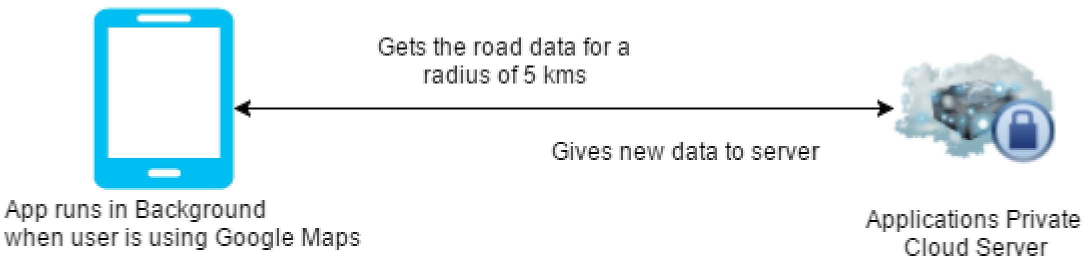

Figure3. Updating the server database with speed breaker and bumpy road information

When the application starts the dynamic detection of speed breaker and bumps module the list of speed breaker and the list of bad road condition for a particular route is loaded into the local device from the cloud database. Then, the vehicle's current location is compared with the speed breakers and bad road of the matching location from the local database.

When a vehicle travels in particular route, the location of all the speed breakers in the route and the bad road are summarized and notified to the user and also the other routes are recommended by the system with the minimum number of speed breaker and bad road than the current route that can be opted by the driver. When a vehicle is approaching a speed breaker and the speed breaker is found within 200 meter distance from the vehicle's current location and a warning message will be provided. The data for the 20KM radius around the current location of the vehicle is fed into the local device.

To detect speed breaker only the amplitude of the acceleration vector is sufficient. The amplitude consist of forces experienced along all the three axes, it already has the component of forces experienced along the z-axis of the vehicle, so that a detection of speed breaker from the time series of amplitude data is possible.

4.1. Detection Techniques

The application is started when the user is navigating using Google Maps. When the car is moving in normal road or a plain surface as shown in Figure 4, the amplitude of the accelerometer does not have much variation as shown in the Figure 5.

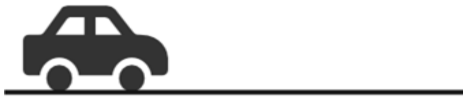

Figure 4. Car moving in a normal road

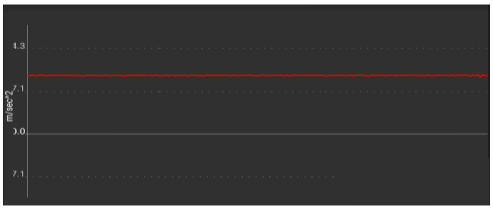

Figure 5. Accelerometer graph on normal road

When the car is approaching a speed breaker as shown in Figure 6, the amplitude of the accelerometer suddenly varies for the time period that is taken from the car to cross the speed breaker and the amplitude becomes normal when the car had crossed the speed breaker as shown in the Figure 7.

Figure 6. A car approaching a speed breaker

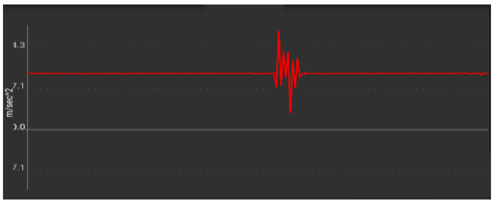

Figure 7. Accelerometer graph on speed breaker

When the car is approaching a bumpy or bad road as shown in Figure 8, the amplitude of the accelerometer varies till the car crosses the bad road as shown in Figure 9.

Figure 8. Car approaching a bumpy/bad road

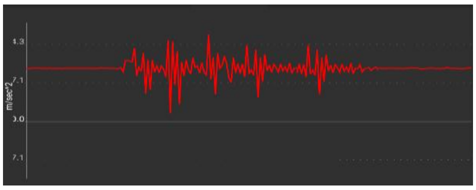

Figure 9. Accelerometer graph on bad roads

4.2. Classification

The data have been collected from different people on various roads in Coimbatore, Tamilnadu, India is using several types of vehicles like cars, bikes and auto rickshaws. For a particular drive based on the accelerometer data, the feature vector are labeled as a speed breaker or not a speed breaker or a bad road. The machine learning algorithm used for the classification is a Support Vector Machine (SVM) since it is a nonlinear, discriminating and no need to make an assumption of data parameters. Each feature was normalized by subtracting the mean and dividing by the standard deviation.

4.3. Datasets

The android application is developed to record the accelerometer data. The android device which is used to measure the accelerometer value is placed irrespective of arbitrarily orientation. Based on the occurrence of the sudden change in accelerometer data, it decides whether it is a speed breaker or a bad road. If it is a bad road, the latitude and longitude values are stored in the list of bad roads in the database. If it is a speed breaker the latitude and longitude value is updated in the speed breaker list.

The data were collected in several roads of Coimbatore, Tamilnadu, India and the total data set distance was 125 km. Vehicles like Car, Bikes, Auto Rickshaw were used for the data collection. The Android device is placed in front of the driver on the dashboard or sometimes in the driver's pocket.

4.4. Results

The results of the proposed system are shown in the below screenshots. Figure 10 shows the markers indicating the speed breakers with a blue marker and the bad roads using a purple marker. These markers get updated as and when the user is travelling. Figure 11 shows how the alert messages will appear in the foreground when the user is driving with maps.

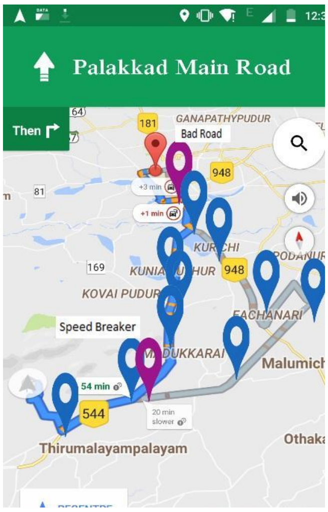

Figure 10. Screenshot of Map

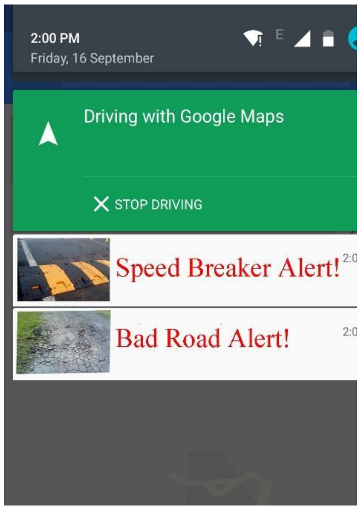

Figure 11. Screenshot of Alerts

5. CONCLUSION

This paper has proposed a proof of concept by developing an android service that acts as a background service to Google maps and collects data on the occurrence of speed breakers or bad roads. An alert is given to the vehicle drivers, which is more efficient in terms of response time. The recommendations of alternate route are given as an alert to the driver when he/she is approaching a bad road. The magnetometer is not required since the reorientation is avoided in this system. It is shown that the system outperforms the previous works and also works well when the smartphone is placed in four wheelers.

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