Real Time Detection of Speed Breakers and Warning System for on-road Drivers

Mahbuba Afrin, Md. Redowan Mahmud and Md. Abdur Razzaque
Green Networking Research Group, Department of Computer Science and Engineering
University of Dhaka, Dhaka - 1000, Bangladesh
Email: {m.afrin.ritu, md.redowan.mahmud}@gmail.com, razzaque@du.ac.bd

Abstract—The excessive use of speed breakers on national highways distracts vehicle drivers. In addition to that, drivers often can’t recognize the appearance of unmarked speed breakers and loose control of the vehicle, causing serious accidents and loss of lives. In the literature, there exist a few methods to warn on-road drivers about the upcoming speed breakers which are highly error-prone and time consuming. Moreover, none of them pay any heed to track the information of infringing speed breakers. In this paper, we come forward with a system that facilitates autonomous speed breaker data collection, dynamic speed breaker detection and warning generation for the on-road drivers. Our system also incorporates real-time tracking of driver, vehicle and timing information for speed breaker rule violations. The proposed system outperforms the state-of-the-art works with which it is compared to in terms of response time and accuracy.

I. INTRODUCTION

Road traffic accidents have been increasing dramatically worldwide, which have become the leading cause of death by injury and the tenth-leading cause of all deaths [1]. The Global status report on road safety 2013 indicates that worldwide the total number of road traffic deaths remains unacceptably high at 1.24 million per year [2].

Human error (e.g. user behavior, speed limit violation, driver fatigue etc.), faulty transportation and highway infrastructure defects (e.g. potholes, sharp bends, poor road conditions, etc.) are the three major factors that lead to traffic crashes and fatalities [3]. Driver-related factors include impaired, aggressive and distracted driving. A 5% increase in average speed leads to an approximately 10% increase in crashes that cause injuries and a 20% increase in fatal crashes [2]. Safe speed thresholds vary according to different types of road, different types of collision and road users, with their inherent vulnerability [2]. Motorists should drive within speed limits and with a speed consistent with road conditions. Speed breakers (speed humps, bumps, table, rumble strips) are traffic calming devices constructed to make an intention of slowing down or reducing speed of a vehicle as well as to improve safety for pedestrians [4].

Ignoring speed breaker on highway roads is one of the major causes for occurring road accidents. According to the Road Accident Report 2014 published by the road transport and highways ministry in India, while 4726 lives were lost in crashes due to humps, 6672 people died in accidents caused due to potholes and speed breakers [5]. Speed-breakers are unobtrusive due to low visibility conditions, like when there is snow, fog, rain or at night. Lack of warning system for the upcoming speed breakers on highways is one of the major causes for road accidents due to not controlling speed limit. Real time detection of speed breakers and warning system for on-road drivers in any kind of road condition can be a solution to lessen the road accident rate due to over speeding.

In the state-of-the-art, a very few number of research works have been done addressing this problem. In [6], a machine learning based detection of vehicle braking and road bumps has been proposed using accelerometer and magnetometer of mobile phones. A similar work is a smartphone based speed breaker early warning system using accelerometer [7]. However, smartphone accelerometers are not competent enough to track existence of speed breakers when the vehicle is running at high speed. Furthermore, the magnetometer is not present in all mobiles and [6] requires GPS for orientation, which increases overall complexity. Besides, running simultaneously the accelerometer and GPS devices in a smartphone is quite energy hungry and may produce erroneous results. Moreover, the need to store information regarding violation of alert system of speed breakers is not focused in the state of the art works.

In this paper, we bring forward a dynamic route based real time detection and warning system for imminent highway speed breakers. To collect the information about speed breaker, an autonomous data collection module has been developed where the iterative speed behavioral patterns of vehicles are analyzed and probable location for the speed breakers are identified. Here, speed breakers are clustered into routes according to their longitude and latitude values. Based on the collected data, speed breakers are detected and warning message is generated using Haversine distance formula. The system is designed in such a way, that extraneous database searching as well as access to cloud server each time is not mandatory. Moreover, as GPS provided by smartphones does not give the unerring result always and it quests for additional energy, a solution external GPS device is used for our proposed system which comes up with better performance. Therefore, the key contributions of this work can be summarized as follows:

- Development of an autonomous system for speed breaker data collection, analysis and route construction.
- A real-time and light-weight mechanism for detecting speed breakers ahead that is runnable as a Smartphone ap-
plication. The detection system is smart enough to handle multiple road-intersections, U-turns and can dynamically determine a new route and its speed breakers.

- Development of an accurate and time-efficient warning system so that the driver can control vehicle speed in advance of time. Notification to vehicle owner/manager is an added feature of the system in the case the driver violates a speed breaker warning.

- Finally, the proposed system works in adverse environments as well, e.g., night, foggy or rainy weather, etc.

The remaining of the paper is organized as follows. The Section II contains a study on the related work and Section III gives an explicit insight of our proposed system. The Section IV and V elaborate the prototype implementation and performance evaluation, respectively. Finally, the work is recapitulated in Section VI.

II. RELATED WORK

A machine learning technique to detect road anomalies and braking events from accelerometer and magnetometer data is proposed in [6]. The method requires magnetometer for reorientation but magnetometer is not present in all phones which is susceptible to magnetic interference and increases battery consumption as well. Another method for detecting speed bumps and braking events was also proposed in [8] which did not differentiate between potholes and speed-breakers. It requires GPS for reorientation, increasing overall complexity and battery consumption. To avoid reorientation complexity, mobile phone crowd-sourcing based pothole detection algorithm is developed in [9].

An early warning system that uses a smartphone based application to alert the driver in advance when the vehicle is approaching a speed breaker, is being developed in [7]. The application constantly monitors the smartphone accelerometer to detect previously unknown speed-breakers [7]. However, the authors did not describe in detail the methodology of warning system such as how to calculate distance between running vehicles and upcoming speed breakers. Their system depends only on accelerometer and built-in GPS sensor in smartphones. But sometimes the GPS service on smartphones takes a long time to get a fix in adverse environment and it does not always give the actual accuracy.

In our proposed system, an autonomous system is unfolded for speed breaker data collection, detection as well as to warn the vehicle-drivers and notify the owners which is efficient in terms of time and cost and requires less bandwidth as well as limited access to database.

III. PROPOSED SYSTEM MODEL

Our proposed system is comprised of three inter-dependent modules; Autonomous Data Collection of Speed Breaker, Dynamic Detection of Speed Breaker, Warning Generation and Notification as shown in Figure 1. Moreover, here we assume that each vehicle is provided with a GPS tracker and enabled with such functionality that helps to communicate with a cloud server through Internet and to execute small scale computation.

A. Autonomous Data Collection of Speed Breaker

To collect the information about speed breaker location, some volunteer vehicles are configured with speed breaker data collection module. In general it is seen that just before passing a speed breaker drivers slow down the speed of their vehicles and as soon as they pass the speed breaker, they increase the speed as shown in Fig. 2. Taking cognizance of the fact, this module gathers a volunteer vehicle’s speed behavioral pattern against location and sends it to the cloud server. In cloud server all volunteer vehicles speed behavioral pattern are analyzed and probable location for speed breaker are identified where vehicles satisfy the breaker speed threshold. To perform this operation, cloud server conducts analysis of variance (ANOVA) on the provided speed behavioral pattern [10] and breaker speed threshold is set by system administrator. As similar characteristic may be shown by the vehicles in other cases, this procedure is highly suspected to create false positive problems. Data collection through several iterative runs on different times of a day can make this procedure trustworthy.

![Volunteer vehicle’s speed behavioral pattern](image)

However, after identifying the probable location, the speed breakers are clustered according to the changing rate of their
longitudes and latitudes. If between two speedbreakers their longitude and latitude values are changed in a linear order, they are assumed to be within the same route. Each route is marked with the location of two endpoints. All routes and their related speedbreaker location information are then fed into a cloud storage for further use.

B. Dynamic Detection of Speed Breaker

Dynamic Speed Breaker detection module enables a vehicle to detect speed breakers dynamically based on the data provided by the volunteer vehicles. This module directly communicates with the cloud storage that contains the route wise location related information of speed breakers. As soon as this module commences, it starts to find out the nearest route from the vehicle’s current location using equation 1. The relevant notations and definitions for this module are listed in Table I.

\[
\min \sum_{i=1}^{n} d_i
\]

Here, \(d_i\) refers to the Haversine distance between \(i^{th}\) route and vehicles current location. Haversine distance can be formulated as follows [11],

\[
a = \sin^2\left(\frac{\Delta \phi}{2}\right) + \cos \phi_1 \times \cos \phi_2 \times \sin^2\left(\frac{\Delta \lambda}{2}\right)
\]

\[
c = 2 \times \arctan2(\sqrt{a}, \sqrt{1 - a})
\]

\[d = R \times c
\]

Determining the probable route, this module loads the corresponding list of the speed breakers to the database of vehicle’s local computational unit in a suitable order. It then begins to calculate the Haversine distance between the current vehicle’s location and the speed breakers. If the distance of the vehicle from a speed breaker becomes smaller than a threshold value, Warning and Notification module will generate a warning message.

However, when a vehicle is in a particular route, it is surely approaching towards one of the route end points or towards the next speed breaker. If it is not so, the vehicle is assumed to be getting out from the route. In this case, the module destroys the local database and initiates the search for the next nearby route. Moreover, it might happen that, the vehicle enters into a route whose corresponding speed breaker information is not available. In this scenario, the vehicles will act like volunteer vehicles and contribute to collect speed breaker related data through speed breaker data collection module.

C. Warning Generation and Notification

This module is responsible for alarming the on-road vehicle drivers about the forthcoming speed breaker. For each speed breaker, a voice recorded alarm will be generated as warning message which is played for two times so that the drivers do not get irritated with the continuous alarm while driving. Moreover, it is expected that while passing a speed breaker, vehicles speed should be slowed down. If any driver does not obey this, a notification will be sent to the vehicle owner with proper information. This information might contain the speed comparison of the vehicle just before and after passing the speed breaker.

IV. Prototype Implementation

In order to implement the proposed system, we have considered a smart mobile handset as the vehicle’s local computational unit with internet connection. A Garmin GLO Bluetooth GPS is used [12] which is wirelessly paired with the mobile device and provides location and speed related data. These data are more accurate compared to the mobile device GPS given data. Moreover, a mobile application is developed that combines all the three aforementioned modules along with a Java Web Application and JDBC on Google Cloud Platform to perform cloud assisted computations. This developed mobile application is vehicle and device(android) independent.

However, for Speed Breaker Data Collection the mobile application gathers mobile device’s accelerometer and Garmin GLO provided speed and location related data and sent to cloud server where the speed behavioral pattern of vehicles are analyzed and probable location of speed breakers are identified. Besides, here the nearby speed breakers are clustered within a single routes and corresponding information are feed into database. Table II and III partially represent our collected route and speed breaker related data respectively.
When the application is configured with Dynamic Speed Breaker Detection module, the route wise speed breaker list is loaded into local mobile device from the centralized cloud database. Then, the Garmin provided vehicle’s current location is compared with the routes and speed breakers location from the local database following the method mentioned in section III.

If the next speed breakers is found within 100m distance from the vehicle’s current location a audio warning message will be played. Moreover, if the driver disobeys the rules regarding speed breaker a notification will be sent to the owner account hosted in the cloud server along with the speed related data of the vehicle. Thus it performs the functionality of Warning and Notification module.

V. PERFORMANCE EVALUATION

To evaluate the performance of our proposed system we have voluntarily collected location of 100 speed breakers under 35 different routes of Dhaka, Bangladesh. Among them only 3% of data gave false positive. And almost no error has been recorded to detect those speed breakers and to generate warning message and notification. Besides, a significant improvement in response time is observed when the nearby speed breakers are assumed to be in lied a single route and instead of distant cloud storage, local route and speed breaker database is taken into account. Figure 3 demonstrates the response time for varying number of speed breakers in both route and non-route wise clusterization of speed breakers. Figure 4 depicts the comparison between local and cloud storage searching for speed breakers in terms of response time. In both cases our proposed concept outperforms the remaining. Compared to mobile device GPS, the use of external GPS gives better accuracy (approximately 15% improvement).

VI. CONCLUSION

This paper develops a system that can dynamically collect, detect and generate warning for upcoming speed breaker to the on-road vehicle drivers which is more efficient in terms of response time as well as bandwidth usage. We plan to bring forth more competent system in future to overcome the false positive condition in identification of speed breaker to ensure better quality of service.

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