Pothole Detection Using Smartphone

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Abstract

In India, road transportation has dominated over all the other means of transportation. Due to the increasing demand for road transportation and service the roads are flooded with traffic. One of the major problems the roads are facing is worsened road conditions. Here we propose a system of 'Pothole detection System' which assists the driver in avoiding potholes on the roads. Our motivation is to create an Android Application that detects potholes automatically using mobile sensors such as gyroscope and accelerometer. Quality of the road is analyzed using Accelerometer and Gyroscope, the SVM algorithm is used for training the pothole data then the location of the detected pothole is stored on the cloud. Our system displays the perfection of 97.04%. Unexpected barriers on the road may cause more accidents so we provide feedback to the car driver and also to authorities which will help manage the road.

Keywords: Pothole Detection, Machine Learning, SVM, Heroku, Accelerometer, Gyroscope, Android.

I. INTRODUCTION

India one of the fastest developing countries today. Although India is doing unusually well in fields like education, industrialization, and fashion there are still certain areas where the country is lagging behind. India's road network is gigantic and said to be the second largest network road network. One of the striking fundamental facts is the condition of the roads. Since roads indirectly contribute to the growth of the country it is extremely essential that the roads are strong and well laid out. India is home to several bad roads let it be the metropolitans, the cities or the villages. Bad road conditions are nothing new to India and the problem is being addressed since the last 30 years [1]. Since India is a developing nation there is a constant demand for good quality infrastructure. But since India is a huge country with quite a sizable population this problem still has not been addressed in totality. Road conditions are making it difficult to drive upon which is leading to accidents causing fatal injuries and deaths.

This paper introduces a road condition monitoring framework which is based on accelerometer, gyroscope, and GPS built in smartphones to give us the quality of road using machine learning techniques. The paper can be summarized as follows:

- First, we use the SVM machine-learning algorithm to classify road segment as compared to previous works that use simple thresholds. Our tests show that our system is able to detect and classify events related to road conditions with an accuracy of 97.04%.
- Our proposed system, unlike existing systems that need external hardware, is an inexpensive simple and efficient solution that is able to monitor road quality. It is realized on Android smartphones which are highly portable and easy to maintain. Our application provides proper feedback to drivers and local authorities by plotting the evaluated road location on a Map and saving all the data on the cloud.
- Through Android application, it is possible to collect real-time and automatic accelerometer and gyroscope data and analysis it in order to get road surface labels as compared to previous works that mostly use offline methods (videos, images for data labeling).
- While most of the previous works only work with accelerometer data, we are using a gyroscope sensor along with the accelerometer sensor to derive more accurate road quality prediction.

II. LITERATURE SURVEY

With the increase in the world's population, there has been an increasing load on the infrastructure and. transport. Roads have been flooded with the vehicular traffic. It has become increasingly difficult to manage this traffic. This is the prime motivation behind making a vehicle intelligent enough to aid the driver in various aspects. One of the increasing problems the roads are facing is exacerbated road conditions. Because of many reasons like rains, oil spills, road accidents or inevitable wear and tear make the road difficult to drive upon. Unexpected hurdles on the road may cause more accidents. Also because of the bad road conditions, the fuel consumption of the vehicle increases; causing wastage of fuel. Because of these reasons, it is very important to get information about such bad road conditions. Collection of this information and distribution to other vehicles is necessary, which in turn can warn the driver. But there are various challenges involved in this. Various challenges involved in this first characterize the pothole telling how severe it is second data gets collected from various vehicles then Data representation should be in such a way that potholes information is understandable easy to work with last Analysis of other aspects involved detection like speed, roads banks, incline angles, etc.

Several efforts have been made for developing a method which can automatically detect and recognize potholes. Detailed surveys on methods for pothole detection can be found in "RoadSense: Smartphone Application to Estimate Road Conditions using Accelerometer and Gyroscope" by AzzaAllouch, Anis Koubaa, Tarek Abbes, and Adel Ammar [3] a real-time Android Application RoadSense that automatically predicts the quality of the road based on tri-axial accelerometer and gyroscope, show the road location trace on a geographic map using GPS and save all recorded workout entries. SVM is applied to training data to classify road segments and to build our model. J. Eriksson, L. Girod, B. Hull, R. Newton, S. Madden, and H. Balakrishnan, "The pothole patrol: using a mobile sensor network for road surface monitoring", in Proc. 6th Int. Conf. Mobile System Appl. Services, New York, NY, USA, 2008, pp. 29; [4] is an application that reports the road surface conditions. It requires particular hardware equipment integration; for each vehicle, an embedded computer running Linux is needed for data processing, a Wi-Fi card for transmitting gathered data, an external GPS for localization, and a 3-axis accelerometer to monitor road surface. It uses a machine-learning algorithm to detect potholes.

Nericell [5] is a system developed by Microsoft to monitor roads and traffic conditions. It requires extremely complicated hardware and software setup. It uses several external sensors such as a microphone, GPS, SparkfunWiTilt accelerometer. The detection is not very accurate, the system may confuse between smooth, uneven and rough roads. The system employs Android OS based smartphones having accelerometer sensor and simple algorithms to detect events from acceleration data.

III. PROPOSED SYSTEM

In our system will collect the information of potholes distribute it to other vehicles, which in turn can warn the driver. consists of two components one is mobile and cloud platform. Cloud is responsible for storing and sharing the information about potholes and broadcasting the information to other vehicles. Whereas Mobile placed in a vehicle is responsible for sensing those potholes which it did not have previous information about, locating and warning the driver about the potholes which it has information about and giving the data about newly sensed pothole to other users through the cloud.

IV. SYSTEM ARCHITECTURE

The System consists of three subsystems: Sensing, Communication, Localization. These three subsystems work independent of each other, but have one center point they revolve around; that is data. Sensing system generates the data; Communication collects, coordinates and distributes the data; lastly, Localization uses the data and generates information for the driver. The overall design can be given as follows

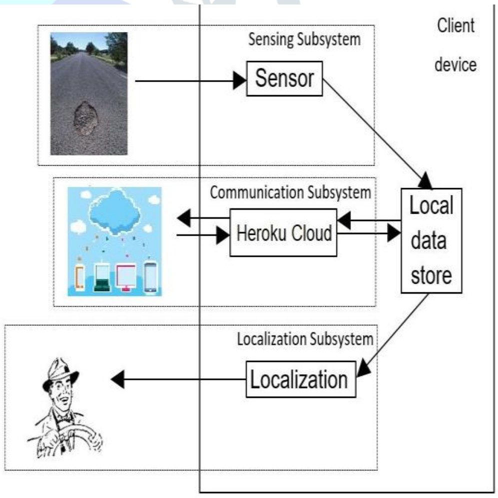

Fig: Architecture

There are different ways in which these subsystems can realize and implement. All the ways have there owned pluses and minuses. We explain some of the ways In this section and mention some of their pros and cons. We try to choose the best working system and we justify the choice taken.

Sensing Subsystem

This subsystem is responsible for getting the data. The data, in this case, would be the data about pothole e.g. location of the pothole, the severity of the pothole. There was one method under consideration for this subsystem is vibration based.

Vibration-based method:

This method uses 'Accelerometer' to sense potholes.

Accelerometer: This is a device that measures the total specific external force on the sensor. For example, if the device is stationary, it will show some reading corresponding to the earth's gravitational force. An accelerometer falling freely in the vacuum will show zero reading. The design of the accelerometer is often very simple. The simplest design can be a mass hanging by a thread and some sensor to measure its deflection for the original. The device is popularly used to measure vibration or inclination.

Gyroscope: A gyroscope is a device used for measuring or maintaining orientation and angular velocity. It is a spinning wheel or disc in which the axis of rotation is free to assume any orientation by itself.

Localization subsystem

Localization subsystem uses the data given by access point to actually find the location of the pothole and warn the driver about it. As we explained earlier Localization is especially challenging in the situation we selected. Because there is no access point situated near the location of the pothole. So, a vehicle has to find its own way.

GPS (Global positioning system):

As we all know this is a very popular location finding system. It is also the first and till recently the only global and fully functional location finding system. It is based on communication with 24 satellite orbiting around the earth. It works as follows.

These 24 satellites are revolving around the earth in 6 different paths. Theoretically, at any point, you need a point to point connection with at least 4 satellites to get your position.

It basically takes 4 measurements to determine 4 parameters x, y, z, t. And then represents in the form understood by the user like latitude/longitude. In the real setting, It might even require fewer satellites if one of the parameters is known. For example, ships sailing in the sea know their altitude to be zero. Also, more the satellites you can connect to a more accurate location you will get. GPS locations can get as accurate as up to 15 meters.

In our system data about potholes is stored in terms of x, y, z parameter. Also, a long length of a bad road maybe saved as a [(x1, y1, z1), (x2, y2, z2)] which indicate the start and end of a bad road. This data can be used by vehicles directly. As when they get the data from the access point the places where potholes are there can be shown distinctly on the GPS map. According to the severity of the pothole or road, it can be shown with different brightness. Also, when the vehicle senses a new pothole it stores the corresponding GPS parameters in its local memory and gives us feedback to immediate next Access point.

But there are several problems with this technology. First of all, it is highly expensive. Not just for maintaining but even the GPS receiver is costly. Another problem with GPS it needs a clear view of orbiting satellite; so, it does not work properly in-doors and mainly in the newly forming urban canyons where it is needed the most. Also, it has a high operational cost if it is made to work in real time, as it needs to update its location at real time.

Communication Subsystem

Heroku

Heroku is a platform as a service based on a managed container system, with integrated data services and a powerful ecosystem, for deploying and running modern application. Our system resides on Heroku, the container in Heroku contains python SVM model where we send the accelerometer (accx, accy, accz) and gyroscope (gyrx, gyry, gyrz) coordinates. The model is responsible for predicting a pothole initially the readings are given as an input to the SVM algorithm based on which the prediction of the pothole is done and the model sends back the pothole data i.e., the location coordinates of the detected potholes to the application.

V. SYSTEM METHODOLOGY

Preliminary data from the accelerometer sensors were collected using a smartphone device on an urban road with various potholes. The device is based on accelerometer & gyroscope sensor. The collected data is again used for performing the following operations.

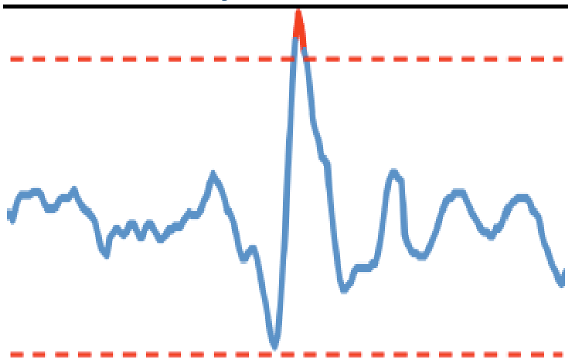

FIG. : Z- THRESH

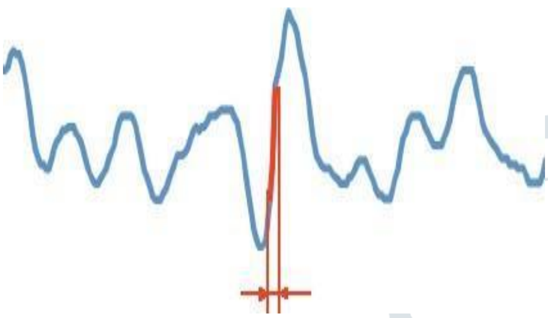

FIG.: Z-DIFF

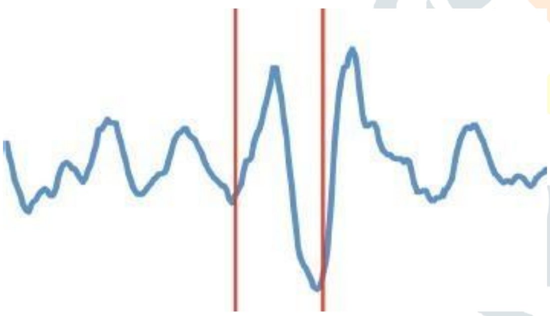

FIG. : STDEV(Z)

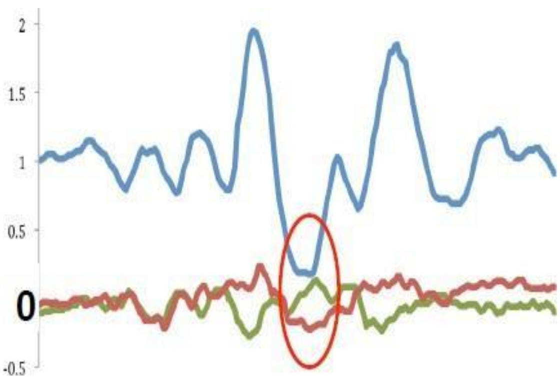

FIG.: G-ZERO

The first and simplest operation is Z-THRESH (Fig. 1) were tested on the acquired data set. It can threshold the acceleration amplitude at Z-axis. The features that classify the measurements are the values exceeding specific thresholds that identify the type of the potholes, e.g. a large pothole or a cluster of potholes. The algorithm assumes that the information about the Z-axis position of the accelerometer is known. Next, a slightly more advanced operation was Z-DIFF (Fig.2) tested on the acquired data set. Contrary to Z-THRESH a search for two consecutive measurements with the difference between the values above a specific threshold level was performed. Thus the algorithm detected fast changes in vertical acceleration data. The algorithm requires the determination of the Z-axis position similar to the previous approach. After the analysis of the related work, We decided to implement some of the techniques that were used for post-processing. One promising technique for implementation on a resource-constrained device was using a standard deviation of vertical axis acceleration. It was implemented in operation STDEV(Z) (Fig. 3). However, the window sizes and specific threshold levels had to be determined for the tuning of the algorithm and especially for pothole event detection.

While using visual data analysis tools and searching for specific data patterns we found that there exist certain events characterized by specific measurement tuple. All three- axis data in this tuple was with values near to the 0g. The empirical analysis of these data sets led to two preliminary conclusions:

1) such data tuples could be acquired when the vehicle was in a temporary free fall, for example, entering or exiting a pothole;
2) such data tuples could be analyzed without information about exact Z-axis position of the accelerometer.

We named this operation G-ZERO (Fig. 4) after the main feature of the detected event.

A Support Vector Machine (SVM) is a classifier which is defined by a separating hyperplane. SVM is used for two class or multi-class classification problem. In our system SVM is responsible for classifying the pothole and no pothole region, firstly features are extracted from dataset and SVM is trained with the training set.

Algorithm 1. Local SVM algorithm (kSVM)

```
input :
        training dataset D
        number of local models k
        hyper-parameter of RBF kernel function γ
        C for tuning margin and errors of SVMs
output:
        k local support vector machines models

begin
    /*k-means performs the data clustering on D;*/
    creating k clusters denoted by D_1, D_2, ..., D_k and
    their corresponding centers c_1, c_2, ..., c_k
    #pragma omp parallel for
    for i ← 1 to k do
        /*learning a local SVM model from D_i;*/
        lSVM_i = SVM(D_i, γ, C)
    end
    return kSVM − model = {(c_1, lSVM_1), (c_2, lSVM_2), ..., (c_k, lSVM_k)}
end
```

Heroku

Applications that are run on Heroku typically have a unique domain (typically "applicationname.herokuapp.com") used to route HTTP requests to the correct dyno. Each of the application containers, or dynos, are spread across a "dyno grid" which consists of several servers. Heroku's Git server handles application repository pushes from permitted users. All Heroku services are hosted on Amazon's EC2 cloud computing platform. The working can be summarized into two major categories: Deploy The main content of the development is the source code, related dependencies if they exist, and a Profile for the command. The application is sent to Heroku using either of the following: Git, GitHub, Dropbox, or via an API. There are packets which take the application along with all the dependencies, and the language runtime and produce slugs. These are known as build-packs and are the means for the slug compilation process. A slug is a combination/bundle of the source code, built dependencies, the runtime, and compiled/generated output of the build system which is ready for execution. Next is the Config vars which contain the customizable configuration data that can be changed independently of the source code. Add-ons are the third party, specialized, value-added cloud services that can be easily attached to an application, extending its functionality. A release is a combination of a slug (the application), config vars and add-ons. Heroku maintains a log known as the append-only ledger of releases the developer makes.

VI. EXPERIMENTAL SETUP

The system is developed using Python. The database is stored in SQLite. The application is create using Android Studio.

Dataset: The dataset is generated using the accelerometer and gyroscope application. Dataset contains the X, Y, Z coordinates of the accelerometer and gyroscope which are needed to train the machine learning algorithm.

VII. CONCLUSION

The Pothole Detection System is an attempt to provide its users with better knowledge about the routes of their transportation. The system will help to improve road conditions. Potholes are hazardous road features that damage wheels, suspension systems, vehicle frames, and potentially injure drivers and passengers. They are responsible for millions of dollars in insurance claims and roadway repairs each year. Drivers and automated vehicle systems would benet from the knowledge of pothole locations, and an automated detection system would assist municipalities in planning repairs.

VIII. ACKNOWLEDGEMENT

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