Street Bump System: Sensing and Classifying Roadway Obstacles

Supreeth Kumar Y P, Bhanu Prakash K, Nihal Choubey, Venugopal P

Abstract— Traffic Management and maintenance are the utmost important challenges among the Smart City challenges. The condition of the road surface is the major factor indicating road quality, and it will remarkably influence fuel consumption and driver safety. Currently, road surface audit is performed manually. The anomalous formed on road surfaces, such as manhole and potholes, can motive accidents when not identified by the driver. Therefore, we developed an infrastructure free system for sensing and classifying the roadway anomaly (i.e, Street Bump) based on data collected through the accelerometer and a GPS sensor seated in an automobile. This approach is capable of classifying roadway anomalous into predefined classes effectively using supervisory machine learning algorithms. Results on the actual dataset generated on Vellore, India roads illustrate the effectiveness and the feasibility of our system in practice.

Index Terms— anomaly detection, classification, machine learning, smart cities, speed bump.

1 Introduction

The urban population of the planet is growing rapidly since 1950, having raised from 751 million to almost four billion in 2018. Asia, despite being less urbanised than most different regions nowadays, is home to 54\% you look after the world's urban population, followed by Europe and Africa[1].

Traffic management is the most difficult and current challenge of the smart city. The traffic monitoring system using cameras have already been installed [2] [3], and the Global Positioning System for modern vehicles are also implemented for a better source of information [4] [5]. This data is used by authorities to predict and avoid the congestion of roads. Still, there are many factors which machines are not going to consider, such as sensing of the road surface, which is currently performed by humans.

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Sensing And Classifying Roadway Obstacles

According to The Indian Express, as much as 60 percent of Indian roads and highways are in bad condition, which increases the rate of accidents. As per the report, 34.5 percent accident deaths occur on national highways, and the 29.9 percent of accidents occur on state highways and these accidents are majorly due to anomalies on the highway surfaces [6].

To detect roadway obstacles in an automated and cost-effective manner, we are proposing a system which reads the linear acceleration in terms of G (i.e, Acceleration due to gravity) using an Accelerometer sensor and Global Position (i.e, Latitude and Longitude) using GPS sensor. This information can adequately describe and locate "bumps" as the automobile fitted with our system drives through the streets in Vellore City. We use the term "bump" in a generic sense to symbolize various anomalies which include pothole, sunk castings, utility patches, drains, train track and scientific speed bumps. All these are substantial enough to be clearly sensed by the driver and cause damage to parts of vehicles.

Collection of data through crowd sourcing approach allows contributing a massive and continues data collection without any deployment of infrastructure. Moreover, there is a social benefit of reinforcing participation in the development of smart cities.

The main objective of this paper is to develop an anomaly detection and classification system. Based on the setup introduced in [7], the present paper discusses the large variety of machine learning methods to classify roadway anomalies and validate the proposed algorithm. The raw data consists of both actional=ble and non-actionable bumps.

Actionable bumps are due to potholes and castings which are occurred by nature or accident and which requires action to fix it. Non-actionable bumps are either expected, known such as train tracks and scientific speed bumps, which do not require any actions. The goal of the system is to classify all detected anomalies into actionable and non-actionable based on raw data collected by the system in a supervisory manner.

2 Related Work

In [8], they developed a system using gyro , accelerometer and gsm sensors which is mounted in car to collect and

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process the data and genetic algorithm is used to form a model for classification of roadway obstacles.In [13], free space system(Real time) detection model is presented usin LIDAR (Light Detection and Ranging) sensor and camera.

In [9], they presented a infrastructure free method to detect and classify roadway obstacle and collecting data through smartphone application (Street Bump). This is an effective method for classification of obstacles in categories(Actionable and Non Actionable) using machine learning approach.In [13], smartphone based method is used for sensing method to analyse roadsurface conditions, this method uses in built sensors of smartphones like accelrometer and gps.. This method gives a better accuracy with detection rate of 88.6\% and 88.9\% for potholes and bumps respectively.

Image Processing: It is automated driver guidance system.This system is based on frame by frame analysis and recognises motion of frames and it gives alarm signal accordingly using image processing and pattern recognition[10].

In [11] a smart transportation model is developed for drivers in traffic and transport area for safe driving. It uses gaussian and median filter method. It substracts median filtered image from gaussian filltered image, the result of this substraction converted into binary image and image is analysed through connected component approach.This method is better than smartphone approach.

3 Comparative Analysis

TABLE 1
Comparison of Existing Systems

Reference	[14]	[15]	[16]
Method	System Evaluation	Threshold	Regression
Sensing Unit	Mobile Accelero	Mobile Accelero	MPU6050
Location	Mobile GPS	Mobile GPS	BU353-S4
Connectivity	Mobile Carrier	Mobile Carrier	RPI WLAN
Classification	YES	YES	NO
Crowd Sensing	YES	NO	NO
Accuracy	95.52%	93.6%	97.14%

4 Design of Prototype

Until now, the sensing of roadway obstacles were mostly done using Sensors available in the smartphones like accelerometer and GPS Sensor .In our project, we try to implement this using standalone sensors like GY-521 accelerometer and gyroscope, GPS Sensor Questar G702-001UB, which are interfaced with LPC2148 ARM-7 Development Board to get the Accelerometer raw data and process it further to detect an anomaly on the road.

4.1 LPC2148 ARM 7 Development Board

We are choosing the ARM 7 microprocessor for our project because we need the processing capability of a 32 bit microprocessor to quickly process the data received from the accelerometer, compare it with the threshold and sense if it is a road anomaly or not.

ARM 7 based development board, LPC 2148, is chosen due to the fact that there are I2C support, 2 UART peripherals available on board, which area basic necessity of our project to interface the 3 different modules i.e. the accelerometer, GPS sensor and Wi-Fi module.

Fig. 1. ARM 7 Development Board.

4.2 GY 521 module

This module has a MPU-6050 sensor IC containing a MEMS accelerometer and MEMS gyroscope on a single chip.The accelerometer sensor detects the tilts in the three directions i.e. x-axis, y-axis, z-axis.

The angles that have been detected are used to calculate the altitude.When the tilts are observed by the sensor the body will incline in that direction due to gravity. It has an on-board voltage regulator so that it can be used with 5V or 3.3V supply.

The 16 bit ADC hardware available for each channel makes it very accurate and also makes it flexible to collect data on all x,y,z channels simultaneously. This module outputs the 16 bit data in I2C format which is very easy interface with any microcontroller.

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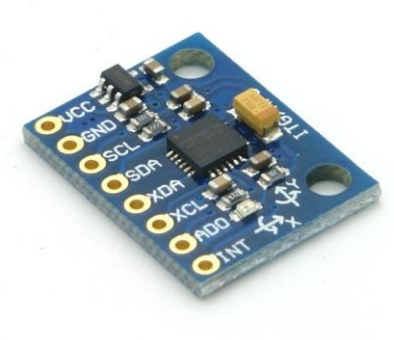

Fig. 2. Accelerometer.

4.3 GPS Sensor Questar G702-001UB

This module has a 3rd generation Patch-antenna On Top (POT) GPS Sensor. It has high sensitivity, high speed and accurate positioning capability. And also has high tracking capability in urban conditions, which makes it ideal for our application. The output is in the form of oldNMEA (National Marine Electronics Association) strings, which will be sent serially to any microcontroller as raw data. The microcontroller should then process the data to extract required longitude and latitude from the raw data. Output in the form of serial data also makes it easy to interface.

Fig. 3. GPS Sensor Questar G702-001UB.

4.4 ESP-8266 Wi-Fi Module

It is a 3V Wi-Fi module famous in the IoT domain. Maximum voltage it can withstand is 3.6V.This little module manufactured by Ai Thinker Ltd. facilitates microcontroller to connect wirelessly to a network, make simple TCP or IPtransactions, send and receive data over the network using AT Commands.

This plus point is the sole reason for us to use this module in ourapplication. We use this chip to send the data during anomaly detected interval to the server using this chip as a Wi-Fi client, which isconnected to the hotspot of mobile or a Wi-Fi connection.

5 Methodology-Decision Support And Anomaly Detection System

5.1 Data Collection

LPC 2148 consists of the ARM 7 processor which interfaces all the 3 modules mentioned in the Prototype section.It is programmed in such a way that the ESP 8266 Wi-Fi module gets connected to the hotspot of mobile internet or a Wi-Fi connection on Reset. ESP 8266 is now ready to act as a Wi-Fi client and all set to send data to the server at immediate instance of anomaly detection.

The MPU 6050 sensor keeps sensing the Accelerometer readings every instance of time and keeps updating the data to themicrocontroller. The ARM 7 based microcontroller reads this raw data, keeps monitoring it every microsecond and if it crosses the threshold mentioned for anomaly, detects it as an anomaly and reads successive 10 accelerometer readingsand also takes the GPS data such as longitude and latitude of the location where the variation in readings was detectedand stores this data in relevant strings . These strings are appended to each other to form the data to be sent to the server.

Then the Wi-Fi module ESP 8266 establishes a TCP Connection with the server, sends the prepared data string to the server, receives back the Bump ID generated on successful reception of data in the server and then closes the TCP Connection.

After the data is sent to the server via the ESP 8266 module, the microcontroller continues to monitor the accelerometer 3-axisreadings for crossing the threshold in order to detect an anomaly. This is done continuously. Data gets collected in the server for each and every anomaly detected using the accelerometer readings.

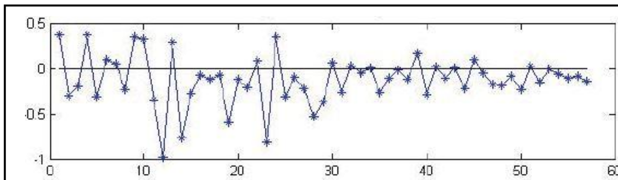

Fig. 4. Raw Street Bump Signature.

5.2 Model Construction

In this section, we describe the methods used for classification of the anomaly. The aim is at distinguishing actionable and non-actionable bumps. It can be done in 2 methods: *(a) supervised classification approach*, and *(b) unsupervised classification approach*. As in this paper, we are going to use the supervi-

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sory approach.

In supervised clasification there are many approches like soft-margin svm and sparse soft-margin svm, logistic regression and regularization, adaboost with stumps and a hierarchical approach of clustering and classification.

In this paper, we are going to implement 2 hidden neural layers which are taking raw data x,y,z (i.e, Accelerometer Reading) at the time and repeated for x0-x9, y0-y9, and z0-z9. In this hidden layer, a rectifier activation function (as shown in fig6) is used and whose weights are altered using the backward approach using stochastic gradient descent as shown in fig7. The output of the Rectifier function will become the input to the next hidden neural layer which is the final output layer. The output layer will be trained based on Sigmoid function (as in fig 8) using a backward approach.

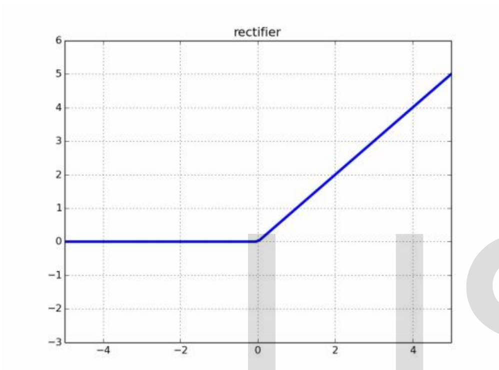


Fig. 5. Raw Rectifier Activation Function

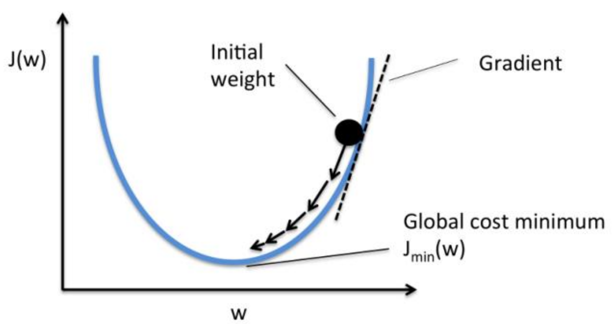


Fig. 6. Stochastic Gradient Decent

The Output of the final hidden layer will be in binary format if the output is TRUE the input signature is classified as Actionable else as Non-actionable. Based on the result of the output layer if the signature is Actionable the Global position (i.e, Latitude and Longitude) is made available to the road construction department for taking certain actions against it.

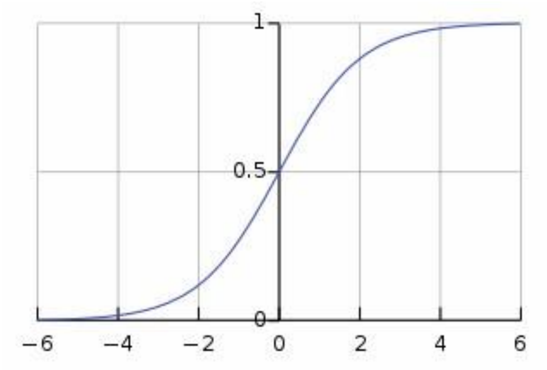
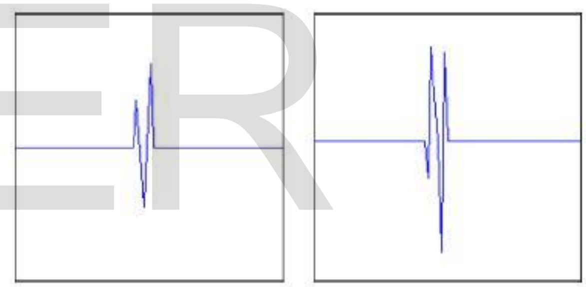


Fig. 7. Sigmoid Activation Function

6 Results

Main issue of our project was the right identification of large changes in the vertical acceleration signal related to the road anomalies.Once we were able to identify the right threshold for anomaly detection, and then we looked forward for accelero pattern of bumps and potholes.



(a) Road Pothole Pattern (b) Road Bump Pattern

Fig. 8. Pothole and Bump patterns

Many features can be extracted from vehicle movement such as a vehicle first descends into a pothole whereas vehicle has to ascend on a bump and then descend down the bump. We could further generate the template references for both pothole and bump detection for classification as seen in (fig 9). Accelero signature over a potholed road and over a bumpy road is as shown in figures 10 & 11.

Recorded data specifies that regardless of the placement of device in the vehicle, detection of road anomalies was all the same.The precision and accuracy achieved in the real world is not the same as that achieved in the laboratory.In the machine learning domain, the data sets should have been greater in size than that of what we used, so that even higher accuracy could be achieved.

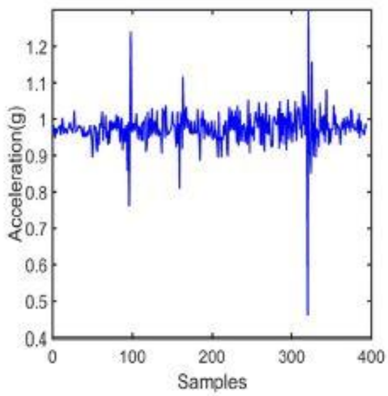


Fig. 9. Accelero Signal over a potholed road

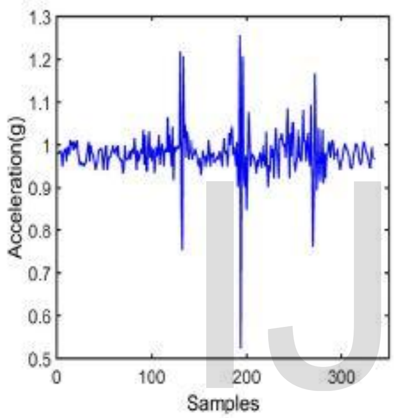


Fig. 10. Accelero Signal over a bumpy road

7 CONCLUSION

This paper proposes a method to detect anomalies on streets using the accelerometer readings, generate an anomaly signature by taking the subsequent 10 readings after the anomaly is detected,and then the corresponding latitude and longitude are captured using the GPS sensor and then this data is sent to the server using the Wi-Fi module.

At the server end, the anomaly signature generated is fed to the neural network, where the neural network gives us an output, whether it is a pothole or a bump, using a sigmoid function as a filter.

The aim of our project was to differentiate between actionable bumps which require immediate attention and non-actionable bumps such as speed bumps, cobble stone streets etc. This classification proves vital for City Corporation Officials to look after good condition of roads.It is also difficult to differentiate anomalies because of there is heterogeneity and high variability in road and vehicle conditions.

The average detection rate of our proposed method is in par with the currently available techniques.Our prototype enhances accuracy and precision of detection of potholes & bumps because of exclusive use of accelerometer and accuracy of geotagging is also high due to usage of standalone GPS sensor.

8 FUTURE WORK

As the future step of this work, it is important to differentiate between different types of anomalies under actionable class such as distinguish a pothole from a sunk casting. The vision is that the raw data collected using the system can be used in additional applications like detecting curvature, slippery nature of the road. All these results, in combination, could potentially integrate a global **road smoothness** and **road quality**. Integrating with google maps, Waze and Apple map to benefit the citizens to select the best route.

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