Android Pothole Detection Application

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Mini Project - III

Submitted in fulfilment of the requirements

For the degree of

Bachelor of Technology in Computer Engineering

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CERTIFICATE

This is to certify that the project entitled "Pothole Detection" submitted by Vraj Desai (17BCE018) and Dev Gagrani (17BCE019), towards the partial fulfilment of the requirements for the degree of Bachelor of Technology in Computer Engineering of Nirma University is the record of work carried out by them under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination.

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Abstract

Road condition analysis is used to provide smooth and safe road infrastructure to its users and maintain it over time by officials. The key to this is to detect road surface anomalies, such as potholes, cracks, and bumps, which affect driving comfort and on-road safety. Road surface anomaly detection can be done with 3D laser sensors, machine learning based image processing of geo-tagged images or vibration-based methods such as using smartphone sensors. Smart-phone sensors can be helpful in such a way that everyone riding a car owns a mobile device and sensor ratings from different devices and frequency leads to more accurate and precise prediction. Also, this way of detecting road surface is cost-effective as no further system of sensors, lasers or camera is required. In this project, current approaches for using smartphones for road surface anomaly detection are reviewed and implemented with calibrating phone orientation that affects sensor ratings as well.

Introduction

Good road condition is always desired to increase safety and comfort level of riders and prevent massive accidents and vehicle damages or failures. Hence, it is of utmost concern of the government to monitor road condition and enhance it to ensure maximum transportation safety. But the fact is, government municipalities and agencies typically rely on statistical data derived from build and structuring of the road rather than live data. They might be using vehicles fitted with sensor systems or special instruments for measuring and monitoring road condition which includes ultrasonic radars, or laser sensors which costs tons and needs to be maintained over a period which makes them labor-intensive as well. For the above reasons, low-cost, higher-efficiency detection methods are desired and are in demand. They want a . Traditionally, 3D reconstruction, vibration, and vision-based approaches are better solutions for such problems with probable difference in overall cost of these systems. These approaches are discussed below:

- A 3D reconstruction method relies on 3D laser scanning to create precise road surface models. These models are then compared to a base model of perfect/regular road for comparison of road condition. In this approach, a sensor device with 3D capabilities is used to identify distance from sensor to road to detect, such as potholes, cracks or bumps. Hence, the anomalies can be recorded, identified and extracted from the model. This approach is very costly when monitoring large-scale road networks as the dataset of the images/videos to be stored and the processing power needed to run the model continuously on live video input of higher resolution grows much larger than current capacities of such systems. Cloud resources are needed to compute and run the model and larger network bandwidth on edge devices are required in this case as well which could be a major drawback of these kinds of systems.

- A vision-based approach relies on image processing which uses live captured images of road and classify either as posthole, crack, bump or clear road via either supervised or unsupervised approach. The main idea behind this approach is to use geotagged images (meaning location of captured image is stored with image itself) captured by a camera/video system which is at the bottom of the vehicle facing downwards at road looking for cracks, pothole in moving vehicle. Road anomalies such as potholes, cracks and bumps can be detected from the images by applying, for example, a ML based prediction model to classify the live images or live video. Even though this approach is cost effective over 3D laser based method, at the night time, the system goes completely ineffective and hence insufficient than other methods because the images at night does not have clear brightness and shadow properties to detect pothole and hence it is a major drawback of these kinds of systems.

- With a vibration-based approach, road condition can be detected as the car over any pothole, cracks or bumps would surely vibrate more than over regular smooth surfaces. The smartphone sensors available to record physical attributes on phone such as current gravitational forces, speed of device, orientation of the device: all combined can be the best solution to detect any road anomaly.

Smartphone-based sensing has become the dominant technique for detecting road surface anomalies as the overall cost of the system is reduced, the accuracy is increased and the large user base is the key for success of such methods. Mobile phones are not only widespread but also equipped with multiple different sensing abilities. Measuring and analyzing motion sensors' data from different types of moving smartphones in the same car, may have different frequency of sampling and different rate of change in data for exactly the same impact on all the devices. Hence weight of device, weight of car, sensor's characteristics and quality, device's position and orientation, vehicle's speed and the suspension capabilities has to be taken into consideration while developing these kinds of systems.

Pre-processing

Data obtained from sensors is noisy and cannot be used directly for analysis and prediction of potholes, thus preprocessing of data is necessary. In preprocessing data from sensors is properly formatted and smoothed, the noises from data are filtered out. There are three ways in which data can be pre-processed, these filtering techniques are: high-pass and low-pass filtering, band-pass filtering and moving average filtering.

Moving average filter removes noise by smoothing the signal, here the average of last N readings are taken to give the filtered reading, here the value of N is important because if N is very large then information would be lost and if N is small then noise may still persist. This filter removes the high frequency noise from the readings.

The blue signal is an input noisy signal, and the red signal is a filtered signal.

Code for moving average filtering

```
// SUM has sum of last N readinga
// Remove the oldest entry from the sum
SUM = SUM - READINGS[INDEX];
// Read the next sensor value
VALUE = getReading();
// Add the newest reading to the window
READINGS[INDEX] = VALUE;
// Add the newest reading to the sum
SUM = SUM + VALUE;
// Increment the index, and wrap to 0 if it exceeds the window size
INDEX = (INDEX+1) % WINDOW_SIZE;
// get the filtered value by averaging
AVERAGED = SUM / WINDOW_SIZE;
```

There also exists another reason to do preprocessing and it is the orientation of the sensor, if the sensor's axes don't align with the axes of motion of the vehicle then prediction will go wrong. Thus in preprocessing we also reorient the data obtained from the sensors. This makes the predictions less dependent on the place where sensors are placed.

To reorient the values of acceleration Euler angles can be used.

For vehicle at rest the values of acceleration are

$$a_x = 0\,m/s^2;\ \ a_y = 0\,m/s^2;\ \ a_z = 9.81\,m/s^2 = 1g$$

x', y' and z' are axes which are not oriented. So we can find the euler angles from the following equations.

$$\alpha = tan^{-1}\left(a_y'/a_z'\right) \qquad \beta = tan^{-1}\left(-a_x'/\left(\sqrt{(a_y')^2 + (a_z')^2}\right)\right)$$

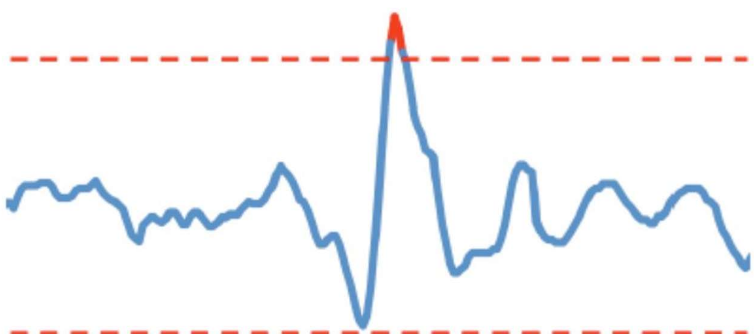
Now using the euler angle and unoriented values of acceleration, oriented values of acceleration can be found using below equations, where c represents cosine of angle and s represents the sine of angle.

$$a_{xreor} = c_\beta a_x' + s_\beta s_\alpha a_y' + c_\alpha s_\beta a_z';$$
$$a_{yreor} = c_\alpha a_y' - s_\alpha a_z';$$
$$a_{zreor} = -s_\beta a_x' + c_\beta s_\alpha a_y' + c_\beta c_\alpha a_z'$$

Processing

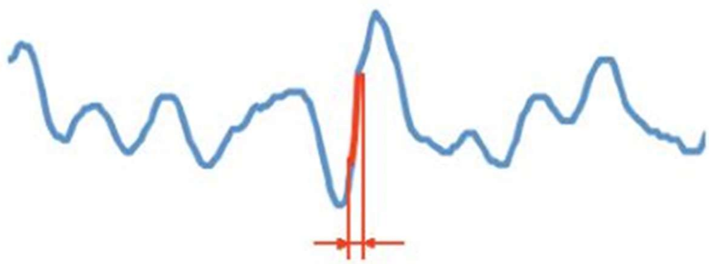
While predicting potholes on mobile devices key points to remember is that the predicting process should not be cpu-intensive and should have a high level of battery consumption. So methods used don't require much cpu power but still give good predictions. The four methods are:

1. **Z-axis Threshold**



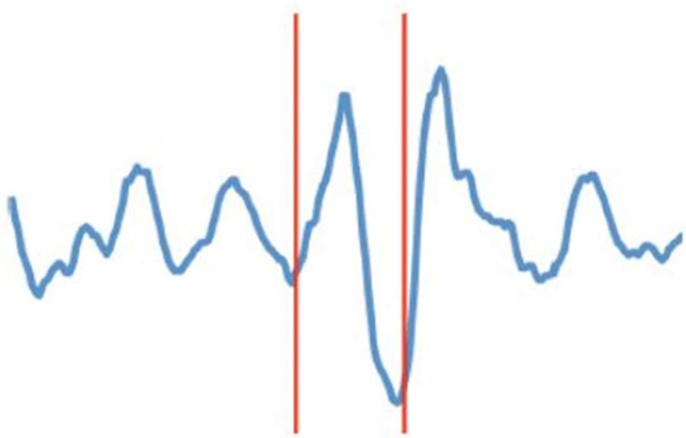
In this method we decide a threshold of acceleration along the z axis and when the value crosses the threshold pothole there is a possibility of a pothole.

2. **Z-axis Difference**



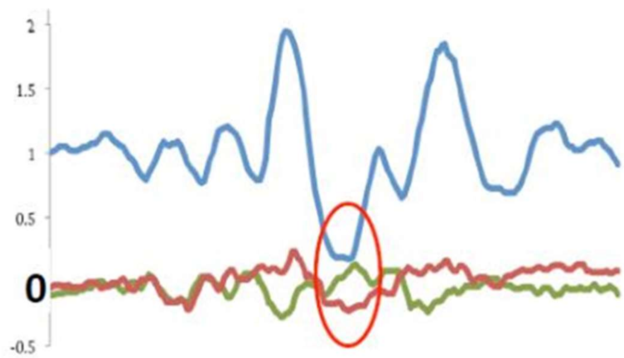
In this method we place a threshold on the difference of acceleration values between two consecutive readings from the sensors, this detects if there are any major changes in the value of acceleration. If the threshold is crossed then it may be a pothole.

3. **Z-axis Standard-Deviation**



In this method we calculate the standard deviation of acceleration along the z-axis for a window of constant time, and if the standard deviation crosses the threshold decided then the pothole can be predicted.

4. Zero gravity



When a vehicle is entering a pothole it is in a state of free fall for a very short duration of time and at that time all the readings of acceleration along all axes are near to zero, thus we predict a pothole when acceleration readings are close to zero.

These methods may even detect potholes when the door of the vehicle is closed, so we also use the speed of the vehicle while detecting, if the vehicle is at rest then the event of pothole detection is rejected.

Post-processing

Data from all the users can be gathered on a central system. This data can be used in betterment of accuracy of potholes detection. It also makes the application scalable. By combining the data of pothole predictions from the users we can make our predictions more accurate and precise. If at a certain location if several users have detected pothole then, the surety of pothole being there is high and if very few detect pothole and others don't then chances are there that no pothole exits there.

We should also get the data of manholes and bumps from other sources, and if a pothole is predicted at places where manholes or bumps are there we can safely ignore the predictions, which in turn reduces the number of false predictions.

By using a central database we can also detect if some device is making false predictions and thus we can make predictions from those devices less significant, and similarly if some device is making much accurate predictions we can increase its significance in pothole predictions. The data of potholes can be used to show the potholes path on map to the users and alert them.

Application Description

Labels:

Red marker – places where potholes were detected

Blue dot – current location of device

Calibrate – to calibrate sensor if orientation of mobile was changed

At bottom – number of potholes encountered

Conclusion

Even though smartphone sensors are the best available choice for a pothole prediction system, it continues to face some challenges. The performance of algorithms which classify a road anomaly is difficult to compare as pre-built datasets of correctly identified potholes are not available or are less trusted itself. For threshold-based methods, the threshold for different devices and different frequency of sampling were not taken into consideration for generalization of those algorithms.

Therefore, the newly generated algorithms should be generalized for all kinds of smartphone sensor ratings, their sampling rate, orientation of devices and weight of devices as well. The speed, weight of transportation vehicles, and suspension system of vehicles are again the limiting agents for algorithms to predict potholes correctly. On the other hand, the increasing number of smartphone holders, large coverage of such systems, increased accuracy due to verification of single pothole by multiple devices, live monitoring and easily available mobile and GPS network connections makes the approach better than the other available ones. The government or road agencies can directly use the live data generated by the systems to maintain that particular road and users can also get alerts about road condition and approaching potholes well in advance.

Moreover, the driverless car technology can get easy benefits from such systems as different frameworks can be built to communicate information regarding potholes, cracks or bumps faced by one smart car to all the other smart cars in its neighbourhood to avoid accidents well in advance and to increase security levels of such smart systems. It can be done by collecting and transmitting most updated live data to other cars and combined with warning of approaching anomaly in the application. Hence, V2V (Vehicle to Vehicle) communication technologies can be included in pothole detection systems for more secure and trusted driverless systems.