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Research Article

Potholes and speed bumps detection

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Abstract

Roads make a crucial contribution to economic development and growth and bring important social benefits. They are of vital importance in order to make a nation grow and develop. Roads open up more areas and stimulate economic and social development. For those reasons, road infrastructure is the most important of all public assets. Poor state of roads in country has significantly increased the number of road accidents, leading to loss of lives and properties. This project aims at automatic identification of roadway obstacles like potholes and road bumps, literature study shows that much work is already done in past regarding automating this process like manually capturing photo of pothole or obstacle and reporting it to authorities by using ways like web application, telephone reporting, manual paper or by using android application. In most of cases mentioned here user manual intervention is required and it is time consuming and costly at the same time. As roads are large in numbers, total length of roads is much high and new roads are constructed daily. Main problem is due to : Lack of a mechanism to trace and fix bad roads; There is no method to track potholes, so it takes long periods to fix them and then, the quality is also compromised. There is a need to develop application which will gather realtime data on poor road conditions, including potholes and road bumps which can help the organization in spotting potholes and fixing them before things get out of hand. Accelerometer and gyroscope of phone's sensors can be used to detect when the user's vehicle slows down and a bump is hit, while the GPS determines location. Data records or samples are taken at particular frequency. The algorithms in the application filter down to distinguish between potholes, speed bumps and stretches of bad road. The information is sent off into a larger data stream of information from users. When enough people hit a big bump in the same spot, the application recognizes it as a pothole. Number of users need to be taken into consideration to get the better result and if number of users goes on increasing it will result in better result of course application developed will not be 100% accurate but with more data coming in, the application accuracy will goes on increasing.

Keywords: *Accelerometer; gyroscope; style; android apps; gps; pothole; speed bumps*

Introduction

Citizen's active participation is much needed to make any application successful when the application or system is built by keeping their benefit in mind. Collecting, uploading, data sharing and reporting problems related to roads and road safety is a expected behavior from a citizen but problem lies in a human nature, when it comes to manually filling form and uploading the problems there will be scenario of negligence. This raises demand for a system which will automate this detecting and reporting phase by utilizing advanced technology features. Road quality assessment is important factor in this case as it will reduce accidents by ensuring trip safety and will reduce transportation time. Automating manual process of road problems detection will lead to, in timely attention of authorities on road segments. Literature study shows that there mainly two approaches are used in general to automate the road problem detection

i) Use data collected by inertial sensors fitted either on vehicle or available in mobile
ii) Placing dedicated devices in a vehicle like Ground Penetrating Radar (GPR) to optically analyze obstacles on the road

In order to optimize the identification of potential problems, several road quality determination systems have been proposed. Among the past few years, smart phones have become very popular, providing at the same time a ubiquitous and low-cost access to the Internet. This has led different research teams to take advantage of the wide use of smart phones to detect road anomalies. Examples of data collected on smart phones for pothole detection are acceleration and GPS (vibration based methods). Current methods for road anomaly detection using smart phones can be classified into two classes: threshold-based methods and classification-based methods. Threshold-based methods are simple algorithms that identify potholes by checking if sensed data, or a derivative of a sensed data, are above or below a given threshold. Examples of sensed data are ax (the component of the acceleration vector which is in the same direction as the Smartphone motion), az (the vertical component of acceleration). Examples of derivative data are the difference between the maximum and the minimum sensed data or the standard deviation. With classification-based methods, features are first extracted from the data using various methods. Then, a classification is applied to these features to divide them into two groups, road anomaly or safety.

Literature Survey

Literatures study gives brief idea on much work done previously on detecting anomaly in a road construction. Survey mainly focused on work done using inertial sensors and applications developed for smart phones to make use of sensors embedded within the Smartphone's.

In the paper [1], Pothole detection system using 2D LiDAR and camera, to improve the pothole detection accuracy, the combination of heterogeneous sensor system is used. By using 2D LiDAR, the distance and angle information of road are obtained. The pothole detection algorithm includes noise reduction pre-processing, clustering, line segment extraction, and gradient of pothole data function. Next, image-based pothole detection method is used to improve the accuracy of pothole detection and to obtain pothole shape. Image-based algorithm includes noise filtering, brightness control, binarization, addictive noise filtering, edge extraction, and object extraction and pothole detection. To show the pothole detection performance, experiments of pothole detection system using 2D LiDAR and camera are performed.

Vision based approach is exploited to detect road anomalies in [2] Computer vision based detection and localization of potholes in asphalt pavement images, it addresses the detection and localization of one of the key pavement distresses, the potholes using computer vision. Different kinds of pothole and non-pothole images from asphalt pavement are considered for experimentation. Considering the appearance-shape based nature of the potholes, Histograms of oriented gradients (HOG) features are computed for the input images. Features are trained and classified using Naïve Bayes classifier resulting in labeling of the input as pothole or non-pothole image. To locate the pothole in the detected pothole images, normalized graph cut segmentation scheme is employed. Proposed scheme is tested on a dataset having broad range of pavement images. Experimentation results showed 90 % accuracy for the detection of pothole images and high recall for the localization of pothole in the detected images.

Survey shows that some study uses Stereo vision [3] to detect pothole, it propose a stereo vision system which detects potholes during driving. The objective is to benefit drivers to react to potholes in advance. This system contains two USB cameras taking photo simultaneously. It use parameters obtained from camera calibration with checkerboard to calculate the disparity map. 2-dimensional image points can be projected to 3-dimensional world points using the disparity map. With all the 3-dimensional points, it use the bi-square weighted robust least-squares approximation for road surface fitting. All points below the road surface model can be detected as pothole region. The size and depth of each pothole can be obtained as well. The experiments it conducted show robust detection of potholes in different road and light conditions.

[4] Paper presents a vibration based approach for automatic detection of potholes and speed breakers along with their co-ordinates. In this approach, a database is maintained for each road, which is made available to the public with the help of global database or through a portal. Potholes and speed breakers are detected along with their severity using android's built-in accelerometer. The results of the proposed approach are tested over a 4 km flat road and compared to manual inspection of pothole and speed breakers on the same considered road. The accuracy of the proposed approach came out to be 93.75% for detection of potholes and speed breakers.

In a [5], paper propose a low complexity method for detection and tracking of potholes in video sequences taken by a camera placed inside a moving car. The region of interest for the detection of the potholes is selected as the image area where the road is observed with the highest resolution. A threshold-based algorithm generates a set of candidate regions. For each region the following features are extracted: its size, the regularity of the intensity surface, contrast with respect to background model, and the region's contour length and shape. The candidate regions are labeled as putative potholes by a decision tree according to these features, eliminating the false positives due to shadows of wayside objects. The putative potholes that are successfully tracked in consecutive frames are finally declared potholes. Experimental results with real video sequences show a good detection precision.

One of the ways to reduce road accident is to identify the humps and potholes present in the path. In [6] paper, an internet of things based road monitoring system (IoT-RMS) is proposed to identify the potholes and humps in the road. The pathway which is affected by the pothole is greatly influenced by the scattering signal of the ultrasonic sensor. So the magnitude of the reflected signal decreased due to the roughness of the surface and the signal amplitude is difficult to analyze. The Kirchofft's theory basically applied for realtime analysis and it has certain limitations. To overcome this difficulty, an accelerometer has been included with the ultrasonic sensor to measure variation present in the signal and optimized using honey bee optimization (HBO) technique. The IoT-RMS automatically updates the status of the road with location information in the cloud. Each road vehicles can access the information from the server and estimate the speed according to the potholes and humps present on the road. The simulation has been done and the result shows that the IoTRMS can be accommodated in road vehicles to reduce the accidents. The proposed system is implemented and tested using Arduino Uno with ESP 8266.

Several methods suggest detecting potholes using sensors. However, these methods require an installation on the vehicle in order to collect data of the pavement. Meanwhile, other methods are using Smartphone's sensors to reduce a cost of deployment and get an advantage of sensitive sensors without a complex installation on the vehicle. For this reason, a method using a Smartphone camera with the artificial neural network becomes a way in detecting a pothole on a pavement. [7] Investigate the performance in detecting potholes with an image classification method based on the deep convolutional neural network models.

The need for monitoring the quality of roads is undeniable. There are many different approaches for road quality controls. Among them, the one making use of Smartphone has recently become very popular. Nevertheless, building a system that saves energy for Smartphone's and adapts to real conditions remains a big challenge. [8] Introduce a lightweight architecture to sense and analyze potholes based on data collected with Smartphone's. In this model, it improves some algorithms for real-time road-anomaly detection using Smartphone. The efficiency of these new algorithms has been verified by experiments with multiple vehicles.

Proposed Methodology

The proposed architecture contains mainly two layers

Layer 1 will consist of smart phones with sensors and algorithms to process input data

Layer 2 will consist of server modules consisting modules for filtering input data, classifying it, databases consisting sample data, historical data etc.

A. Architecure

1) Layer1

As shown in fig, layer 1 will be Smartphone with below modules

i) GPS

The Global Positioning System (GPS), originally NAVSTAR GPS, is a satellite-based radio navigation system owned by the United States government and operated by the United States Air Force. It is a global navigation satellite system (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.

Here I use GPS to detect and track location where road anomalies are detected so that responsible authorities will track and find them with ease and will take corrective actions.

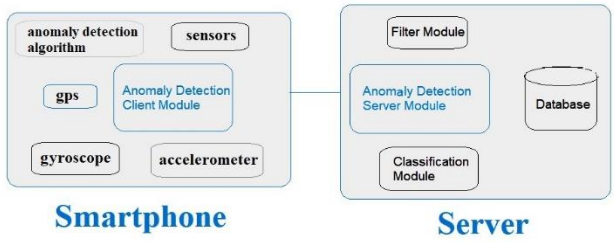

Fig. 1 System Architecture

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 (spin axis) is free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum.

It is used to assist in stability or be used as part of an inertial guidance system.

ii) Accelerometer

An Accelerometer is a device that measures proper acceleration. Proper acceleration, being the acceleration (or rate of change of velocity) of a body in its own instantaneous rest frame, is not the same as coordinate acceleration, being the acceleration in a fixed coordinate system. For example, an accelerometer at rest on the surface of the Earth will measure acceleration due to Earth's gravity, straight upwards of g 9.81 m/s2. By contrast, accelerometers in free fall (falling toward the center of the Earth at a rate of about 9.81 m/s2) will measure zero.

Accelerometers are used to detect and monitor vibration in rotating machinery. Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright. Accelerometers are used in drones for flight stabilization. Coordinated accelerometers can be used to measure differences in proper acceleration, particularly gravity, over their separation in space; i.e., gradient of the gravitational field. This gravity gradiometry is useful because absolute gravity is a weak effect and depends on local density of the Earth which is quite variable.

iii) Other sensors

Some other sensors can be used like Magnetometer Sensor to detect direction, Pedometer Sensor to detect movement of Smartphone bearer. This data will help to filter and classify input data received from other sensors.

iv) Anomaly detection algorithm

This will be light version of server module which will perform some processing before sending data to server for further processing and will benefit in reducing processing time by avoiding non required communication between server and Smartphone.

2) Layer2

i) Anomaly detection server module
The Anomaly Detector is the component that initially detects potholes. A resident program is installed on the phone as well as on the server to read and process received data from the accelerometer, gyroscope and the GPS sensor. These data are passed to the anomaly detection component. The program installed on Smartphone then send anomalies to the server when connecting and module present on a server will process those anomalies for further filtering it.

ii) Filter module
The Fault Exclusion component aims at eliminating false anomalies that occur when the Smartphone user is in motion, eg. when a brake occurs.

iii) Classification module
The Anomaly Classification component discriminates anomalies between potholes and bumps.

iv) Database
Database is required to store input received from smart phones for processing, storing records of detected anomalies for further action by respective authorities database will also have sample data to be used for reference purpose in detection algorithms.

B. Algorithms

Algorithm [1]: Anomaly Detection Step 1 - Begin
Step 2 - Initialize the parameters
Step 3 - Get sensor reading
Step 4 - Compute reading
Step 5 - Check if reading is equal to threshold value
Step 6 - If reading is greater than threshold value, go to next step else go to step 3 and continue
Step 7 - Provide input to filter module, if filter module output is no anomaly then end else go to step 8 and continue
Step 8 - Provide input from step 7 to classification module
Step 9 - Post result from classification module to server application
Step 10 - Provide data received as input to anomaly detection module and check whether same type of readings are received for same location from other users also if yes go to step 11, if no reject readings and go to step 3
Step 11 - Log the result in database
Step 12 – End

Algorithm [2]: Anomaly Classification
Step 1 - Define initial threshold limit for differentiating between potholes and speed bump.
Dlp is differentiating limit for pothole
Dls is differentiating limit for speed bump
For Pothole
Dlp = 0.5g
For Speed bump or speed breaker
Dls = 1.5g
Step 2 - Get the acceleration value A.
Step 3 – Apply conditions on differentiating limit
A < Dlp, pothole is detected
A > Dls, speed bump is detected
Step 4 – Check result from Step 3, calculate accuracy rate, if result is not accurate, adjust differentiating limit and repeat algorithm.

Result and Discussions

The goal of this article was to identify a real-time pothole and speed bump detection algorithm that can adapt to many real-life conditions and require as less resources as possible on a Smartphone. I proposed to apply the algorithms to find and locate road anomalies by finding outliers in sensor data sets. In this way, potholes and speed bumps are seen as anomalies in the surrounding area under the same conditions. Therefore, this method promises to adapt to different practical conditions. I also proposed a way to process acceleration data as a continuous sequence, not cutting them into windows like other research works do. To build ground truth in accordance with this method, I proposed to mark the ground truth with time. Results were analyzed based on the Precision-Recall Curve. This work also highlighted the necessity of combining more filters to exclude other causes (braking, user actions, etc).

Conclusions

This paper presents an efficient, economical and simple way of detecting road anomalies. It has been shown that the proposed analysis system allows complete automation with the detection of potholes and speed bumps using easily available hardware of smart phones.

It has been shown that using algorithms at both server and client side for detecting anomaly increases accuracy and greatly helps in filtering out noise.

Using inputs collected from multiple devices for a particular location helps in validating result and filtering out hardware errors, user mistakes and hence increasing accuracy

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