Road Quality Management System using Mobile Sensors

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Abstract—**One of the major problems in developing countries is maintenance of roads. Well maintained roads contribute a major portion to the country's economy. Identification of road distress such as potholes and bumps, helps drivers to avoid accidents, vehicle damages and it also helps authorities to maintain roads. In this paper, we discuss the previous pothole detection methods that has been developed and proposes a cost-effective solution to identify the potholes and bumps on roads. In our system, mobile phone sensors are used to identify the potholes and bumps. The proposed system captures the geographical location of the potholes and bumps using GPS sensor in the Mobile phone. These sensed-data are send to the cloud storage for further processing. This serves as a valuable source of information for the government authorities and vehicle drivers. An android and web application can be used to display the road condition in the map.**

Index Terms—**Road Quality System, Pothole detection, Pavement management**

I. INTRODUCTION

INDIA, the second most populous Country in the World and a fast growing economy, is known to have a gigantic network of roads. Roads are the dominant means of transportation in India today. They carry almost 90 percent of country's passenger traffic and 65 percent of its freight. However, most of the roads in India are narrow and congested with poor surface quality and road maintenance needs are not satisfactorily met. No matter where you are in India, driving is a breath-holding, multi-mirror involving, potentially life threatening affair. Pathetic condition of roads is a boosting factor for traffic congestion and accidents. Roads in India normally have speed breakers so that the vehicle's speed can be controlled to avoid accidents. However, these speed breakers are unevenly distributed with uneven and unscientific heights.

To address the above mentioned problems, a cost effective solution is needed that collects the information about the severity of potholes and humps and also helps drivers to drive safely. With the proposed system an attempt has been made to endorse drivers to ward off the accidents caused due to potholes and raised bumps.

II. PROBLEM STATEMENT

Road is a vital part of people's day-to-day lives. When road is put into use after construction, it will lead to develop various anomalies due to continuous rolling under the wheels, and snow, rain and other natural factors. This will affect the quality of driving. With the availability of information regarding the road conditions, road users can be cautious about or avoid the bad roads. It is desirable to have a mechanism for detecting the condition of roads and get them repaired as soon as possible. . The road bumps and potholes are kind of conditions which are needed to immediate monitoring and sharing. Bad roughness condition may cause uncomfortable ride, extra fuel consumption, unexpected vehicle maintenance costs and safety. Road infrastructure maintenance and management is very important to keep the infrastructure in good condition so that it does not affect road users especially in terms of vehicle maintenance, fuel consumption and ride quality.

III. OBJECTIVE

The main objective of this system is to design an application to know about the road quality. Nowadays we all use Google maps and its application for navigation during travelling, but these applications couldn't able to tell you any road's condition or its complexity. Road Quality Management System using android phone proposes to utilize the GPS system of phone and different sensors like accelerometer, magnetometer, etc. of android phone, so we could analyze the road and can upload this information of that road on central server so every application user can use this information during traveling. This information can be helpful to user at the time if there are multiple routes and for destination and he can choose one of the finest and shortest route

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IV. Challenges

Although a lot of effort has been done to detect road conditions, a lot of methods/systems have been developed using Smartphone sensors, a highly reliable method is yet to be built. Real time road anomalies detection is so challenging that none of the methods using Smartphone sensors can address it alone completely. Some of the challenges are

A. Vibration patterns of sensor data

A given pothole or any other road anomaly may not necessarily give the same pattern during each drive over it. The sensors readings depend upon the speed of the vehicle, how it approached the road anomaly and the position of the sensor i.e. its orientation. It also depends upon the suspension system of the vehicle, if the suspension system is not in normal condition, sensors will show more deviation based on the large vibration experienced by the vehicle.

B. Benign events

There are many events that are not considered as road anomalies such as expansion joints, railroad crossings, door slams etc. These events are to be differentiated from the potholes. An efficient system is to be developed that is able to classify different events effectively.

C. GPS error

GPS provides the longitude and longitude values of a location. It is used to detect the location of potholes to users. It has an error of 3.3 meters. This error must be minimized to get the exact location where events to be detected have occurred. It may also be possible to miss some GPS data in urban areas among tunnels and tall buildings. A method to minimize the localization error is still an open problem.

D. Network overload and delay

The sensor data is to be uploaded on the server at back-end. If a large amount of data is needed to be send over the network it may lead to network congestion leading to delay or loss of data. Therefore, the application is needed that must keep the network usage to minimal. It will also save the communication cost.

E. Privacy

The application requires the location of the device to detect the location of road anomaly and can be retrieved by user; hence it may lead to privacy breach. There is a need of an application that is able to hide user identification to maintain the privacy of user.

V. Social Impact

India is the second largest country with huge number of population and vehicles. In India most of the communications are being dependent on road transport only. Often the road accidents may occur due to Reckless Driving and improper road conditions. Government of India has taken necessary steps to maintain the road conditions. Even though the technology has improved a lot there will not be of accuracy. Due to heavy rain the road conditions are being damaged easily. Road monitoring can also help to predict the estimated arrival time from one place to another. This paper presents a detailed survey of methods for detecting road conditions. Form the survey, it is noted that the most commonly used sensors accelerometer and GPS. Smartphone sensors are gaining importance in this field as they are cost effective and also increase scalability. Analyzing form the research activities, it is certain that this area will gain more importance in recent future. There are several research issues that can be explored for improvement in existing methods and develop a highly reliable method

VI. Literature Survey

Yulu Luke Chen et al., proposed a system called Inexpensive Multimodal Sensor Fusion System for Autonomous Data Acquisition of Road Surface Conditions [1] which is a field application of a novel, relatively inexpensive, vision-based sensor system employing commercially available off-the-shelf devices, for enabling the autonomous data acquisition of road surface conditions. Detailed evaluations and enhancements of a variety of technical approaches and algorithms for overcoming vision-based measurement distortions induced by the motion of the monitoring platform were conducted. It is shown that the proposed multi-sensor system, by capitalizing on powerful data-fusion approaches of the type developed in this paper, can provide a robust cost-effective road surface monitoring system with sufficient accuracy to satisfy typical maintenance needs, in regard to the detection, localization, and quantification of potholes and similar qualitative deterioration features where the measurements are acquired via a vehicle moving at normal speeds on typical city streets.

Rajeshwari Madli et al., proposed a system called Automatic Detection and Notification of Potholes and Humps on Roads to Aid Drivers [2] which is used to detect the pavement distress such as potholes and humps not only helps drivers to avoid accidents or vehicle damages, but also helps authorities to maintain roads. This paper discusses previous pothole detection methods that have been developed and proposes a cost-effective solution to identify the potholes and humps on roads and provide timely alerts to drivers to avoid accidents or vehicle damages. Ultrasonic sensors are used to identify the potholes and humps and also to measure their depth and height, respectively. The proposed system captures the geographical location coordinates of the potholes and humps using a global positioning system receiver. The sensed-data includes pothole depth, height of hump, and geographic location, which is stored in the database (cloud)

Juan Martin Raya Bahena et al., proposed a system called Speed booms detection for a ground vehicle with computer vision [3] which is a new stereo vision system for ground vehicle to detect speed bumps. The damage for cross speed bumps fast can result in harms to people breakdowns to vehicles. In this paper we propose speed booms detection method using Disparity, Border detection, Morphological Image processing, canny edge detector. The system was built using two web cameras. The importance of this work is to present a methodology to detect speed booms in a ground vehicle.

Jakob Eriksson et al. proposed a system called Pothole Patrol system [4] uses 3-axis accelerometer and GPS mounted on the dashboard to monitor road surface. It not only identifies potholes but also differentiate potholes from other road anomalies. It collects the signals using accelerometer. It uses machine learning algorithm to identify potholes. These signals are then passed through a series of signal processing filters, where each filter is designed in such a way that it will reject one or more non-pothole events.

Chen et al., proposed a system called RCM-TAGPS [5] which is used to collect the sensor data using three-axis accelerometer and GPS. The sensor data has 4-tuples: current time, location, velocity and three direction accelerations. This system also does the data cleaning before processing or analyzing it to deal with technical challenges like GPS error, transmission error.

Mednis et al., proposed a system called Real time pothole detection using android smartphone with accelerometers[6] which uses Android OS based Smart-phones having accelerometer sensor for detection of potholes in real time. This system detects events in real time and also collects the data for off-line post-processing. The data is collected using 3-axis accelerometer sensor present in Smart-phones.

Bhoraskar, R et al., proposed a system called Wolverine: Traffic and Road Condition estimation using Smartphone Sensors Wolverine [7] method uses Smartphone sensors for traffic state monitoring and detection of bumps. It uses accelerometer sensor to collect the data. The device (phone) is to be reoriented as it can have any arbitrary orientation when kept inside the vehicle. This system reorients the phone in two steps using accelerometer and magnetometer.

VII. System Architecture

The basic system architecture of our project contains 4 tasks sensing, storing, analyzing and retrieving the data. In the first task, we acquire the data from the mobile phone sensors. The second task is to send the sensed data to the Cloud storage. The third task is to analyze the cloud data to predict the road conditions. The fourth task is to retrieve the data and display the condition of the road as the markers in the map, the user can easily be able to access the data from the various devices. Fig. 1 shows the basic system architecture of our system.

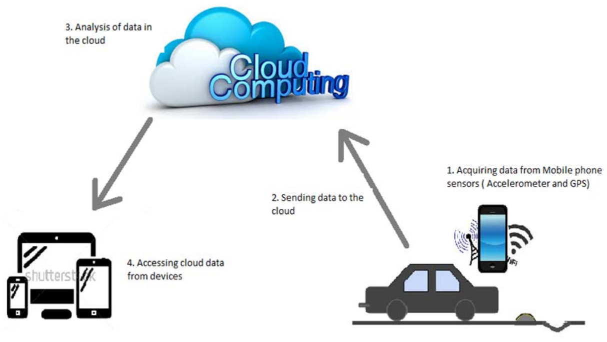

Fig. 1. System Architecture

A. Sensing

In the broadest definition, a sensor is an object whose purpose is to detect events or changes in its environment and sends the information to the computer. Today sensors are used in everyday objects. Our mobile phone contains so many sensors. We had used the accelerometer and GPS sensors in the mobile phone to detect the pothole and to find out the current location and speed of the vehicle. We can detect the potholes by observing the accelerometer data patterns. If we identified the pothole, immediately we access the location of the pothole by using the GPS sensor in the mobile phone. We can also find the speed of the vehicle by using the GPS values. Fig.2 shows the flow chart for sensing the data sets from the mobile phone.

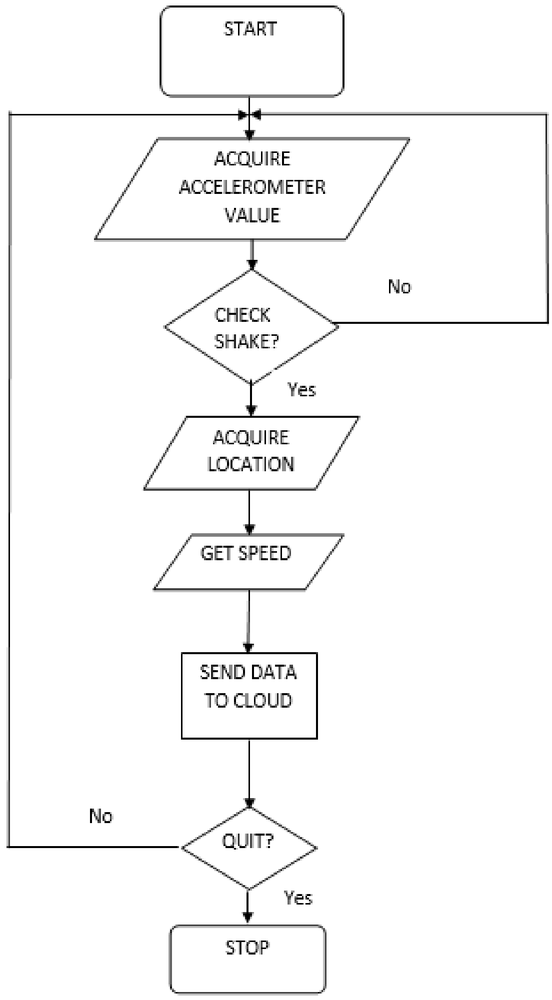

Fig. 2. Flow chart for sensing the data

This module helps in finding bumps and potholes on the road using accelerometer and GPS sensors. Now-a-days everyone has a smartphone with them. We can collect the data set from everyone using the application. We created an android application to detect the bumps and potholes in the road by using the in-build accelerometer and GPS sensors in the mobile. This application detects the potholes or bumps by observing the sudden changes in the accelerometer values. A standard value is considered as a threshold value for detecting the bumps and potholes. If the accelerometer difference value crosses the threshold value, immediately the location and the speed of the vehicle was recorded using the GPS sensor.

B. Storing

Storing is the second task performed after all the data sets are sensed from the mobile devices. In this subsystem, the user send the sensed data to the cloud storage. This can be said as the backbone of the system. This subsystem collects the data from different vehicles and Co-ordinates the data. Since our domain is Internet of Things (IOT), it requires the uninterrupted network support for sending the data to the cloud storage. Here all the data sets are send to the public cloud storage and it is further used for analyzing process. The sensed data sets from the first task are send to the cloud storage using the HTTP request using either GET or POST method.

C. Analyzing

Analyzing is the third task that is done after all the datasets are send to the cloud storage. Here the sensed data are compared to the other values that are already available in the cloud storage. Based on the comparison the quality of the road is predicted by the web application. This subsystem is responsible for determining the road conditions and adds the result into database. Other main function of this subsystem is to provide data to the user as per user's requirements. It collects all the data send by the different mobiles. The centralized web application is running on the cloud to analyze the data before it gets stored in the database. There may be many chances for the data received to be false values. So we have to check whether the values coming from the application are all valid or not. The challenges we referred in the chapter 1 are resolved in this module. Most of the data anomalies occur because of the false vibration pattern of the mobile, benign events, GPS error, network overload and delay. We have to avoid these kind of false values by analyzing the data before storing it in the central database. Data module plays the vital role in our system. Fig. 3 shows the flow chart for analyzing and displaying the data stored in the cloud.

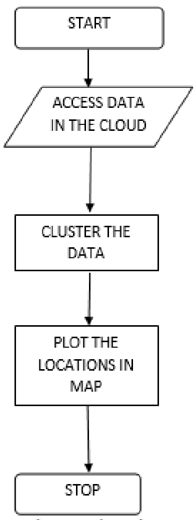

Fig. 3. Analysing and displaying the data in the cloud

D. Retrieving

Retrieving is the fourth task, here the datasets present in the public cloud are accessed first. The location of the potholes are plotted as markers based on the latitude and longitude values present in the cloud storage. This module provides the user interface for showing where the potholes are located. A web application is used for showing the plotted map to the user. The user can easily view these data from any device.

This module provides the view to see the data stored in the centralized data storage. The user gets the details of the road from the web application. This web application will display the road conditions in the map. Road conditions are marked as the different color markers on the map. If the user needs to choose between the routes, he/she can check this web application from anywhere to check the condition of the road.

VIII. METHODOLOGY

To ensure road surface quality it should be monitored continuously and repaired as necessary. The optimal distribution of resources for road repairs depends on the availability of comprehensive and objective real time data about the state of the roads. Participatory sensing is a promising approach for such data collection. This system presents the development of a cost-effective, sensor system using commercially available off the-shelf devices for autonomous data acquisition of road surface conditions. This system is a easy-to-use sensor system that is relatively inexpensive, which could be easily mounted on vehicles, to perform periodic pavement data collection, and maintains data in a main server. This system can be mounted on any vehicles using a clamp. Such frequent data gathering can provide an improved understanding of the formation and evolution of defects in time, thus leading to earlier measure to curtail the degradation of the pavement surface.

Our system consists of 3 subsystems: Sensing the data, Data processing and plotting the data. These three subsystems work independent of each other, but have one center point they revolve around; that is data. All the data sets are collected at the initial subsystem and gets processed at the second one and then finally gets displayed at the third subsystem.

A. Sensing the data

This subsystem is responsible for getting the data. The data in this case would be the data about pothole e.g. location of pothole, the severity of the pothole. Sensors are widely used in all other fields. In our system sensors are used to predict and test the road conditions. Using various sensors, we can predict the location of the pothole by using the two methods: Vision based method and Vibration based method. In Vision based method, cameras are used as sensors to predict the road condition. The camera captures the images in real time. These images are applied to image processing algorithms to predict the presence of the pothole. This process will take more time for processing. In Vibration based method, accelerometers are used as a sensors. We can characterize the pothole on the basis of the magnitude of change in reading of accelerometer. It consumes less time and power than the vision based method.

1) Accelerometer Sensor

An Accelerometer Sensor is a device that measures Proper Acceleration. Proper acceleration is not the same as coordinate acceleration. Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery. 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 is useful because absolute gravity is a weak effect and depends on local density of the Earth which is quite variable. Single and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration, as a vector quantity, and can be used to sense orientation, coordinate acceleration, vibration, shock, and falling in a resistive medium. Micro Machined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input. In our system, accelerometer plays an important role in detecting the potholes and bumps. Characterization of potholes and bumps in the roads can be done using the readings of the accelerometer. Sudden change in the accelerometer values will indicate the presence of the pothole in that location.

Deployment of mobiles in the vehicle is the major challenge we faced. When the mobile phone is deployed on the vehicle there are many things that should be taken into consideration to get the accurate reading. The accelerometer sensor had 3 axis values. Fig. 4 shows the alignment of these 3 axis of accelerometer in the mobile phone.

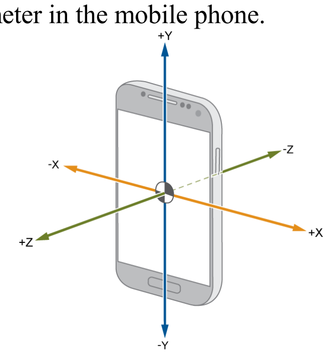

Fig. 4. Accelerometer alignment in mobile phone

2) GPS Sensor

A GPS sensor was added to the data acquisition system to record the location of defects and the speed of the vehicle. If the accelerometer sensor detects the potholes or the bumps in the road, then immediately the Geo-location and speed of the vehicle has to be calculated from the GPS sensors. The Geo-location data will contains the coordinates of the potholes or bumps. The speed of the vehicle will be used for analyzing the data for efficient working of our system.

GPS accuracy in our deployment is important if potholes are to be properly located and multiple detections combined to report a single pothole. Accuracy is the tendency of your measurements to agree with the true values. Precision is the degree to which your measurements pin down an actual value. The question is about an interplay of accuracy and precision. As a general principle, you don't need much more precision in recording your measurements than there is accuracy built into them. Using too much precision can mislead people into believing the accuracy is greater than it really is. Generally, when you degrade precision--that is, use fewer decimal places--you can lose some accuracy. Accordingly, if your accuracy needs are, say, give or take 10 meters, than 1/9 meter is nothing: you lose essentially no accuracy by using six decimal places. If your accuracy need is sub-centimeter, then you need at least seven and probably eight decimal places, but more will do you little good.

Table 1. Decimal degree meaning of a GPS value

Decimal places	**Decimal degrees**	***Distance***
0	1.0	111 km
1	0.1	11.1 km
2	0.01	1.1 km
3	0.001	110 m
4	0.0001	11 m
5	0.00001	1.1 m
6	0.000001	0.11 m
7	0.0000001	11 mm
8	0.00000001	1.1 mm

3) GPS Speedometer

Speed is the measurement of distance over time. But a car speedometer doesn’t actually measure how fast you travel from Point A to Point B. Car speedos usually work by measuring rotation of the car’s drive shaft, axle or wheel. They then use some basic math to extrapolate that rotation and determine how fast you are travelling. It’s a very similar concept to a bicycle speedometer. However, if the diameter of the wheel/tire alters, the extrapolation calculation will be incorrect. For example, the diameter will increase if you put new tires on the car or increase the tire pressure. This means that, for each revolution of the wheel, the car is travelling further, meaning your speed is greater.

Satellite navigation units (either portable or integrated into the car) calculate your car’s speed by measuring actual distance travelled over time using GPS satellite tracking. They repeatedly locate your exact position on earth via satellite and calculate how far you have travelled, then divide by the time it took for you to travel that distance. The accuracy of this method is determined by satellite signal quality and is unaffected by your car’s tires.

Speed= Distance/Time

B. Data Processing

This can be said as the backbone of the system. This subsystem collects the data from different vehicles and Co-ordinates the data. It is a web based application. It acts as an interface between the user and the system. Central server accepts the data send by the application in the URL format. It evaluates the data before storing it in the database. These data consists of co-ordinate values of the potholes, speed of the vehicle and the accelerometer difference value. The analysis of the captured data is done at Server Side and it is used to derive the conclusion from analyzed data i.e. whether road is safe to journey or not is carried out and Store it on the web server.

C. Plotting the Data

This subsystem is used to share the stored data in the central server to everyone. It is a web application to display the condition of the road. This subsystem displays the details of the road as per the location data present in the central server. In this method we can plot the markers in the map for every latitude and longitude values present in the server. We are using different markers to differentiate the severity of the road condition. These severity measures are done at the server side along with the clustering. If any of the clusters have more values, then we can mark this location as severely damaged road. We Plot the road conditions based on the surveillance values and the analyzed values from the data module. Fig. 5 shows the example values plotted in the map.

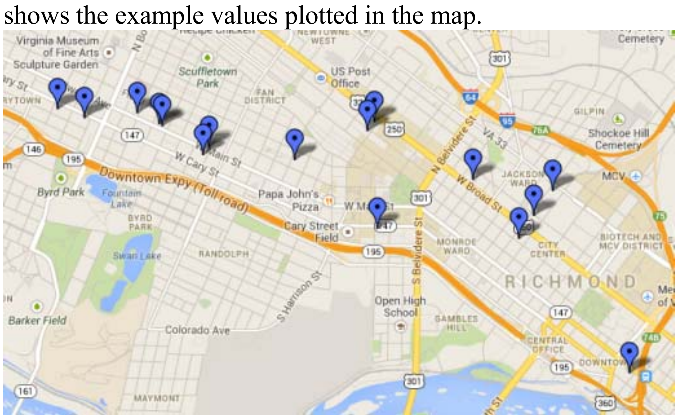

Fig. 5. Road condition displayed in the map

IX. CONCLUSION

Roads has to be monitored continuously for maintaining the roads to avoid the inconvenience of the road users. The result of this activity led to the conclusion that the possibility of determining the road condition using mobile sensors. The main aim of this research activity is to find out the location of potholes and bumps in the road using the mobile sensors. It is a cost efficient system for maintaining the road condition. Smartphone sensors are having more importance in this research, as they are cost effective and increase scalability.

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