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Estimation of Road Surface Roughness Condition from Android Smartphone Sensors

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Abstract— In day to day life transport to the desired location is the most common activity. Road plays vital role in the whole process of transportation. It is necessary that road condition should not be bad in any case for safety and avoid inconvenience. The road bump is kind of conditions which are needed to immediate monitoring and sharing. Currently, the implementing methods for road bump detection are done by a human visual confirmation and a mechanical measuring of road surface shapes by using profile meter. It needs to use many human resources, long lead time and special equipment. In proposed system, the road bump detection method, which is named Bump Recorder, that can be done more easily, is proposed. Bump Recorder is one kind of the extensional smartphone probe which can be put on the vehicle dashboard, and the vehicle is driven as usual. At first, pedometer gets used for the prototype Bump Recorder which is, the bump detection principle and an actual measurement result are explained which was measured at the Niigataken Chuetsu-oki Earthquake in 2007. And next, for the first generation Bump Recorder which is used the three-dimensional accelerometer that is installed on the smartphone, the bump detection logic and experiment result are explained. At last, for the second generation Bump Recorder which is used three-dimensional gyro sensor is explained. In proposed system, road smoothness (Quality) and Ghats (kind of hilly road) complexity analysis will be performed by using GPS system of smartphone and with the help of different sensors like accelerometer, magnetometer, etc. of phone. Information about analysis of the road roughness and Ghats will be uploaded on central server which will be used by user through app during travelling gives reliability & awareness about the road.
Index Terms—mobile sensing; potholes; accelerometers; magnetometers; algorithm

I. INTRODUCTION

Road roughness condition is the irregularity in the road surface that usually occurs due to the deterioration of the road surface over time, the type of the surface material, and quality of the pavement work. 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. In developing nations, particularly, maintaining a good quality road infrastructure is a big challenge for almost all road authorities. To obtain road surface condition data, which is crucial for the maintenance and management planning, there are two main approaches listing from visual inspection and the use of sophisticated profilers. The former approach, though quite accurate, is labor intensive and very time consuming because it relies mainly on manual inspection of the inspectors.

II. LITERATURE SURVEY

It is increasingly common to find many useful sensors on today's smartphones. Beside the use in the smartphones' user interface and features, many researchers and developers have also adopted the sensors for use in numerous applications in several fields and purposes [1].Dangerous road surface conditions are major distractions for safe and comfortable transportation. Both drivers and road maintainers are interested in fixing them as soon as possible. However, these conditions have to be identified first [2].

Maintaining and monitoring road infrastructure is a challenging task for almost all governments and road authorities. One of the reasons is that the task requires the collection of substantial amount of road network condition data, which is very important for maintenance planning and monitoring, over time, in addition to the significant efforts that have to be directed to actual maintenance of the road network [3]. Municipalities around the world spend millions of dollars to maintain and repair their roadways.1 Despite this investment, few people are happy with the quality of the roads where they live or work. The reason is that bad roads damage vehicles, are sometimes hazardous to drivers and pedestrians, and, at the very least, are annoying to drive or bike on [4].

The analysis and maintenance of a road surface is a difficult problem that pavement engineers have been facing for many years. Detection of the condition of a road profile is important for many reasons, such as safety and economic savings, but profiling methods using direct measurements of the road itself are usually expensive. The aim of this paper is to develop a method of estimating the general condition of a road by utilizing technology that increasingly exists in everyday vehicles [5].

Road surface condition information is very useful for road users because with the availability of such information, road users can avoid or be cautious of the bad road ahead. In addition, for road authorities, the information is very important as it can be applied in decision making processes especially for strategic planning such as asset management planning, maintenance planning and programming [6].

Road pavement condition can be defined by the irregularity, which may be in the form of surface unevenness, potholes, cracks, deterioration or damages and so forth, in the pavement surface that adversely affects the ride quality of vehicles. Road roughness is an internationally accepted indicator to which it is usually used to measure the condition of road pavement. Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs. The International Roughness Index (IRI) is a measurement indicator that has been used internationally for road pavement condition [7].

Roads are key part of the people in their lives. Hence monitoring the road conditions has expected a significant amount of attention. Road smoothness is one of the most important road condition measure and primary indicator of the utility of roads [8].

III. UNDERSTANDING PROPOSED SYSTEM

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 and Ghats complexity analysis 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.

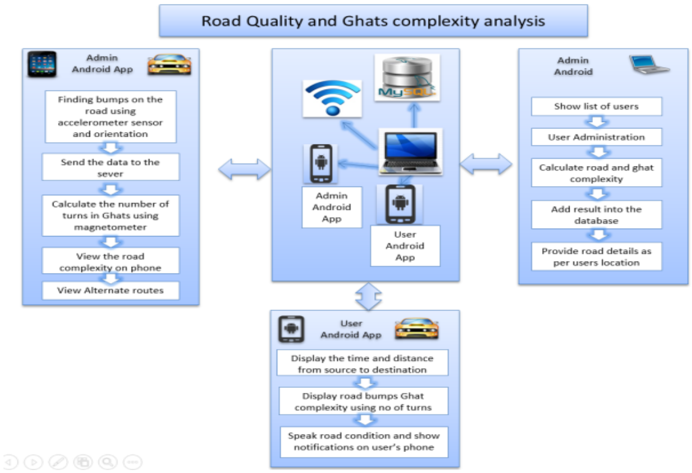


Figure 1:System Architecture Design

a.Admin Android App

This module helps in finding bumps on the road using accelerometer and orientation sensors. The admin is responsible to collect the data of required path using his Smartphone. A standard value is considered as sensitivity as sensitivity differs from Smartphone to Smartphone. This helps in considering proper values for the co-ordinates.
Connection is established between central server and Android Admin App. This data is send as a text file on the central server by the admin app .Every millisecond the text file or log file is updated. Admin Android App helps in calculating the number of turns in Ghat(hilly Road) using magnetometer sensor.

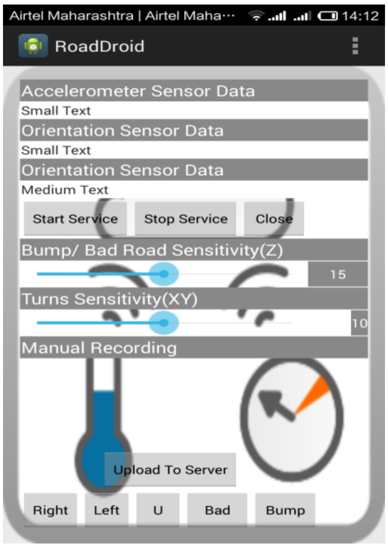


Figure 2: Admin App

b.Central server

It is a web based application. It acts as an interface between admin and the user. Central server accepts the text files send by the admin app. It evaluates the data from the text file. Text file consists of co-ordinate values per mille-seconds. Standard deviation is performed on the text file and appropriate values ar1e considered. Graphs are generated of X, Y and Z coordinates.
Date-wise log of text files is maintained at the server end. Central Server also has list of users. This module is responsible for calculating road and ghat complexity and adds the result into database. Other main function of central server is to provide data to the user as per user's requirements.

c.User module

This module gets road details as per his location from the central server. In User android App of the User, Time and Distance from source to destination is displayed. Road conditions are displayed in different colors on the map. Alternate routes are displayed on the app.

Figure 3: User App

Working of the system:

i. Bump Detection

The lowest layer of the system is on the application running on the Smartphone. The application collects data from the accelerometer, magnetometer and GPS and then processes this to detect braking and bump events. It then attaches a time and
Location tag to this event data, and sends it across to the web server for further processing.
Bump is detected using sensor data gathered from admin phone, details of location of bump is stored on the server side for other users.

ii. Finding Ghats complexity:

As we have seen the data which we get from accelerometer and magnetometer, in that we consider y axis for Ghats detection, here we calculate the angle of 'Y' axis with the north direction by which we can get how much car is turned at right or left side. For this we also consider the previous angle of 'Y' axis with north direction. This helps to count the number of turns in specific alarm, and also we can conclude how much they are tough.

iii. Evaluation Of Road at Server Side

The REST web service on the server receives the event traces of several Smartphone's along with the time and location tags. Using this information, the web service infers higher level of evaluation such as road is smooth or it is with too much speed bump, Ghats are too complex or they are easy to drive, etc.

iv. Make data available to Other users

The web service needs to send over the inferred events to the Smartphone running the application. The Smartphone sends over its location, and the web service responds with events of interests in the vicinity of this location. These events are displayed on a map on the phone, so that the user of the application can choose to take alternate routes based on this.

IV. EXPERIMENTAL RESULTS

1. Road Bump Detection Logic

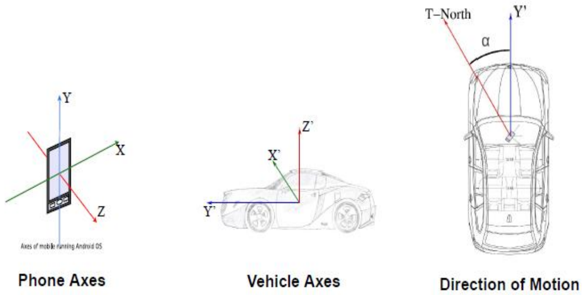


Figure 4: Axes & Directions

Based on the experiment result, road bump detection logic is designed as follows.
Condition 1: Both of the Y-axis or running direction and Z-axis or vertical direction, 50[ms] Standard deviation is large.
Condition 2: These sections are appeared with wheelbase time.
Here, each variable is defined as follows. A recording order number is defined 'i'. An acceleration data are defined X(i), Y(i), Z(i) for each axis. For Y-axis or running direction and Z-axis or vertical direction, 50[ms] standard deviation is defined SDy(i), SDz(i). For the condition 1, simultaneity index is defined SDyz(i), and it is calculated by equation 1.

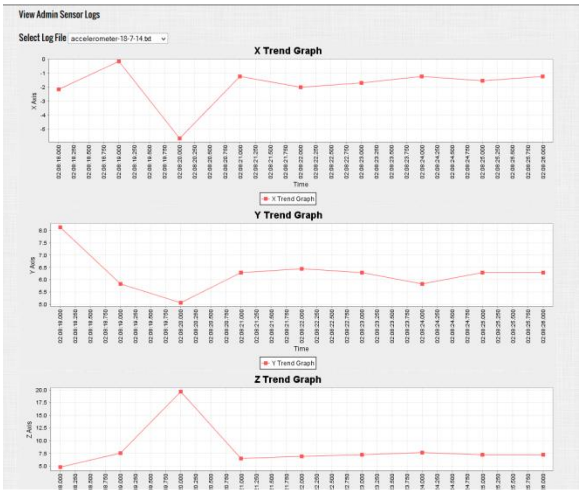
$$SDyz(i) = SDy(i) * SDz(i) \qquad \text{------- (equation 1)}$$

Cycle number of wheelbase time is defined Nw. For the condition 2, Bump Index is defined Byz(i), and it is calculated by equation 2.

$$Byz(i) = SDyz(i) * SDyz(i + Nw) \qquad \text{------- (equation 2)}$$

Nw is related with vehicle speed. Vehicle speed is defined V[m/s]. Vheelbase is defined Lw[m].Recording cycle is defined H[Hz]. Nw is calculated by equation 3.

Nw = (Lw/V) * H ------- (equation 3)



Graph 1:Server Side Axes Graph

This logic is applied to data. The 50[ms] standard deviation of Z-axis acceleration or vertical direction SDz(i) is drawn in Fig. Simultaneity index SDyz(i) is drawn in Fig.
Bump index Byz(i) is drawn below:

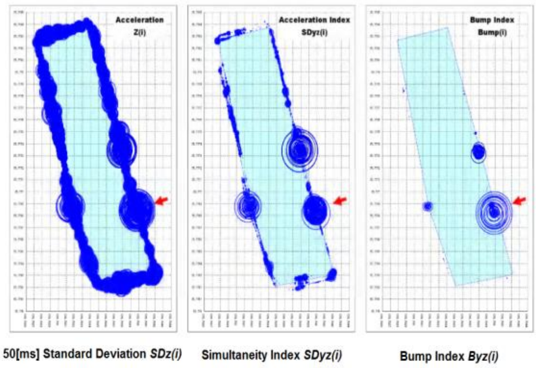


Figure 5 : Standard Deviation

Standard Deviation(SD):

$$\sigma = \sqrt{\frac{\sum(x-\overline{x})^2}{N}}$$

$where$

$\sigma = the\ standard\ deviation$

$x = each\ value\ in\ the\ population$

$\overline{x} = the\ mean\ of\ the\ values$

$N = the\ number\ of\ values\ (the\ population)$

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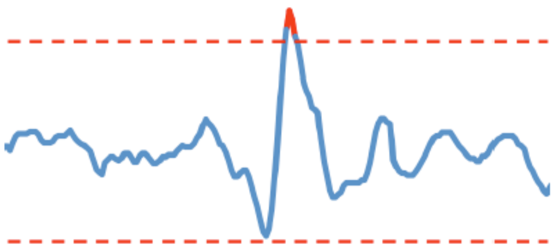

Figure 6: Pothole detection algorithm Z-THRESH. Events are represented by measurements with values exceeding specified threshold levels.

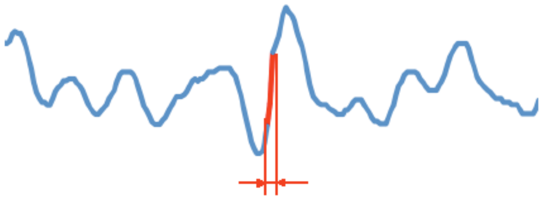

Figure 7 : Detection of Pothole using algorithm Z-DIFF. Events are represented by consecutive measurements with difference value above specific threshold level.

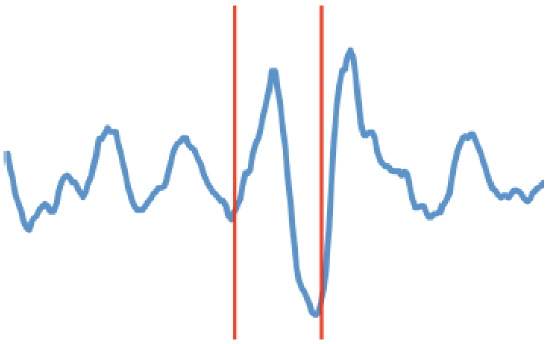

Figure 8: Detection of Pothole using algorithm STDEV(Z). Events are represented by measurements with standard deviation value above specific threshold level.

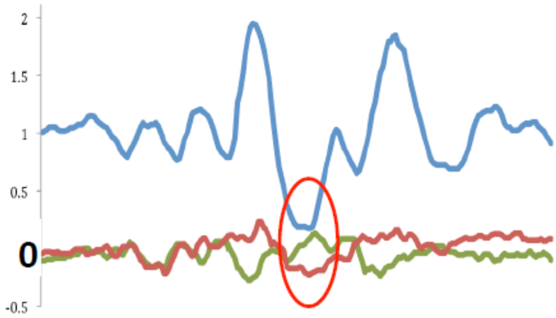

Figure 9 : Detection of Pothole using algorithm G-ZERO. Events are represented by tuple of measurements with all three axis values below specific threshold level.

2. Location Based Distance Calculation

This uses the 'haversine' formula to calculate the circle distance between two points – that is, the shortest distance over the earth's surface – giving an 'as-the-crow-flies' distance between the points.

Haversine formula:

$a = \sin^2(\Delta\varphi/2) + \cos(\varphi 1).\cos(\varphi 2).\sin^2(\Delta\lambda/2)$

$c = 2.\text{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$d = R.c$

Where φ is latitude, λ is longitude, R is earth's radius (mean radius = 6,371km)

Note that angles need to be in radians to pass to trig functions!

V. CONCLUSION

Capturing sensor data from Android Smartphone Application Get speed information of vehicle. Analysis of the captured information is done at Server Side and Drawing conclusion from analyzed data i.e. whether road is safe to journey or not is carried out and Store it on the web server.

The main aim behind such scenario is to Display Road Bump, Potholes and whole Roughness of Road Surface on users' phone Also Display user's current location and alternate routes on map and Sending rout information as per his location updates So that user can avoid Bad roughness condition which may cause uncomfortable ride, extra fuel consumption, unexpected vehicle maintenance costs and safety.

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