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# ESTIMATION OF ROAD ROUGHNESS CONDITION BY USING SENSORS IN SMARTPHONES

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**ABSTRACT**

*Today's every smartphone is integrated with many useful sensors. The sensors are originally designed to make the smartphones user interface and applications more convenient and appealing. These sensors are potentially useful for many other applications in different fields. The smartphone sensors like accelerometer and orientation are used to estimate road roughness condition. These sensors are used to collect vibration data. Using these sensors data about road is collected. The smartphones are placed at more realistic locations and under realistic manner inside a moving vehicle to collect the data which is useful to evaluate its relationship with the actual road roughness. In this paper, road roughness (Quality) and Ghats complexity analysis using smartphone proposes to utilize the GPS system of phone and different sensors like accelerometer, magnetometer, etc. of phone, so we can analyze the road and can upload this information of that road on central server so every application user can use this information during traveling.*

**Key words:** Smartphone, Accelerometer, orientation, Road smoothness and practical settings.

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## 1. INTRODUCTION

Road roughness is one of the most important road condition measure and primary indicator of the utility of roads. As roads are key part of the people in their lives,

hence monitoring the road conditions has expected a significant amount of attention. So the road users can avoid or be cautious of the bad road ahead by using road surface condition information. By looking importance of road that initiates the development of the road surface inspection system. Road roughness condition can be defined by the irregularity, which may be in the form of surface bumpiness, potholes, cracks, corrosion or damages and so forth, in the pavement surface that adversely affects the ride quality of vehicles.

To Maintain and monitor road infrastructure is a challenging task for almost all governments and road authorities. The reason for this is that the task requires the collection of large amount of road network condition data and which is very important for maintenance planning and monitoring in excess of time, addition to the significant efforts that have to be directed to actual maintenance of the road network. In the developing countries, the concentration on the data collection is generally ignored or neglected mainly due to the need of technology and budget. Therefore in these countries, road smoothness condition data is often left out-of-date and this makes difficult for correct planning and programming of the maintenance. One of the most important road condition measures throughout the world is road roughness and it is constantly recognized. The time to time recording of roughness data allows pavement managers to review the smoothness progression rate of pavements and to take appropriate action as a result[1]. The Road smoothness condition is measured by the International Smoothness Index (IRI) and that has been used widely for road infrastructure maintenance and monitoring for many years [2]. To measure IRI, many approaches are available but majority of them on one hand requires sophisticated profilers and tools and which are expensive to buy and for operating on it requires skillful operators. On the other hand, a popular practice in many developing countries is visual inspection. The visual inspection is relatively cheaper option and it is very labor intensive and time consuming.

The use of smartphone to collect the data is a promising alternative because of its low cost and easy to use feature in addition to its potentially wide population coverage as probe devices. In the previous study [3] they explored the use of smartphones fixed to vehicles with predetermined orientation to estimate road smoothness where promising results have been observed. The proposed system will take a further step by attempting to estimate road roughness from smartphones under more practical settings, which is away from fixed orientation of standalone accelerometer. The collection of data is fast. This means the smartphone are located on dashboard inside a car while driving.

To estimate road surface condition, the smatphones are a very helpful. Because the smartphones already have sensors that are able to record useful reading for road surface condition estimation likewise to those used in many high-tech profilers. As the number of smartphone users are rapidly increasing, that means the chance of having plenty of data with inexpensive investment is large. For this reason, the approach is not useful only for developing but also for developed countries.

After the collection of data using smartphone phone, the data is analyzed with simple techniques. The road surface condition is estimated based on analyzed data. The data is available to road condition system for useful to application users.

The system for road smoothness estimation can be viewed as following

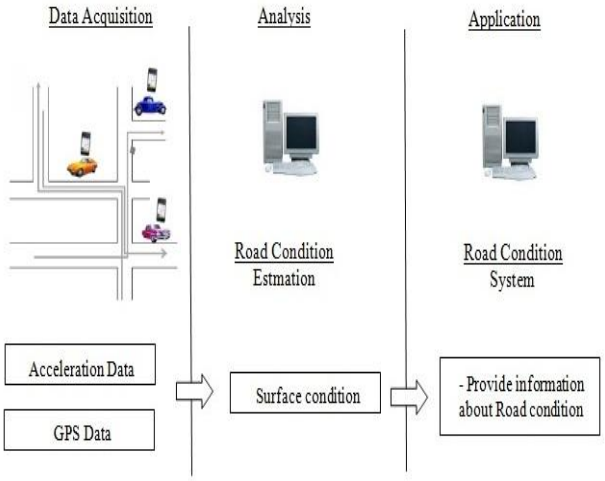



**Figure 1** Conceptual image of road condition system

## 2. RELATED WORK

We present the related research in a systematic manner which enriches our work. The smartphones are used to estimate IRI of road roughness in very limited studies. In previous studies, most of the interest in detecting road bumps and anomalies using mobile sensors.

Cashell, K et al. [4] proposed a system that make the use of a separate accelerometer to fit in a simulation car and use it to assess road roughness condition . The roughness of the road can be estimated from acceleration data obtained from the sensor.

In[5] authors, Eriksson, Girod,, Hull, Newton, Madden, Balakrishnan have developed a system to utilize standalone accelerometers to successfully detect road anomalies. This system uses three axis acceleration sensors and GPS devices deployed on embedded computers in cars.

Ramjee et al. [6] made the use of many sensing components to monitor road conditions from mobile phone [11]. The potholes, bumps, braking and honking can be detected by analyzing data from the sensors,. Then the information is used to assess road conditions. This system is called as Nericell arranges the smartphones to perform sensing and report data back to a server for aggregation.

Selavo et al. [7] and Strazdins et al. [8] have uses Android smartphone devices with accelerometers are used to detect potholes location on road. The approaches for detection includes algorithms like Z-THRESH, Z-DIFF, STDEV(Z), G-ZERO to detect events in the acceleration vibration data.

Tai, Y. et al. [9] explores the use of mobile phone with a tri-axial accelerometer to collect acceleration data while riding a motorcycle. Both supervised and unsupervised machine learning methods are used to identify road conditions.

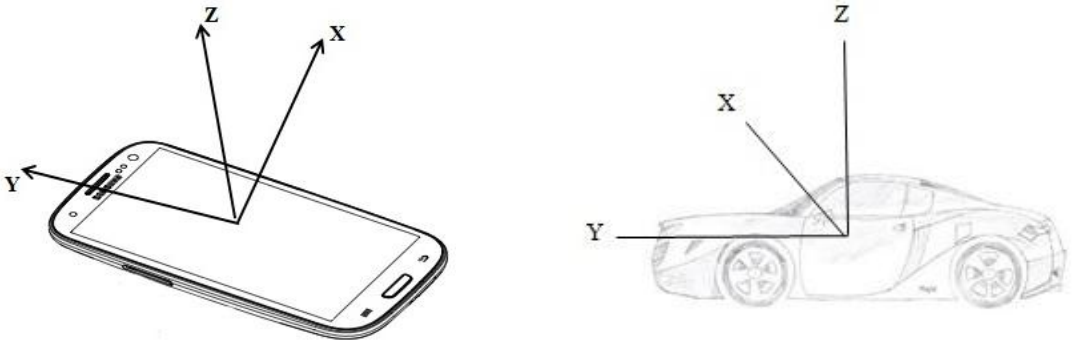
In [10] authors, Perttunen, Mazhelis, Cong., Kauppila, Leppänen, Kantola, Collin, Pirttikangas, Haverinen, Ristaniemi have analyze data obtained by smartphone accelerometers in frequency domain to extract features that are corresponding to road bumps. They developed a pattern recognition system for detecting road condition from accelerometer and GPS readings.

## 3. PROPOSED SYSTEM

The proposed system is used for estimation of road roughness condition (Quality) and ghat complexity using smartphone (android phone). It utilizes the GPS system of

phone and different sensors like accelerometer, magnetometer of android phone, so we can analyze the road and can upload this information of that road on server so every user can use this information during travelling.

The system take the data as x, y, z co-ordinates and the axes can be viewed as along with vehicle axes and phone axes.




**Phone Axes** **Vehicle Axes**

X-axis Horizontal Direction
Y-axis Running Direction
Z-axis Vertical Direction

**Figure 2** Axis Direction

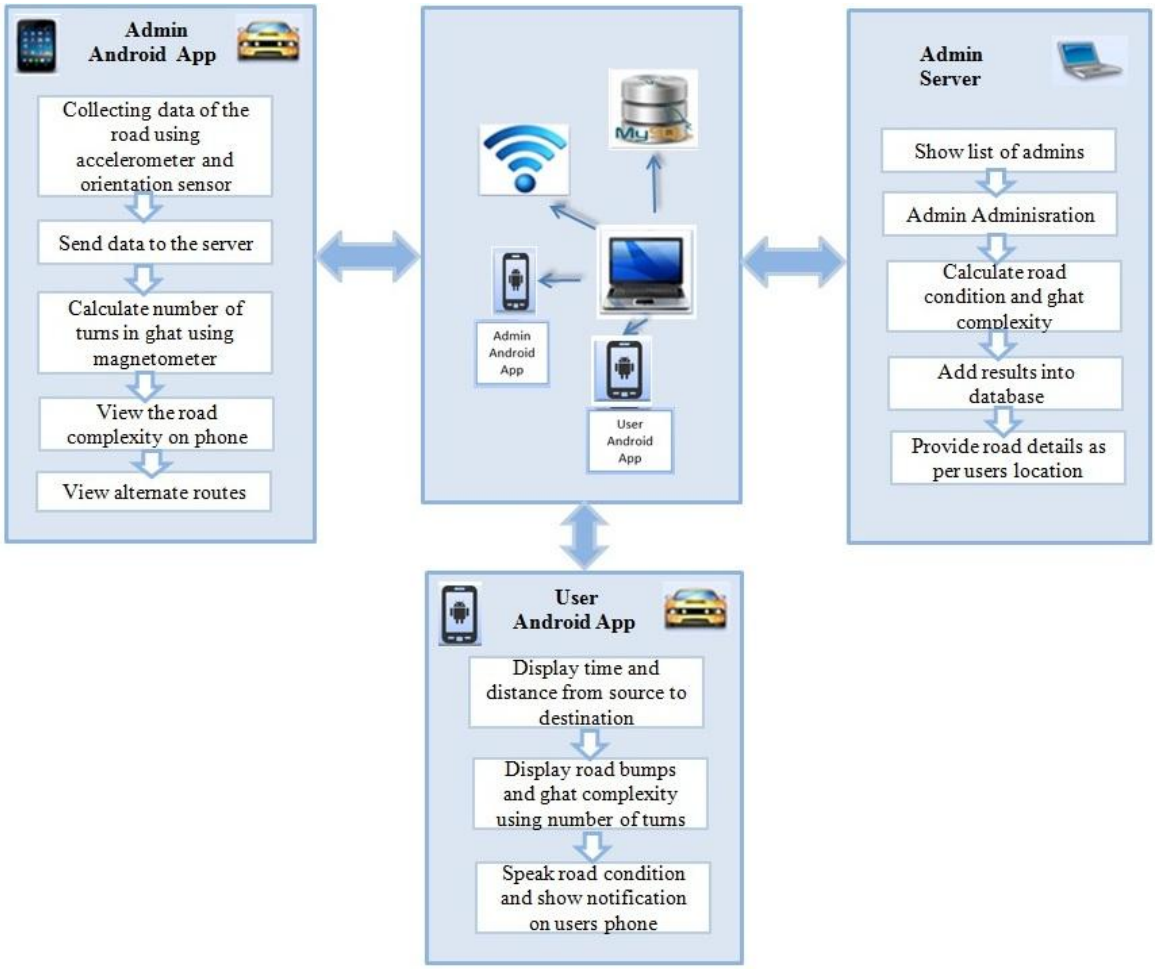



**Figure 3** System Architecture

The above figure shows architecture of road roughness condition detection system. There are three modules that are connected through internet.

The admin android app collects the data using smartphone sensors in text file. The text file is send to the admin server for analysis. The analyzed data is stored in database for later uses. The user android app is useful the user for knowing road smoothness.

The system can be viewed as to perform various functions like:

### 1. Detection of Bump

In the detection of bump, the data is collected using accelerometer, magnetometer and GPS system and this data is processed to detect braking and bump events. The data is collected at every millisecond. The data is collected in the form of x, y, z, co-ordinates as txt file. The data is attached with a time & location tag, sending the data across the web server for further processing. For bump detection standard deviation of y and z coordinate are calculated . As, if the bump is occur the y and z coordinates are affected so, need to consider both values. Bump is detected if the deviation is large. Information is stored on server side for other users.

### 2. Finding Ghat complexity

In ghat complexity estimation, we consider Y-axis for ghat 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 ghat, and also we can conclude how much they are tough.

### 3. Evaluation of road at server side

At server side for evaluation consider the data with time and location tags from android phone. The data is processed using statistical analysis and k-means clustering algorithm. From processed data the bumps on road and ghat complexity is analyzed. 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 simple to drive, etc.

### 4. Make data available to other users

The information about the road is displayed to the user as per requested location. These events are displayed on a map on the mobile, so that the application user can choose alternate routes based on this.

## 4. ALGORITHMS

The main algorithms used in proposed work are illustrated in this section:

### 4.1. Road bump detection logic algorithm:

This algorithm is used for detection of road condition as follows:

1. Collection of data

A recording order number is defined as i.

An acceleration data are defined X(i), Y(i), Z(i) for each axis.

The data is stored in text file. Different text files are generated for accelerometer and orientation sensor .

2. Text files are send to server and data gets separated
3. Calculation of standard deviation

The standard deviation is calculated by:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{N - 1}}$$

SDy(i)-standard deviation of Y-axis

SDz(i)-standard deviation of Z-axis

4. Calculation of simultaneity index

$$SDyz(i) = SDy(i) * SDz(i)$$

5. Road condition:
   i. Consider Y and Z coordinates value. Calculate difference between current z value and previous z value.
   ii. If difference is greater than two and current y value is less than zero then road bump is recorded.
   iii. If difference is less than minus two and current y value is greater than zero then Bad road is recorded.
6. Ghat complexity:
   i. Consider X and Y coordinates value. Calculate difference between current x value and previous x value . Also calculate difference between current y value and previous y value.
   ii. Set turn sensitivity. If difference x and difference y is greater than turn sensitivity then it is right turn.
   iii. If difference x is greater than turn sensitivity and difference y is less than turn sensitivity then it is left turn.
   iv. Ghat complexity is decided on number of turns .

### 4.2. K-means clustering Algorithm

This algorithm is used for analysis of data and for deciding bump on road.

Input:

K: Number of clusters

D: A dataset containing n objects

Output: A set of K clusters

Method:

1. Arbitrarily choose K objects from D as the initial cluster centers.
2. Repeat.
3. Assign each object to the cluster to which the object is most similar based on the mean value of the objects in the cluster.
4. Update the cluster means that is calculate the mean value of the objects for each cluster.

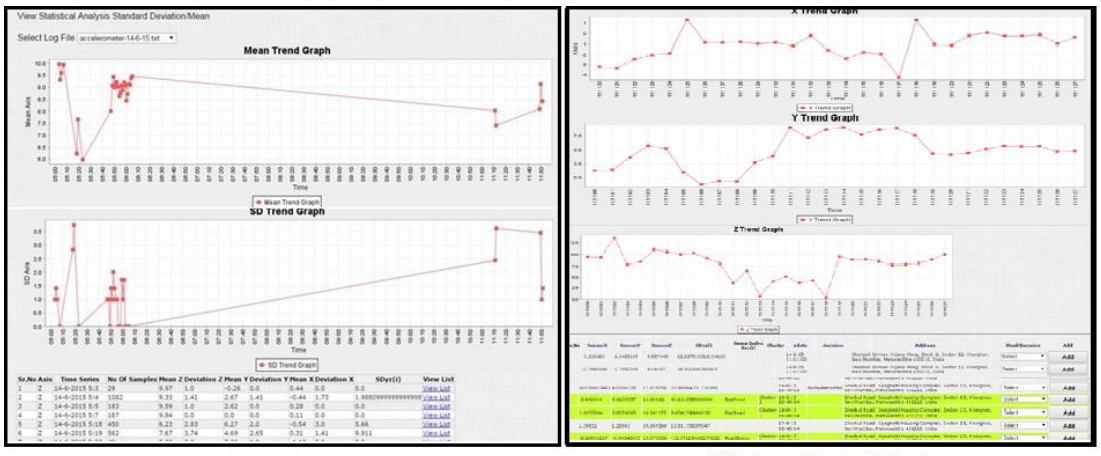
5. Until no change .

## 5. RESULT

The proposed system results are shown below. Figure 4 shows application which is used for collection of data using smartphone sensor . When we select start analysis button then the second window which is shown in figure 4 is displayed. After starting start service button the data gets collected by the use of phone sensor. This data is uploaded to server for analysis purpose and to know road condition. Figure 5 shows statistical analysis and road condition. Figure 6 shows user android app which is used to know road condition as per user requirement.


**Figure 4** Admin Android App

Data collection




a. Statistical analysis of collected data

b. Showing road bump and bad road

**Figure 5** Admin Server


**Figure 6** User Android App

## 6. CONCLUSION

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. We can use the accelerometer, magnetometer and GPS system and use this information to estimate road roughness/quality and Ghat complexity. The use of smartphones because of its low cost and easy to use feature in addition to its potentially wide population coverage as survey devices. The data about road condition is necessary for proper maintenance and programming of road. Road surface condition information is very useful for road users because with the availability of such information, road users can avoid or be careful of the bad road ahead. This information is useful to user during travelling. 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. It is useful for user whether road is safe to journey or not.

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