

# Condition Assessment of Pavements Using Smartphone

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**Abstract**— Evaluating the condition of pavements is an expensive, labor intensive, and time consuming process. Many traditional road evaluation methods utilize measurements taken in situ along with visual examinations and interpretations. Smartphone based pavement condition assessment is a geo in form tic method. An android based application named Andro Sensor was used to collect data from various sensors such as accelerometers available in smart phones. Smartphone was fixed over the dashboard of a car and the data were collected. The acceleration values obtained from accelerometers were analyzed and the relation between the occurrence of major pavement events such as potholes, bumps, left turn, right turn and the these values were found out. The relation between normal braking, sudden braking etc. due to pavement distresses and the acceleration values were also analyzed. A JAVA program was coded to reduce the computations in finding the presence of these events on the pavements according to the acceleration values. Rough meter was used to validate the results. It was concluded that, although Smartphone based method can never entirely replace traditional methods, they do provide an opportunity to reduce the number or size of areas requiring site visits or manual methods

**Index Terms**— Andro Sensor, JAVA program, Pavement condition evaluation, Roughometer, Smartphone based pavement condition assessment.

## I. INTRODUCTION

Providing safe and smooth surface for a traveling public is the basic purpose of a pavement. Drivers and road maintainers are concerned in fixing them as soon as possible. Engineers and managers are concerned in developing a cost effective maintenance and rehabilitation program. Assessing the pavement begins with data collection.

Pavement condition data are traditionally obtained by human inspectors who walk or drive along the road and they assess the distresses and produce report sheets. Some special instruments can also be used for pavement condition analysis. But it is not cost effective or time efficient. Pavement condition analysis can be done in a swifter and safer manner using remote sensing methodologies. It provides new potential for pavement managers to assess large areas in less time. "Pothole Patrol (P2)" is a sensor network system, which is used to identify potholes and other severe road anomalies.

Various algorithms such as z peak filters, x-z ratio filters etc. are used to reject non pothole events. [3]. Another method was described by Mednis et. al, which describes a mobile sensing system for road anomaly detection using Android OS based smart-phones. As in the case of pothole

patrol system, the test data was collected first. After the acquisition of the first test dataset, a search for potential event related features was performed. Here Z-THRESH, STD DEV Z algorithms etc. were used. [4]. The system used by Mahajan et.al, utilizes smartphones for estimating road roughness conditions. The GPS system of phone and different sensors like accelerometer, magnetometer of android phone etc. were considered to analyze the road.[6]

The geo informatics method used in this study utilizes the accelerometers present in smart phones. It obtains the x, y, z acceleration values of various points. Acceleration is more than rate of change of speed. If we pick up an object and throw it horizontally, we can notice how its horizontal velocity gradually becomes more and more vertical. Since acceleration is the rate of change of velocity with time and velocity is a vector quantity, change in direction is also considered as acceleration. [1] Accelerometer is a device that measures total specific external force acting on it. A pattern recognition system can be developed from accelerometer and GPS readings. [5] Driving events, such as left turn, right turn, sudden braking and sudden forward acceleration, and road conditions, such as pothole, bump and rough patch can also be detected using this. [6]

The IRI values measured by the smart-phone application roughness capture were found similar to those

collected with the inertial profiler. A good correlation between the two methods was observed, without the need for system calibration. Experiment was repeated five times to assess the repeatability of the “roughness capture” android-based smart phone application [2].

Roughness data was also collected using rough meter III instrument in this study. Rough meter III was designed to provide roughness data for both sealed and unsealed roads, to assess the performance of any road network. The Rough meter III’s outputs can be used to provide objective data for true evaluation of the roughness level of the road objectively compare and analyze which roads are in need of remedial repair and to monitor roughness deterioration trends, reviewing successive survey results spaced over several months. [8]. The correlation between the results from rough meter and Androsensor was analyzed.

The objective of the present study is to develop a pattern recognition system for assessing the road condition so that we can identify the road stretches which needs immediate repair or reconstruction.

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## **II. METHODS AND PROCEDURES**

### **A. Study Area**

The data was collected from different road segments within Thiruvananthapuram district. This includes, NH/Bypasses, SH, major district roads, minor district roads etc. But majority of the stretches considered were within Trivandrum Corporation limits. The condition of the pavement changes due to various factors such as rainfall, wind, temperature changes, method of construction, type of the pavement etc. So, the road stretches were chosen according to the condition of the road during the time of data collection.

### **B. Data Collection Using AndroSensor**

Android-based cell phone applications are available that can capture acceleration for the purpose of characterizing pavement roughness and individual pavement distresses. One such application is AndroSensor. It is an Android application that can collect data from almost all of the sensors available on the handsets and it is available for free download in Google Play Store. For

analyzing pavement conditions, only acceleration data (x, y, z) from accelerometer; location data (longitude, latitude, speed etc.) from GPS are needed. AndroSensor can keep track of all of our device’s sensors. AndroSensor allows tracking the device’s GPS, Accelerometer, Magnetic Field, Orientation, Proximity, Battery Status, and Sound Level. This application is used to collect the data for the present study. Readouts based on location are given in Latitude and Longitude; readouts based on device position are given based on the position of the device’s axis.

Androsensor application was installed in a Karbonn Titanium Smartphone and it was fixed on the dashboard of a car using a double sided tape. Using this application, the x, y, z acceleration data, speed data, time data, location data etc. were obtained. An accelerometer in a good functional state when left on a flat table must show the x and y axis acceleration values fluctuating close to 0 and z axis acceleration value close to  $9.81 \text{ m/s}^2$ . This condition was satisfied while checking the acceleration values calculated using the AndroSensor. Its accuracy was  $0.00390625 \text{ m/s}^2$ .

### **C. Capturing of Video**

During the time of this data collection, a high resolution camera was fixed over a tripod and placed inside this car. It was used to capture the video of the road stretch where the experiment was performed. This was later used for validating the results.

### **D. Plotting x, y, z Acceleration Values vs. Time Graph**

The x, y and z acceleration values of various road stretches were plotted against time to identify the threshold acceleration values of different pavement events.

## **III. RESULTS**

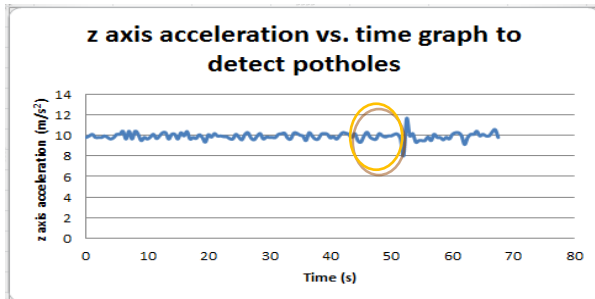
The results of the study are discussed under the following sessions.

### **A. Detection of the Presence of Pothole**

Accelerometer data for different types of potholes present on Koriyama- Parottukonam road, Plamood-Karyavattom road, Chempakamangalam-Alamcode road etc. were collected. The x, y, z acceleration values vs. time graphs for these potholes were plotted. By analyzing this, it was found that, if the change in adjacent values of z axis acceleration is greater than 2, then it indicates the presence of a pothole. Figure 1 shows the z axis acceleration vs. time

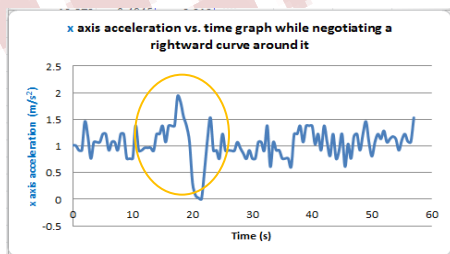
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graph of a pothole present in Kariyom (8.553722 latitude, 76.91723 longitude) –Parottukonam (8.572122 latitude, 76.92504 longitude) road stretch.



**Figure 1: z Axis Acceleration vs. Time Graph of a Pothole**

The above graph occurred while riding over a pothole. But if the driver avoids a pothole while driving, by negotiating a curve around the periphery of the pothole change in acceleration values will be different. Here the x axis acceleration values either decrease first and then increase or increase first and then decrease. First case occurs while negotiating a curve along the left periphery of the pothole and second case occurs while negotiating a curve along the right periphery of the pothole. Figure 2 shows the x axis acceleration vs. time graph while avoiding a pothole along its right periphery. This case occurred while driving along Venjaramoodu (8.680374 latitude, 76.90908 longitude) to Vattappara road (8.593958 latitude, 76.95024 longitude)

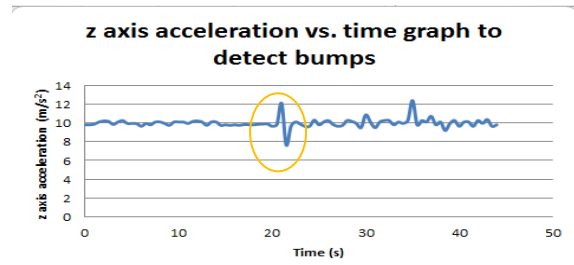


**Figure 2: z Axis Acceleration vs. Time Graph of a Pothole**

**Detection of the Presence of Bump**

Accelerometer data for different types of bumps present on Karyavattam to Arishumood road, Vazhamuttam to Kovalam road, Chempakamangalam-Alamcode road etc. were collected. The x, y, z acceleration values vs. time graphs for these potholes were plotted. By analyzing this, it was found that, if the change in adjacent values of z axis

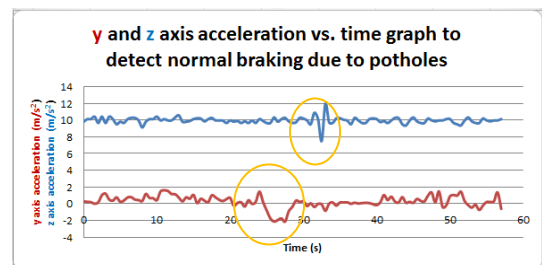
acceleration is less than 2, then it indicates the presence of a bump. Figure 3 shows the z axis acceleration vs. time graph of a bump present in Karyavattam (8.563405 latitude, 76.882851 longitude) –Arishumood (8.564581 latitude, 76.885635 longitude) road stretch.



**Figure 3: z Axis Acceleration vs. Time Graph of a Bump**

**Detecting Normal Braking due to Potholes**

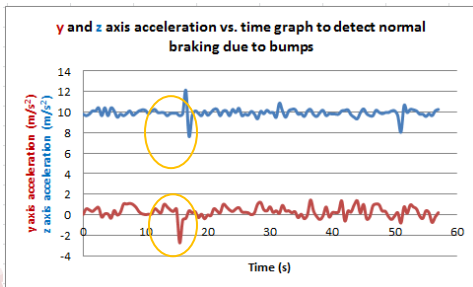
Frequent braking can be due to various reasons such as heavy congestion, bumpy road, environmental factors etc. Here, application of normal brake due to the presence of a pothole is analyzed. While collecting Androsensor readings of various roads, there occurred situations where normal brake was applied due to the presence of potholes. These were found out by replaying the videos of the road captured during the experiment. The x, y, z acceleration values vs. time graphs of these road sections were plotted. By analyzing this, it was found that, if y axis acceleration value ranges from -1 to -3, and change in z axis acceleration value is greater than 2, then it indicates that normal brake is applied due to the presence of a pothole. Figure 4 shows y and z axis acceleration vs. time graph of normal brake application due to a pothole present at Kilimanoor (8.773988 latitude, 76.894245) to Kesavadasapuram (8.582248 latitude, 76.86311 longitude) road stretch.



**Figure 4: y and z axis acceleration vs. time graph of normal brake application due to a pothole.**

**Detecting Normal Braking due to Bumps**

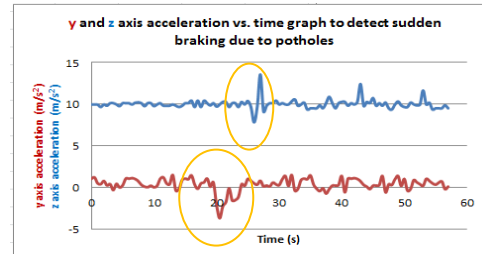
Here, application of normal brake due to the presence of a bump is analyzed. While collecting Androsensor readings of various roads, there occurred situations where normal brake was applied due to the presence of bumps. These were found out by replaying the videos of the road captured during the experiment. The x, y, z acceleration values vs. time graphs of these road sections were plotted. By analyzing this, it was found that, if y axis acceleration value ranges from -1 to -3, and change in z axis acceleration value is less than 2, then it indicates that normal brake is applied due to the presence of a bump. Figure 5 shows y and z axis acceleration vs. time graph of normal brake application due to a bump. This was also present at Kilimanoor (8.773988 latitude, 76.894245) to Kesavadasapuram (8.582248 latitude, 76.86311 longitude) road stretch.



**Figure 5: y and z axis acceleration vs. time graph of normal brake application due to a bump.**

**Detecting Sudden Braking due to Potholes**

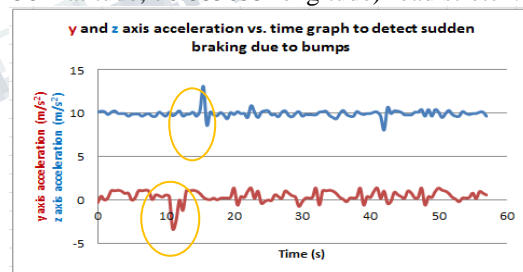
Here, application of sudden brake due to the presence of a pothole is analyzed. While collecting Androsensor readings of various roads, there occurred situations where sudden brake was applied due to the presence of potholes. These were found out by replaying the videos of the road captured during the experiment. The x, y, z acceleration values vs. time graphs of these road sections were plotted. By analyzing this, it was found that, if y axis acceleration value is less than -3, and change in z axis acceleration value is greater than 2, then it indicates that sudden brake is applied due to the presence of a pothole. Figure 6 shows y and z axis acceleration vs. time graph of normal brake application due to a pothole present at Kazhakuttam (8.533004 latitude, 76.872891) to Chavadimukk (8.574004 latitude, 76.91289 longitude) road stretch.



**Figure 6: y and z axis acceleration vs. time graph of sudden brake application due to a pothole.**

**Detecting Sudden Braking due to Bumps**

Here, application of sudden brake due to the presence of a bump is analyzed. While collecting Androsensor readings of various roads, there occurred situations where sudden brake was applied due to the presence of bumps. These were found out by replaying the videos of the road captured during the experiment. The x, y, z acceleration values vs. time graphs of these road sections were plotted. By analyzing this, it was found that, if y axis acceleration value is less than -3, and change in z axis acceleration value is less than 2, then it indicates that sudden brake is applied due to the presence of a bump. Figure 7 shows y and z axis acceleration vs. time graph of normal brake application due to a pothole present at Karyavattam (8.563405 latitude, 76.882851 longitude) –Arishumood (8.564581 latitude, 76.885635 longitude) road stretch.



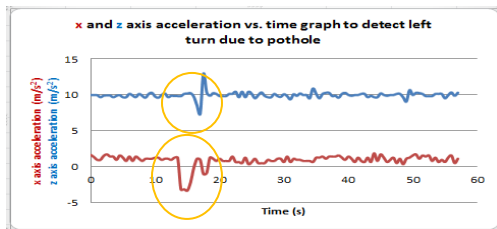
**Figure 7: y and z axis acceleration vs. time graph of sudden brake application due to a bump.**

**G. Detection of Abrupt Left Turn due to Potholes**

In some cases, there will be a tendency for the driver to maneuver an abrupt left or right turns if any pavement distress is seen on the pavement. Here, abrupt left turn due to the presence of potholes is analyzed. Such cases are identified from the videos and the x, y and z axis acceleration vs. time graphs of these sections are drawn. By analyzing this, it was found that, if the x axis acceleration is less than -1 and change in adjacent values of z axis accelerations is greater than 2, then a left turn is caused due to the presence of a pothole. Figure 8 shows such a



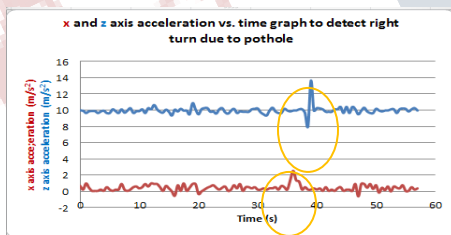
condition occurred while conducting the experiment at Karamana (8.47994 latitude, 76.97062 longitude) to Plamood (8.514617 latitude, 76.9455 longitude) road stretch.



**Figure 8: x and z axis acceleration vs. time graph of left turn due to a pothole.**

**Detection of Abrupt Right Turn due to Potholes.**

Here, abrupt right turns due to the presence of potholes are analyzed. Such cases are identified from the videos and the x, y and z axis acceleration vs. time graphs of these sections are drawn. By analyzing this, it was found that, if the x axis acceleration is greater than 1 and change in adjacent values of z axis accelerations is greater than 2, then a left turn is caused due to the presence of a pothole. Figure 9 shows such a condition occurred while conducting the experiment at Karamana (8.47994 latitude, 76.97062 longitude) to Plamood (8.514617 latitude, 76.9455 longitude) road stretch.

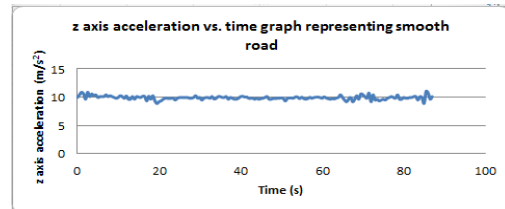


**Figure 9: x and z axis acceleration vs. time graph of right turn due to a pothole.**

**Detection of Smooth Road**

Accelerometer data corresponding to various smooth roads such as Karyavattom-Chempakamangalam road, Kilimanoor-Venjaramood road etc. were collected using smartphone with AndroSensor application. The x, y, z acceleration values vs. time graphs were plotted. By analyzing this it was found that z axis acceleration value for smooth roads is more or less close to 9.81 m/s<sup>2</sup> that is the acceleration due to gravity. Figure 10 shows the z axis acceleration vs. time graph representing smooth road. This

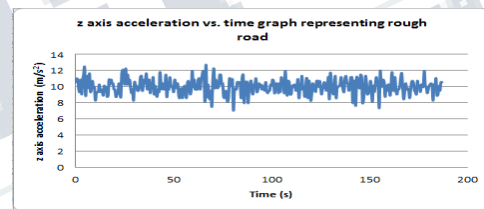
data was collected from Kilimanoor to Venjaramood road stretch.



**Figure 10: z axis acceleration vs. time representing a smooth road**

**Detection of Rough Road**

Accelerometer data corresponding to various rough roads such as Kariyom- Parottukonam road, Sreekaryam-Pulayanarkotta road etc. were collected using the smartphone with AndroSensor application. The x, y, z acceleration values vs. time graphs were plotted. It was seen that the z axis acceleration values varied in a wide range for rough roads. Figure 11 shows the z axis acceleration vs. time graph representing rough road. This data was obtained from Sreekaryam- Pulayanarkotta road stretch.



**Figure 11: z axis acceleration vs. time representing a rough road**

**Threshold Acceleration Values of Different pavement Events**

By using the smartphone with AndroSensor, acceleration data for various pavement events were collected. These were analyzed to find out the exact range of acceleration values to detect the presence of these events. Later, acceleration data for various other road stretches were also collected and found out the location of these pavement events using the identified threshold values. This was cross validated using the videos captured while conducting the experiment. The range of different pavement events identified is shown in table 1.

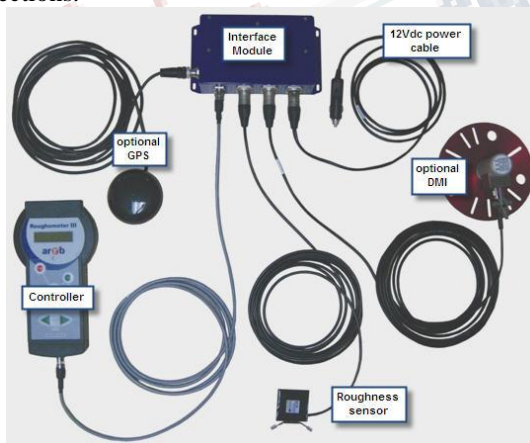
**TABLE I. THRESHOLD ACCELERATION VALUES OF DIFFERENT PAVEMENT EVENTS**

EVENT	AXIS USED FOR DETECTION	THRESHOLD

Normal Braking	y-axis (in negative direction)	-1 to -3
Sudden Braking	y-axis (in negative direction)	<-3
Left Turn	x-axis (in negative direction)	<-1
Right Turn	x-axis (in positive direction)	>1
Pothole	z- axis (change in adjacent values)	>2
Bump	z-axis (change in adjacent values)	<2
Rough Road	z-axis (continuous occurrence of potholes)	+/-1.5

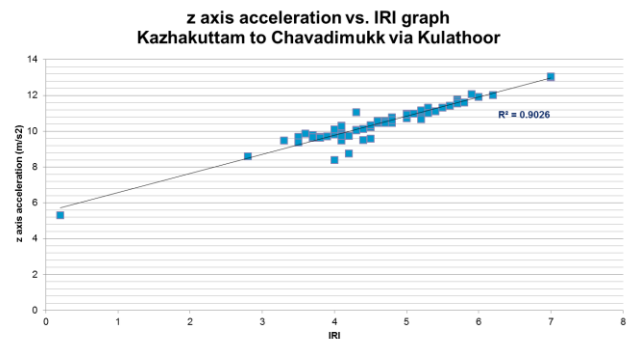
**Correlation between Results of Roughometer and AndroSensor**

Roughometer was used to collect the roughness data of various road stretches. Roughometer is designed to provide roughness data to assess the performance of any road networks. It consists of an interface, GPS, Distance Measuring Instrument, 12Vdc power cable, controller and a roughness sensor. Figure 17 shows the data acquisition hardware components of the roughometer and its connections.



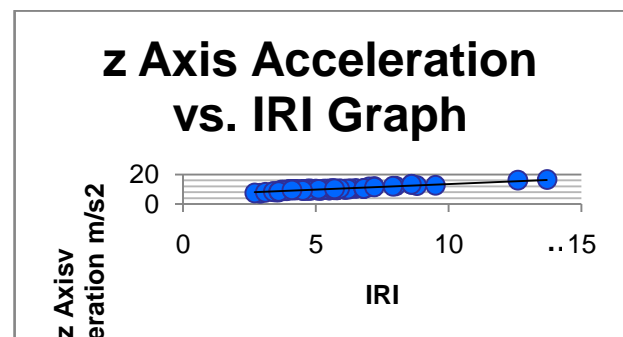
**Fig.17. Data Acquisition Hardware Components of the Roughometer and its Connections**

Experiment was performed by using roughometer and smartphone with AndroSensor at the same time. Graphs were plotted between the IRI values obtained using roughometer vs. change in z axis acceleration values obtained using Smartphone with AndroSensor. Correlation between these values was analyzed. Experiment was performed from Kazhakuttam (8.532992 latitude, 76.92886 longitude) to Chavadimukku (8.574106 lat., 76.86926 long) via Kulathoor. It was found that the average IRI value was 4.6m/km. Figure 18 shows a graph showing the relationship between the change in Z axis acceleration value and the IRI values. It showed a coefficient of determination of 0.9026.



**Fig.18. Change in z Axis Acceleration vs. IRI Values Graph of Kazhakkuttam to Chavadimukku Road**

Similar experiment was performed from Kesavadasapuram (8.514308 latitude, 76.94578 longitude) to Kazhakkuttam (8.582248 lat., 76.86311 long) via NH. Road and the graph showing the correlation between change in z axis acceleration values and IRI values is shown in figure 19. Coefficient of determination was found to be 0.8906.



**Fig.19. Change in z Axis Acceleration vs. IRI Values Graph of Kesavadasapuram to Kazhakkuttam Road**

#### IV. CONCLUSION

The use of Smartphone techniques offers new potential for pavement managers to assess large areas, often in less time. They provide an opportunity to reduce the number or size of areas requiring site visits. The number of Smartphone users worldwide will surpass 200 crores in 2016. Next year, there will be over 191 crores Smartphone users across the globe. From this it is evident that there is an increasing rate in Smartphone users around the world. So if pavement condition can be evaluated using the low-cost sensors present in the smart phones, then it is a promising alternative to all other manual methods. Good correlation between results from Rough meter and AndroSensor shows that Smartphone based method is reasonably accurate. One of the limitations of Smartphone based method is that, it is dependent of vehicle's mass and suspension characteristics. It can be avoided only if the smart-phone is fixed on the axle of the vehicle while performing the experiment.

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