IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

Smartphone Based Pavement Condition Assessment

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Abstract: Evaluating the condition of pavements is an expensive, labour 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 non-destructive remote sensing method. An android based application named AndroSensor was used to collect data from various sensors present in smartphones such as accelerometers, gyroscopes etc. Smartphone was fixed over the dashboard of a car while collecting the data. The acceleration values obtained from accelerometers were analysed to find out its relation between the occurrence of major pavement events such as potholes, bumps, left turn, right turn etc. The relation between the acceleration values and normal braking, sudden braking etc. due to pavement distresses was also analysed. A JAVA program was coded to reduce the computations in finding the presence of these events on the pavements according to the corresponding acceleration values. International Roughness Index values for different road stretches were found out using roughometer III and the correlation between these values and the change in z axis acceleration values obtained from AndroSensor was analysed. It was found to be satisfactory. Hence, 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.

Keywords: AndroSensor, JAVA program, Pavement condition evaluation, Roughometer, Smartphone based pavement condition assessment.

I. INTRODUCTION

Providing safe and smooth surface for a travelling 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 condition 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 (P^2)" 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. [1].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. Z-THRESH, STD DEV Z algorithms etc. were used in their study. [2].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.[3]

The remote sensing method used in this study utilizes the accelerometers present in smartphones. 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. [4] 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 in a study conducted by Buttlar et al. 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

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smart phone application [7].
Roughness data was also collected using roughometer III instrument in this study. Roughometer III was designed to provide roughness data for both sealed and unsealed roads, to assess the performance of any road network. The Roughometer 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 roughometer 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

The methods and procedures of this study are discussed under this section.

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 m/s^2. This condition was satisfied while checking the acceleration values calculated using the AndroSensor.

C. Capturing 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 valuesof various road stretches were plotted against time to identify the threshold acceleration values of different pavement events.

E. Coding of JAVA Program

According to the threshold acceleration values of different pavement events, a JAVA program was coded so that the amount of computation for identification of the location and type of these events will be less.

III.RESULTS

The results of the study are discussed under the following sessions. The orientation x, y and z axis considered by the AndroSensor application is as shown in Fig.1. Here, front, right and up are considered as positive. Rear, left and down are considered as negative.

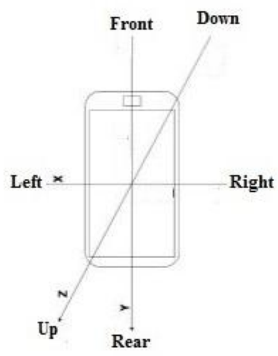

Fig.1.Orientation of x, y and z axis in AndroSensor

A. Detection of the Presence of Pothole

Accelerometer data for different types of potholes present on Kariyom- 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 change in adjacent values of z axis

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accelerations is less than -2, with first value in positive direction and second in negative direction, then it indicates the presence of a pothole. Fig.2. shows the z axis acceleration vs. time graph of a pothole present in Kariyom (8.553722 latitude, 76.91723 longitude) – Parottukonam (8.572122 latitude, 76.92504 longitude) road stretch.

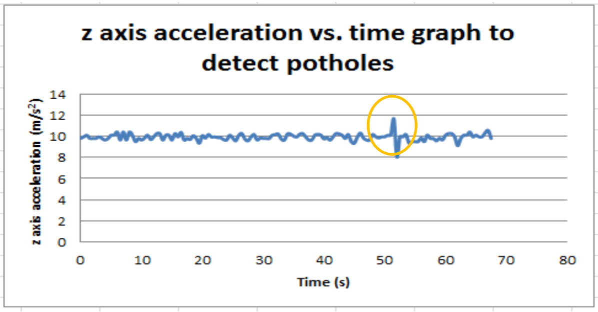

Fig.2.z axis acceleration vs. time graph of a pothole

B. Detection of the Presence of Bump

Accelerometer data for different types of bumps present on Karyavattam to Arashumood 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, change in z axis acceleration value is greater than 2 with first value in negative direction and second value in positive direction and y axis acceleration is less than 0. Fig.3. shows the z axis acceleration vs. time graph of a bump present in Karyavattam (8.563405 latitude, 76.882851 longitude) –Arashumood (8.564581 latitude, 76.885635 longitude) road stretch.

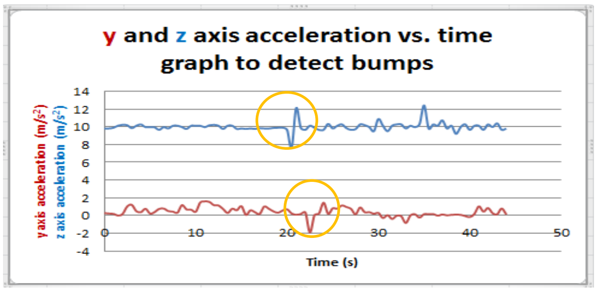

Fig.3.z axis acceleration vs. time graph of a bump

C. Detection of 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 were 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 adjacent values of z axis accelerations is less than -2, with first value in positive direction and second in negative direction, then it indicates that normal brake is applied due to the presence of a pothole. Fig.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.

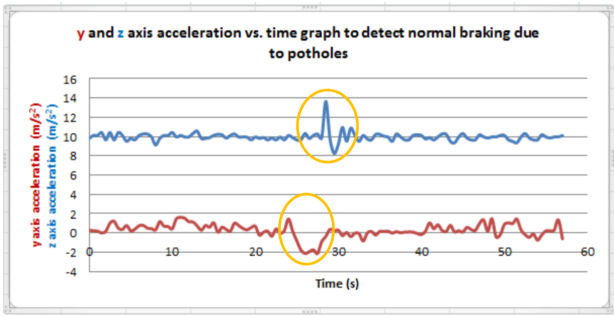

Fig.4. y and z axis acceleration vs. time graph of normal braking due to pothole

D. 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 were 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 is greater than 2 with first value in negativedirection and second value in positive direction, then it indicates that normal brake is applied due to the presence of a bump. Fig.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.

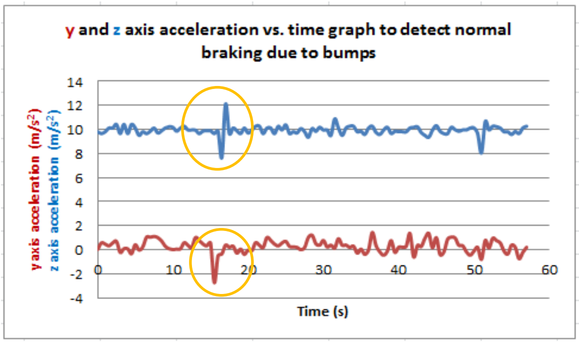

Fig.5.y and z axis acceleration vs. time graph of normal braking due to a bump

E. 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 were

IARJSET

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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 adjacent values of z axis accelerations is less than -2, with first value in positive direction and second in negative direction, then it indicates that sudden brake is applied due to the presence of a pothole. Fig.6. shows y and z axis acceleration vs. time graph of sudden brake application due to a pothole present at Kazhakuttam (8.533004 latitude, 76.872891) to Chavadimukk (8.574004 latitude, 76.91289 longitude) road stretch.

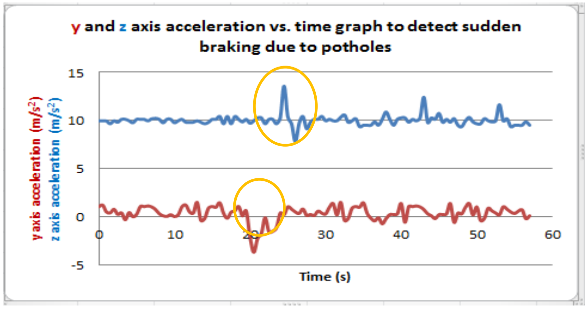

Fig. 6 y and z axis acceleration vs. time graph of sudden braking due to a pothole

F. 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 were 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 greater than 2 with first value in negative direction and second value in positive direction, then it indicates that sudden brake is applied due to the presence of a bump. Fig.7. shows y and z axis acceleration vs. time graph of sudden brake application due to a bump present at Karyavattam (8.563405 latitude, 76.882851 longitude) – Arishumood (8.564581 latitude, 76.885635 longitude) road stretch.

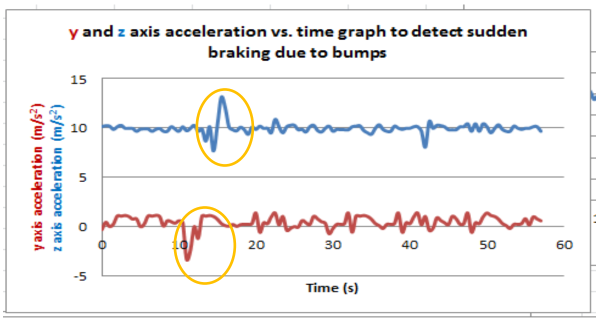

Fig.7 y and z axis acceleration vs. time graph of sudden braking due to a bump

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 less than -2 with first value in positive direction and the second in negative direction , then a left turn is caused due to the presence of a pothole. Fig.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.

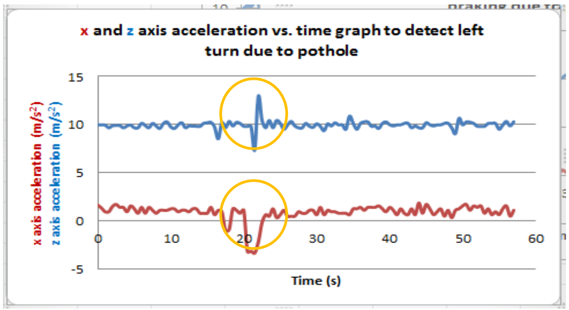

Fig.8. x and z axis acceleration vs. time graph of left turn due to a pothole

H. 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 less than -2, with first value in positive direction and second in negative direction, then a left turn is caused due to the presence of a pothole. Fig.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.

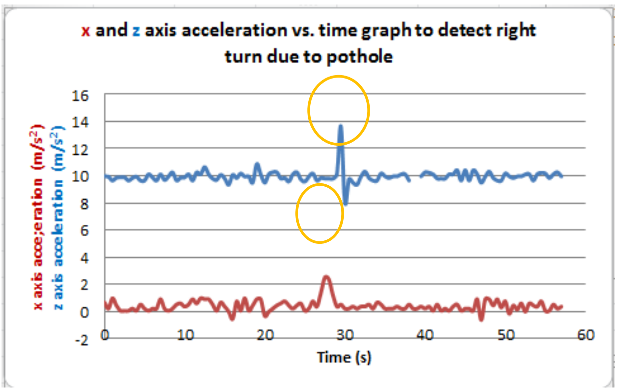

Fig.9.x and z axis acceleration vs. time graph of right turn due to a pothole

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

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I. 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^2 that is the acceleration due to gravity. Fig.10. shows the z axis acceleration vs. time graph representing smooth road. This data was collected from Kilimanoor to Venjaramood road stretch.

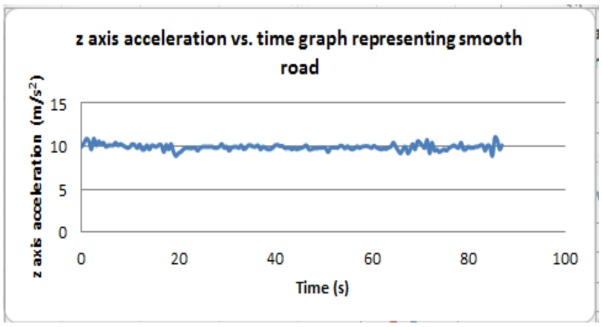

Fig.10.z axis acceleration vs. time representing a smooth road

J. 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, zacceleration values vs. time graphs were plotted. It was seen that the z axis acceleration values varied in a wide range for rough roads.Fig.11. shows the z axis acceleration vs. time graph representing rough road. This data was obtained from Sreekaryam- Pulayanarkotta road stretch.

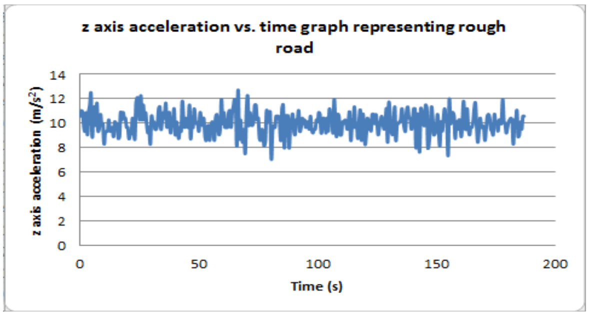

Fig.11.z axis acceleration vs. time representing a rough road

K. Threshold Acceleration Values of Different Pavement Events

By using the smartphone with AndroSensor, acceleration data for various pavement events were collected. These were analysed 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 Acceleration Value
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	Rapid change

L. Java Programming for Easy Computation of values while assessing pavement condition

A program was developed in JAVA so that the time required for the computation of values to detect the presence of various events on the pavement can be reduced. The following data is given as input to check the working of the program.

TABLE II SAMPLE DATA FOR JAVA PROGRAM

Time	Latitude	Longitude	x axis acceleration (m/s2)	y axis acceleration (m/s2)	z axis acceleration (m/s2)
0	8.553722	76.91723	0.919	5.209	8.581
0.5	8.553722	76.91723	0.153	4.597	8.427
1	8.553722	76.91723	0.919	3.064	9.653
1.5	8.553722	76.91723	0	3.217	10.113
2	8.553722	76.91723	0.459	1.685	10.266
2.5	8.553722	76.91723	-0.153	0.612	10.266
3	8.553722	76.91723	0.072	0.153	7.968
3.5	8.553722	76.91723	0.145	0	8.121
4	8.553722	76.91723	0.685	0.612	9.807
4.5	8.553722	76.91723	1.072	0	10.113

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The result of the JAVA program was
Bump at --Latitude =8.553722--Longitude =76.91723time=2.5--
right turn at --Latitude =8.553722--Longitude =76.91723--time=4.5

M. 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. Fig.17. shows the data acquisition hardware components of the roughometer and its connections.

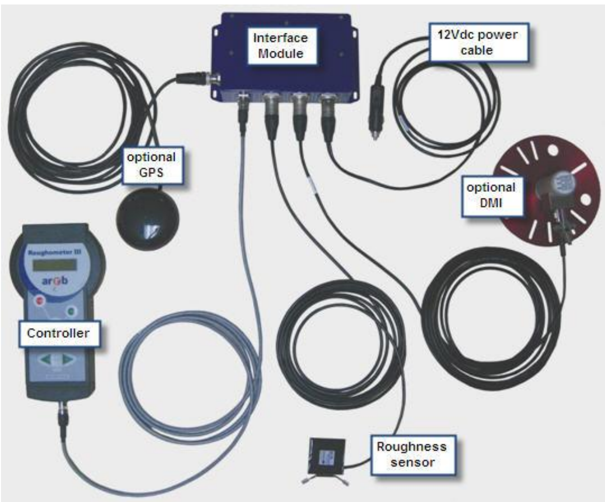

Fig.17. Data acquisition hardware components of roughometer and its connections

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.

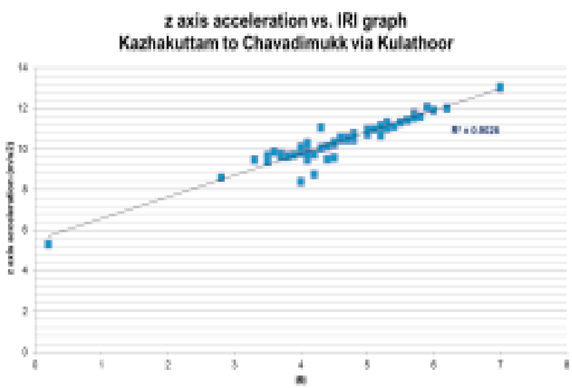

Fig.18. Change in z Axis Acceleration vs. IRI Values Graph of Kazhakkuttam to Chavadimukku Road

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. Fig.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.

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 fig.19. Coefficient of determination was found to be 0.8906.

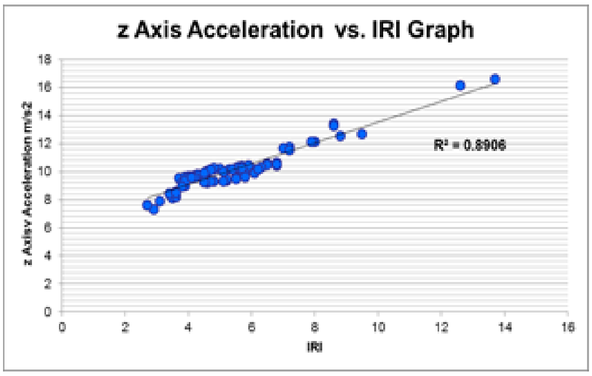

Fig.19. Change in z axis acceleration vs. IRI values graph of Kesavadasapuram to Kazhakkuttam road

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 croresin 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 Roughometer 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.

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions from Department of Civil Engineering, College of Engineering Trivandrum in providing the necessary infrastructure for carrying out the study.

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REFERENCES

[1] Eriksson et.al (2014) "The pothole patrol: using a mobile sensor network for road surface monitoring", International Journal of scientific research and engineering studies

[2] Mednis et.al, "Pothole detection using Android Smart-phones with Accelerometers", 2011 14th International IEEE Conference on Intelligent Transportation Systems.

[3] Mahajan V.D. and Dange T. (2015), "Estimation of road roughness condition by using sensors in smart phones"International Journal of Computer Engineering & Technology (IJCET),pp.41-49

[4] Elert, G. (2015). "The Physics Hyper TextbookJayan Jose Thomas, "Paddy Cultivation in Kerala", Review of Agrarian Studies, pp. 215-226, 2011.

[5] Pertunnen M. et.al (2011) "Distributed road surface condition monitoring using mobile phones" 8th International Conference, UIC 2011, Springer Berlin Heidelberg Publishers, Finland, pp. 64-78

[6] Karla N., Chugh G., Bansal D. (2014). "Analyzing Driver and Road Events via Smartphone" International Journal of Computer Applications (0975 – 8887) pp.5-9

[7] Buttlar, W. G., Islam, S. (2011). "Integration of Smart-Phone Based Pavement Roughness Data Collection Tool with Asset Management System" Journal of Region V Regional University Transportation Centre

[8] ARRB Group Ltd., "User Manual Roughometer III", 2009