AN OVERVIEW OF ROAD HEALTH MONITORING SYSTEM FOR RIGID PAVEMENT BY TERRESTRIAL LASER SCANNER

Arpit Bhatt[1,*],Shruti Bharadwaj [1], Vinamra Bhushan Sharma [1],Rakesh Dubey [1],Susham Biswas[1]

[1]Dept. of Computer Science& Engineering, Rajiv Gandhi Institute of Petroleum Technology Jais, Amethi, Uttar Pradesh, INDIA-(arpitkb, pgi17001, pgi19002, pgi19001, susham) @rgipt.ac.in

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ABSTRACT:

Structural health monitoring (SHM) applications for roads should be created in order to save finances, protect public safety, and provide long-lasting road infrastructure. The terrestrial laser scanner (TLS) will be employed in this project for collecting data, used for monitoring purposes. LiDAR camera mounted on moving vehicle generating 3D point cloud is used for monitoring purpose. Poorly maintained roads result in lower productivity, higher fuel consumption, increased mechanical wear, hazardous operating conditions, driver discomfort, and higher rolling resistances. Road management agencies suffer with pavement repair methods and the finances to keep the existing road networks in good working order. The goal of this research work is to create a low-cost smart road health monitoring system that uses camera-based monitoring and smart phone sensors to identify the road section for maintenance. We have discovered that using accelerometers for pothole detection is ideal for this application. The road patches or pot holes for 2 km area of the RGIPT campus using accelerometer is being done. The smart phone will upload the position and any kind of undulated road surface to the cloud when the vehicle passes over it. Use of accelerometer may detect internal damage of the pavements before it appears on the top surface of the road. When other vehicles move towards an irregular road surface, the cloud will issue an undulated road surface reminder to make sure that the vehicle may safely and smoothly drive through the area. The system is simply dependent on a single phone setting and uses raw accelerometer measurements, which can record irregular driving or quick brakes. The data in this system are collected from the mobile phone and sensor for monitoring and forecasting of road surface. So, every pavement defect has different classification and treatment approach, as well as severity levels.

1. INTRODUCTION

India, is the world's second most populated country with a expeditiously developing economy, is well-known for its extensive road network. Potholes are simply paved areas that have cracked, worn away, and eventually formed a hole. They start as small cracks. Because India has a large network of road transportation, many people travel by road. Potholes are the leading cause of road accidents. Today, roads are the most common mode of transportation in India. They transport nearly 90% of the country's travelling passenger traffic and 65% of its consignment. The monitoring of road pavement conditions has grown in importance. Road pavements that are well-maintained improve drivers and passengers safety for their comfort. As a result, it is critical to continuously monitor the road conditions in order to improve the conveyance system in connection with driving welfare. Potholes are caused by the existence of moisture in the soil strata below the rigid pavement or water above the rigid pavement for an extended period of time.

* Corresponding author

Potholes are especially common during the rainy season, when more water enters the pavement. Another cause of potholes on the pavement is excessive loading on the pavement over time. To establish an effective pothole-maintenance strategy, pothole data must be collected quickly and cheaply across a large area. To put it another way, a system capable of collecting pothole information at varying speeds across a large area is required. Potholes can have a negative impact on road efficiency. Existing manual and laser-scanning technologies are inadequate because they only generate a static data set. Rapid collection of pothole data information over a large area at a economical price is significant for flourishing an effective pothole-prolongation procedure. By the way of explanation, a specially designed system is capable of collecting pothole data at high speeds over a wide area is required. Existing man operated techniques, vibration-based as well as laser-scanning techniques, are not sufficient. The roughness of rigid pavement surfaces is an important indicator of road health. Dynamic road conditions, according to studies, contribute to unpredictable driving behavior and vehicle depreciation, both of which can have an economic impact and, in some cases, result in injuries and fatalities. The impact is greater in developing countries due to poor road infrastructure. An effective road health mapping system can significantly improve driving and pedestrian safety. Road pavement surface monitoring is a obstacle that, at its core, necessitates mobility; it cannot be easily solved by deploying static sensors on the roads. Aside from the absolute size of the highway network, which would form a static sensor utilization of prohibitively expensive in terms of manpower and price, road pavement conditions are sensed naturally by a moving vehicle that can quantify impulses and vibrations while driving. It's a remarkably simple and advanced technique for discovering potholes with less force and more precise work in less time. That's why sensor based pothole detection techniques are implemented successfully. This method monitors the top surface of rigid pavement.

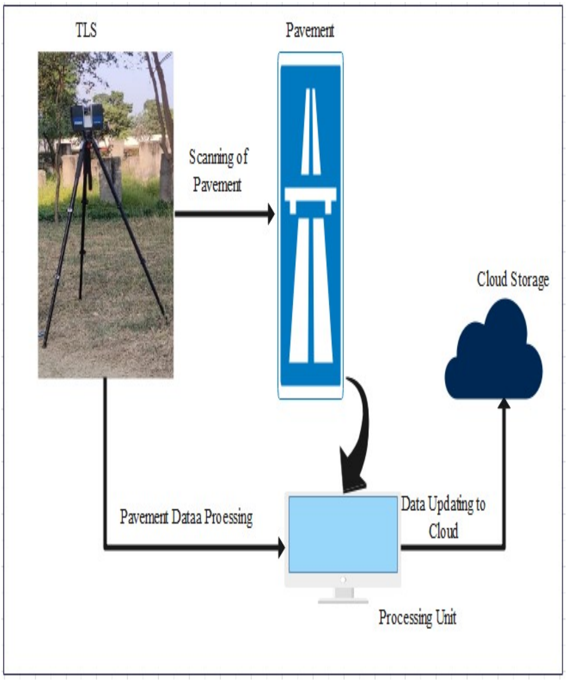

Figure 1. Architecture of road pavement monitoring system.

The goal of present research work is to design a pothole detection system with the help of mobile phone, GPS, camera etc, that can be used by many individuals over a huge area. Moreover, these devices must provide high accuracy in detection at relatively low cost. We examined various devices, and then concluded that combination of the accelerometer and smart phone sensor is the most suitable system for our requirement. It automatically generates real condition data while moving on the road, which is very essential in monitoring the pavement of roads. If present work of pothole detection technique is used in any running vehicles, on roads it will detect potholes. And thus, we can collect large amounts of the pothole dataset detected at various speeds all over wide area of road pavement. A well-maintained road network is critical for the safety and consistency of vehicles travelling on that road, as well as the health and safety of those who use it.

2. RELATED WORK

Image pre-processing employing a combination of Gaussian-Filtering is developed by (Vigneshwar and Hema Kumar 2017), which describes the clustering-based image segmentation techniques is employed in this work for improved results. Edge detection-based segmentation was chosen for its specificity, whereas K-Means clustering-based segmentation was chosen for its quickest calculation time, according to the data. The main goal of this study is to produce a superior method that is both efficient and accurate when compared to current methods. A robot car is developed by (Hegde, Mekali, and Varaprasad 2014), that can identify potholes and send that information to neighboring vehicles. Information with reference to potholes are shared with nearby motorists might reduce the likelihood of an accident or collision. So, provide a pothole detection system that can detect potholes with a minimum specified depth, disseminate the information over a 100-meter distance, and provide the driver with advance awareness of the road pavement state. A vibration based study is done by (Rishiwal and Khan 2016), This system is for detecting and locating potholes and speed breakers automatically. In this technique, each route has its own database, which is then made available to the public through a global portal or database. Potholes and speed breakers, as well as their intensity, are detected by Android's built-in accelerometer. A system for detecting potholes is described by (Eriksson et al. 2008), based on a very responsive accelerometer attached to an embedded computer that is for detecting potholes. Before finding that the correct placement of sensors in the automobile dashboard to be appropriate while generating adequate signals, different sensors in three placements were tried. In this context (Kiran Kumar et al. 2021), equipped a vehicle with laser and high-resolution camera. A high-resolution camera captures photos of the reflected laser, which is used to recognize potholes. Because it is a science-based technique that includes sophisticated mathematical calculations, it may not be more accurate. Manual clicking of pictures to detect potholes is done by (Pereira et al. 2018), has collected the dataset through clicking of pictures as well as through various datasets available externally. Classification of a model if performed based on convolutional neural networks (CNN). The limitation of this method is that the used model does not produce good results for over-fitting cases in Deep Learning models in machine learning. A warning system after detection of potholes is suggested by (Madli et al. 2015), for finding potholes and create a warning system, thus created an architecture that makes use of Wi-Fi. By providing earlier warnings, the system assists the vehicle's driver in avoiding potholes on the road. The pothole detection method recommended in this research work allows the vehicle's driver to access the information about potholes on the road in the vehicle's immediate vicinity. The detection system can be employed in conjunction with moving vehicle to alert the driver via a visual or audio signal, or it could occasionally witch on to the braking system. A further system to detect pothole is developed by (Molano Ortiz et al., n.d.), has generated a system by utilizing 2D LiDAR to detect various potholes, a camera to extemporize the precision of a pothole system recognition A 2D LiDAR is used to obtain statistics on road interspaces and pavement angle. It consists of noise depletion, clustering, line component extraction, pre-processing, and slope of pothole data function. Pothole identification using image-based techniques are used to enhance the precision of pothole detection and to determine the size and shape of the pothole. An algorithm for frame by frame analysis of video shots is developed by ("Obstacle Detection and Avoidance Using Stereo Vision System with Region of Interest (ROI) on FPGA – IJERT" n.d.), found a method for detecting and locating potholes in video footage using a camera placed inside a running car. The video shots covered area is used to detect potholes wherever rigid pavement can be seen frame by frame. An algorithm generates a set of its own regions. The size, background model, intensity surface regularity, length of the outline, and shape of the pothole zones are all extracted. Based on the study's above-mentioned features, a decision tree labels the own areas of conduct as assumed potholes. This algorithm distinguishes false positives caused by the shadows of other objects and suggests a method for detecting and locating potholes in video footage using a camera mounted inside a running car. The video shots covered area is used to detect potholes wherever rigid pavement can be seen frame by frame. An algorithm generates a set of its own regions. The size, background model, intensity surface regularity, length of the contour, and shape of the pothole region are all extracted. Based on the study's above-mentioned features, a decision tree labels the own areas of conduct as assumed potholes. This algorithm distinguishes false positives caused by the shadows of other objects. For better degree of precision in pothole detection system (Lee et al. 2019), has optimized the combination of six algorithms for image processing with a low false rate, such as convex hull, background sub-tractor, wavelet energy field, and saliency map, was compared. To determine the threshold within the RGB value range of 0 to 255, a specific algorithm (Otsu binary algorithm) was used. Background sub-tractor processes the background image, then subtracts the incrust and divides the image object using the seven algorithms mentioned previously to detect potholes inside images and compares the results to detect potholes with the six most accurate recognitions. The system accuracy obtained is 90%.

3. RESEARCH GAP

Previous work on rigid pavement surface monitoring and their data collection precisely in sensor networks is different from what is being done now. It focuses mainly on inscribing the road surface monitoring in a thorough and efficient manner. Major accidents occur as a result of poor road surface monitoring. As a result, there is a large area open for research in this field.

4. OBJECTIVE

The aim of my research work is to develop a low cost smart road monitoring system and pothole detection system using very common devices for providing the information of existing pothole with their shape, size and position.

5. METHODOLOGY

An approach is designed for the determination of pothole detection system for rigid pavement in a small area of RGIPT. The outline of work is presented with the help of the flowchart as mentioned. Global Positioning Sensor is used to find out location of potholes using its coordinates, which helped in classification of pavement points. Accelerometer collects the data of moving vehicle in vertical direction (Z-direction). Accelerometer sensor helped for determining the relation between quality of pavement and obtained values from sensor.

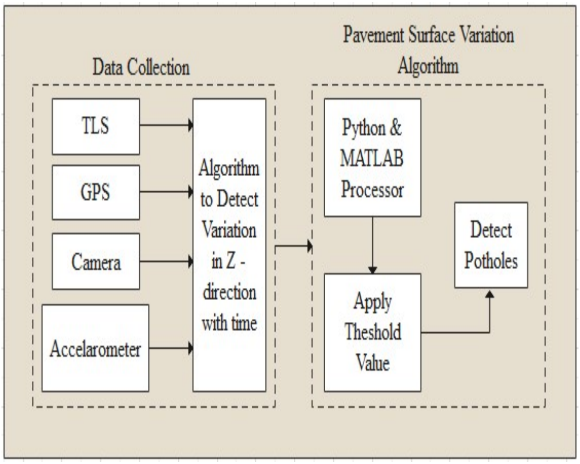

Figure 2. Architecture of pavement health condition assessment algorithm.

Thus work is explained in two parts, first part is about data collection, which is done with the help of terrestrial Laser Scanner (TLS), GPS, camera and accelerometer. TLS samples or scans objects immediately, precisely, and automatically, getting 3D coordinates (x, y, z). TLS operates on a tripod or on a mobile mapping system. Instead of one direction scanner TLS have panoramic and spherical direction. Phase management has a higher data rate and better accuracy (1-3 mm) but for shorter range (20 – 80 mm). TLS contains an integrated camera to color the point cloud. Accelerometer is fitted in a car with GPS and camera to identify the potholes and its shape, size and its location. In next phase processed data identifies the potholes. These potholes data are uploaded to cloud which can be accessed by any user.

Pavement monitoring data is collected with the help of two different instruments so that verification may be done accurately. Different vehicle in other locations may produce different data for potholes. Therefore threshold based classification and machine learning approaches can be used to provide automation in pothole detection.

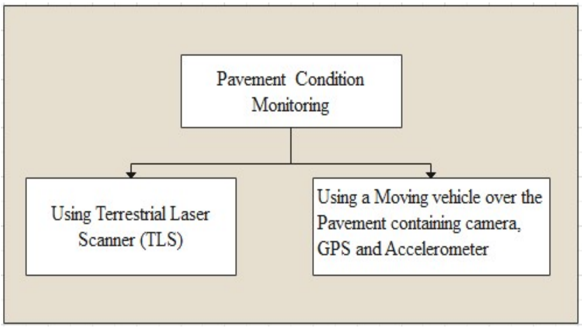

Figure 3. Data collection Methods.

The dataset in first phase is collected with the help of TLS. Terrestrial Laser Scanner scans the road pavements and provides 3D point cloud. In the second phase this data is processed in MATLAB and variation of points are observed with the help of scattered plot of these dataset. Depressed points are later physically verified of the studied surface. In last phase this data is uploaded to server, which can be employed by users. LiDAR data provide 3D point cloud date in global as well as local coordinate system. This dataset consist of various axes values of coordinates and RGB value of that section. Potholes can also be identified with the help of the RGB values. As scattered plot of RGB value gives darker shade is a result of pothole. Thus by defining a threshold value for RGB value in point cloud data, it will automatically identify the depression as well as undulated surface, and potholes easily can be identified with algorithm.

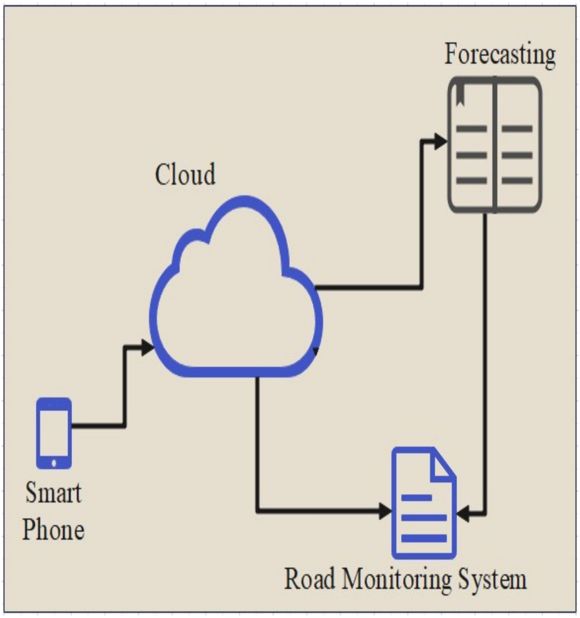

Figure 4. Architecture of road pavement information sharing system.

Pavement surface data is also collected by using accelerometer. This system is focused on data obtained from accelerometer as it provide the dynamic dataset while moving which is actual data considering all factors affecting this system. Pavement detection mainly depends on the error free data, and cannot be validate leading to wrong results. These dataset are collected at specific intervals.

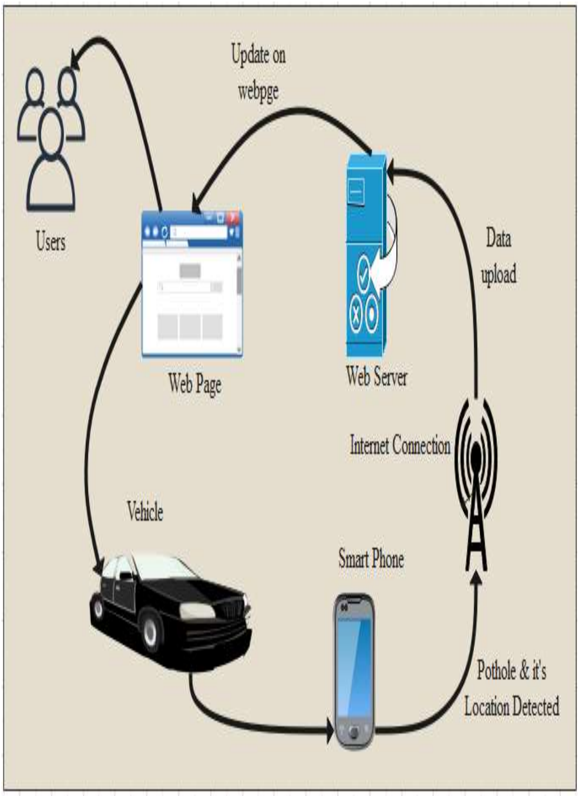

Figure 5. Architecture of road pavement information sharing system to users.

The road surface detection model is mainly based on human data and cannot be validated if there are errors or if it is based on variable judgments, which can lead to incorrect results. If potholes are to be found appropriately and several detections aggregated to identify every single pothole, GPS accuracy in our deployment is critical. We kept a careful eye on the pothole data and drove over it several times to ensure accuracy. We first discover the crest accelerometer data in each drive, and then use linear interpolation between GPS datasets to estimate the location of the car when the peak variation occurred. The standard deviation of the bar's reported placements was 3.3 metres, which is comparable with usual measurement inaccuracies from current GPS receivers when used outside. The location produces the best accessible information of the devices using GPS based on the presently available position providers to regulate the current location information of smart phones or mobile devices, considering latitude, longitude, bearing of operating direction, and velocity of movement.

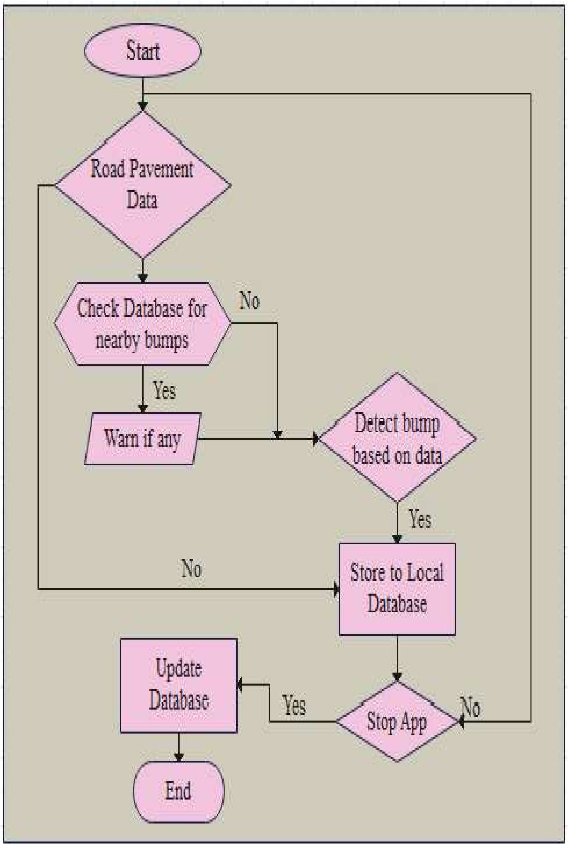

Figure 6. Flowchart of low-cost road detection system.

The low-cost modules are installed on the vehicles, making it more efficient for users because they do not need external sensing consequences when getting on or off the installed vehicles. The system also includes a Bluetooth module, which allows data from the accelerometer sensor to be transmitted to an Android-based smart phone. One of the difficulties is distinguishing potholes from patches. Though they may appear similar, developing a model that can distinguish between the two is an important factor to consider. There are numerous gaps that must be filled because the application involves maintaining a database of potholes as well as their geographic locations. From above flow-chart the working of the algorithm is clearly explained and data storing as well as data processing in methodology is also discussed.

6. RESULT AND DISCUSSION

The data is collected in RGIPT road sections for more than two km, and it was processed using proposed model as explained in this research work. The pavement type of road is rigid and data is being collected in 2022. Figure shows the identification of pothole in pavement surface. Pothole can be seen in image taken by TLS as well as in scattered plot of this dataset in MATLAB in figure 7(a) and 7(b).

Figure 7(a). Actual image of road pavement.

Scattered plot of more than 13000 points of pavement figure 7(a) are done with the help of MATLAB software. Scattered plot is done on the basis of surface coordinates and its RGB values. From image pothole is clearly visible. A clear depreciation can be seen in scattered plot of the pavement in MATLAB.

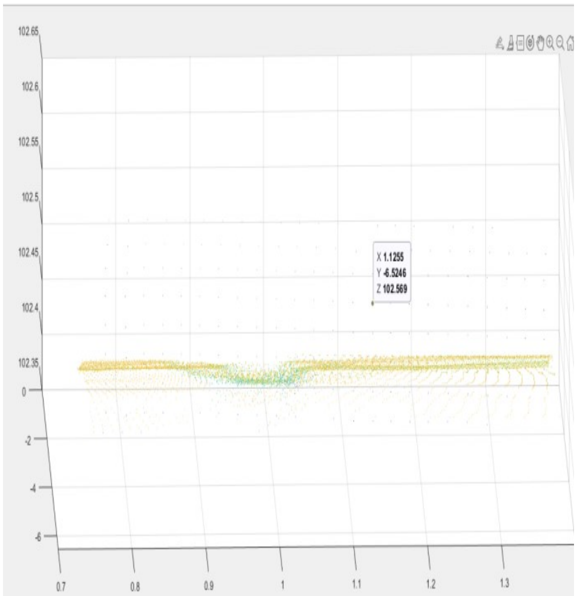

Figure 7(b). Scattered plot of road pavement.

Each pavement defect has a unique classification and treatment approach, as well as severity levels. Because this system encounters all types of pavement defects, the system's defect reading behaviour differs, as previously discussed. Figure 8(a), 8(b) and 9(a), 9(b) depicts a sample example of a defect with and without reading the defect. Road surface without hump don't provide peak after plotting the variation of Z-axis whereas when bump in road take place it shows crest in Z-direction.

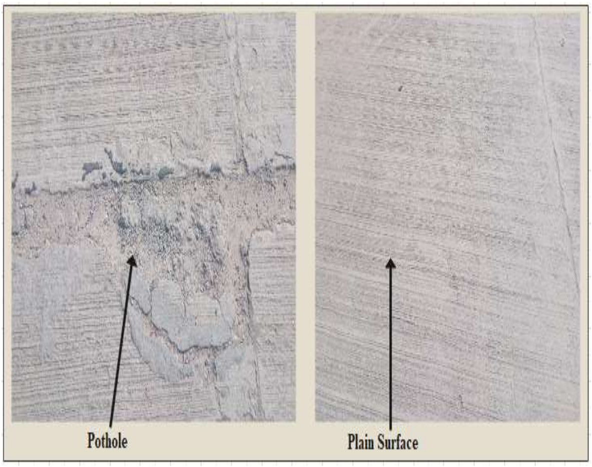

Figure 8(a) Figure 8(b)

Figure 8. Actual image of road surface data with & without potholes.

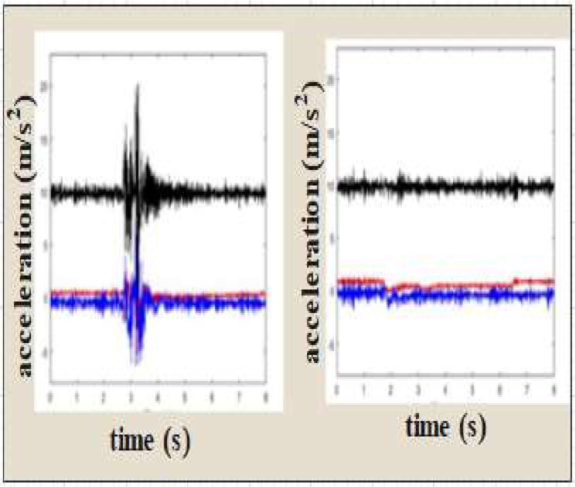

Figure 9(a) Figure 9(b)

Figure 9. Plotted image of road surface data with & without potholes.

Figure 9(a) shows the behaviour of the with defect data, and figure 9(b) represents without defect data behaviour. Our method mainly relies on the accelerometer generating constant data for a particular pothole, as well as the on-board GPS providing reliable event localisation. In this section, we'll go over some of the tests we ran to ensure that our sensors were working properly. The accelerometer z-axis average is computed, before applying threshold limit to collected dataset of accelerometer. Average of Z-axis is computed using the relation-

$$\frac{\sum_1^n Z - axis\ variation\ values\ at\ different\ locations}{n}$$

Threshold value is less than the average of the Z-axis to obtained potholes. The crest of the obtained spikes from accelerometer dataset is normalized.

Because of the wide variation in road conditions, detecting potholes from the dataset of accelerometer is difficult. That's why before reporting any detection, each data sample window has passed through a number of filters. The proposed low-cost automated method is intended to address this difficult transportation industry problem. It is obvious that road pavement management needs detecting portions that requires the fixing up of the surface.

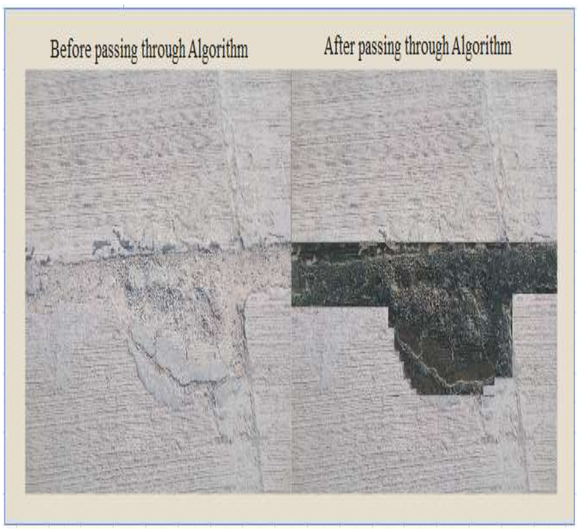

Figure 10. Road section after passing through algorithm.

The findings are obtained for various integrated points obtained within a specified area of considered section of road surface. Black portion shows that road surface of that portion is damaged, which is also verified by manual visuals. In this region sensors are recorded with jerks and corresponding spikes also recorded. The car passed through potholes of the road and its location and size is recorded in the system. The small portion of the road is considered for compact study so that classification for removing the additional flaws due to the fluctuation in collected data with accelerometer sensor. The proposed low-cost approach for monitoring road health using LiDAR data, smart-phones and sensors can help road management authorities plan better maintenance schemes. The method is more user-friendly and precise.

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Sr. No.	Location	Average Z value (mm)	Threshold value of Z to detect Pothole (mm)
1.	RG Plaza	76.0916	70.00
2.	Subway Gate	76.1513	70.00
3.	Academic Block -1	76.2627	70.00
4.	Gate -2	77.9509	70.00

Table 1. Result of pothole for different locations of RGIPT for Z value.

Sr. No.	Location	Average RGB value			Threshold value of RGB to detect Pothole		
		R	G	B	R	G	B
1.	RG Plaza	120	131	124	110	110	110
2.	Subway Gate	124	112	113	110	110	110
3.	AB-1	190	187	165	110	110	110
4.	Gate - 2	205	199	166	110	110	110

Table 2. Result of pothole for different locations of RGIPT for RGB values.

7. CONCLUSION

The abnormal road conditions can be identified and saved in the traffic centre based on real-time road conditions evaluation. Vehicle drivers can use agile warning signals to acquire nearby road information from other vehicles in order to manage their driving behaviors and improve driving precaution, comfort, and efficiency. The road conditions can be improved, and people will be more comfortable. Road surface issues have become a source of public concern in today's world. Government of India spends millions of rupees to repair and maintain the roads. A well-maintained road network is critical for the safety and consistency of vehicles travelling on that road, as well as the health and safety of those who travel in such vehicles. According to research, pavement management necessitates identifying sections that require repairs or overhauling, which is a very expensive and time-consuming process. This study created a sensor and camera-based cloud application that can aid in pavement management in order to make this process more timely and cost-effective. The results show a high level of accuracy in detecting road quality in real time. The purpose of this paper was to investigate a smart phone sensing application: such as detecting, monitoring and screening of pavement conditions to the user.

Table 1 and table 2 is the finding of pothole identification using threshold in 3D point cloud data which collected by LiDAR camera mounted on moving vehicle.

8. FUTURE SCOPE

In future this research dataset can be integrated on collected data as CNN or ANN based schemes so that prediction can be made about road sections that require maintenance even before actual harm. Most previous works use unimodal accelerometer data; however, in future using a gyroscope sensor in conjunction with an accelerometer sensor to derive a more accurate prediction of road quality. Fully automated monitoring system of road may be developed later with Artificial intelligence and machine learning (AI & ML).

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