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Advanced Smart Road DeformationDetection System

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Abstract **-Aging roads and poor road-maintenance systems resulted many potholes, whose numbers increase over time. Potholes jeopardize road safety and transportation efficiency. Moreover, they are often a contributing factor to car accidents. To address the problems associated with potholes, the locations and size of potholes must be determined quickly to find the location a data base as to be developed, which requires a specific pothole-detection system that can collect pothole information at low cost and over a wide area. However, pothole repair has long relied on manual detection efforts causing loss of time and money to government. Thus, in this paper, we introduced a pothole-detection system using a commercial "Road sepoy". The proposed system detects potholes using vision-based tracking system and MATLAB algorithm specifically designed to work with road sepoy camera giving us accurately in real-time environment. Geo-mapping the pothole in google maps helps the exact location.**

Keywords**-Vision-based tracking, black-box camera, MATLAB, detection of pothole, size and shape detection, geo-mapping.**

I. INTRODUCTION

India is said to be the fastest developing countries today only after China. Although India is doing exceptionally well in fields like education, industrialization and fashion there are still certain areas where the country is lagging. India's road network is gigantic and said to be only after the United States of America. But one of the striking underlying facts is the condition of the roads. India is home to several bad roads be it the metropolitans, the cities or the villages. Bad road conditions are nothing new to India and the problem is being addressed since the last 30 years. Since roads indirectly contribute to the economic growth of the country, it is extremely essential that the roads are well laid out and strong.

India has a total of about 2 million kilometers of roads out of which 960,000 kilometers are surfaced roads and about 1 million kilometers of roads in India are the poorly constructed ones. Although the figures look impressive, but the underlying fact is that 25 percent of villages in India still having poor road links. Detection of potholes is an interesting issue andhas great significance in the context of highway maintenance. A major problem in planning highway maintenance is the unreliability of manual measurements, which can lead to poor prioritization of remedial work.

1. Pothole

A pothole is a type of disruption in the surface of a roadway where a portion of the road material has broken away, leaving a hole. Most potholes are formed due to fatigue of the road surface. The chunks of pavement between fatigue cracks are worked loose and may eventually be picked out of the surface by continued wheel loads, thus forming a pothole.

Pothole is generally an oval shaped hole in the pavement surface having minimum width of 6". The severity of potholes may be defined depending on their depth as follows: -

- Low – severity potholes are less than 1" deep.
- Moderately severe from 1"- 2" deep.
- High – severity greater than 2" deep.

2. Formation of Pothole

The formation of potholes is exacerbated by low temperatures, as water expands when it freezes to form ice, and puts greater stress on an already cracked pavement or road. Once a pothole forms, it grows through continued removal of broken chunks of pavement. If a pothole fills with water the growth may be accelerated, as the water "washes away" loose particles of road surface as vehicles pass. Potholes can

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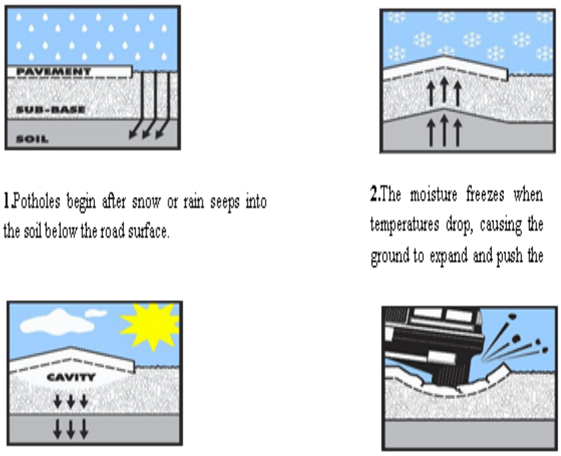
grow to feet in width, though they usually only become a few inches deep, at most. If they become large enough, damage to tires and vehicle suspensions occurs. Serious road accidents can occur as a direct result, especially on motorways where vehicle speeds are greater.



1.Potholes begin after snow or rain seeps into the soil below the road surface.

2.The moisture freezes when temperatures drop, causing the ground to expand and push the

3.As the temperatures rise, the ground returns to normal level but the pavement often remains raised. This creates a gap between the pavement and the ground below it.

4.When vehicles drive over this cavity, the pavement surface cracks and falls into the hollow space leading to the birth of another pothole.

Figure 1 Formation of Pothole.

3. Approach to Pothole Detection

An automated pothole sensing method will result in the generation of huge amount of data that can be used as input into highway maintenance. These packages will help in the streamlining of maintenance planning. The main benefit with automated data collection is the surveying of highway conditions could be extended, highway utilization could be increased, and maintenance costs can be reduced.

This is important in developing countries as well in developedcountries.According to the report road accidents in India, 2011, bythe ministry of road transport and highways, a total of142 485 people had lost their lives because of road accidents. Of these, nearly 1.5% or nearly 2200 fatalities were because of poor conditions of roads. The figures have been steadily growing by 10–15% in the past decade. During monsoon, the number of accidents spike up as the condition of roads deteriorates further.

However, the official numbers hardly reveal the gravity of the situation. Experts believe the actual number of deaths because of bad roads, which is because of the presence of potholes to be muchhigher at around 10 000 per year as most accidents do not get reported. Government spend lots of money in the past five years starting 2014-15, the Brihanmumbai Municipal Corporation (BMC) has spent □ 68.31 crore on 29,726 potholes that appeared on the city's 1,941km of roads under its jurisdiction. In the past three years, the number of potholes recognized by the civic body dropped to 1,433 till date in 2018-19, from 4,044 in 2017-18 and 4,478 in 2016-17. The budget to fill potholes is □ 9.3 crore this year, compared to □ 7.73 crore in 2017-18 and □ 6.95 crore in 2016-17. It's a heavy loss to the government as these figures may increase. The cost is directly related to time due to vast population it is very hard to keep the track of pothole on specific roads, the density of vehicles pre road as also increased this way the government is having hard time to maintain road, due to no real-time data analysis the material and labor sent to fix roads have wrong analysis.

Planning and Execution for pothole there is no proper way that government can follow and data what they get is raw data, so to help with the proper flow this is when pothole detection system with artificial Intelligence Black -box come into picture. This device segregates the data and gives the municipality and government a specific flow where they will be able to fill the pothole. The first step of the solution requires developing a device that is attached to a vehicle and will continually scan the road surface. If a pothole is detected, it will take its longitude and latitude with respect to size, shape and density of the pothole. Black box consists of IMU (Initial Measurement Unit) consisting of accelerometer, gyroscope, and magnetometer helps to detect the density of the pothole.

The image processing unit which will help to detect the actual shape of the pothole and location of the pothole. The second key aspect of the solution is to enable the device to log the position of the pothole via GPS (Global Positioning System). The GPS data can be uploaded via a CSV (Comma Separated Values) module to a network system incorporating mapping software Google Maps. The data in the system can be made available to the general public as well as municipalities and road maintenance agencies. A higher awareness of the location of potholes will result in road users being more careful on certain roads or even less usage of an affected road which would reduce the additional formation of potholes.

II. LITERATURE REVIEW

At present, automatic pavement pothole detection methods mainly include three different types: vibration-based methods, 3D reconstruction-based methods and 2D vision-based methods of which the latter two types belong to computer vision technology.

1. Vibration-Based Pothole detection

Yu and Yu proposed the use of recent data acquisition hardware to develop a vibration-based system for preliminary evaluation of pavement conditions [1]. The distress of the pavement such as cracks and rutting impose impacting forces on the vehicle. The pavement surface conditions can be estimated from the recorded responses of the testing vehicle when driving on the pavement. This system has the advantage of small storage requirement, cost-effective and amenable for automatic real-time data processing. However, it does not provide the complete details of distress characteristics as by video-based system. Also, the service condition of the vehicle such as tire pressure should be calibrated to compare results.

Sri Lanka has an extensive road network that spans the country and new roads are being build every day, yet even the roads in the capital city are not maintained properly. De Zoysa et al. proposed a public transportation system-based sensor network (Bus Net) to monitor road surface condition by adding acceleration sensor boards to the system [2]. Bus Net is a sensor network initially designed to monitor environmental pollution using sensors mounted on public transport buses. The collected acceleration readings are transmitted over the Bus Net to the central collection point at the Main Station. Their work, based on preliminary results, is still in process for collection of more data sets and developing an analytical model. Erikson et al. investigated an application of mobile sensing to detect and report the surface conditions of roads [3].

They developed Pothole Patrol (P2) system gathering data from three-axis acceleration sensor and GPS devices deployed on embedded computers in cars. They deployed P2 on 7 taxis running in the Boston area. Using a simple machine-learning approach, they identified potholes and other severe road surface anomalies from accelerometer data. Also, they uploaded detections to central servers using opportunistic Wi-Fi connections provided by participating open Wi-Fi access points or, using a cellular data service, where available.

Vibration-based methods could provide wrong results that the joints of road or manhole can be detected as potholes and potholes in the canter of a lane cannot be detected using accelerometers due to no hit by any of the vehicle' swheels. Mednis et al. proposed a mobile sensing system for road irregularity detection using Android OS basedsmartphones [4]. The selected test track is 4.4km long and the test drive session included 10 consecutive laps. The technical equipment used during the test drive session included a passenger car BMW323 touring and four differentsmart phones such as Samsung i5700, Samsung Galaxy S, HTC Desire, and HTC HD2. The Evaluation ofselected data processing algorithms presented true positive rate as high as 90% using real world data.

Vibration-based method use accelerometers in order to detect potholes. As the advantages of a vibration-based system, these methods require small storage and can be used in real-time processing. However, vibration-based methods could provide wrong results that the hinges and joints of road can be detected as potholes and potholes in the center of a lane cannot be detected using accelerometers due to no hit by any of the vehicle's wheels [3].

1. 3d Reconstruction

3D reconstruction methods can be further classified into 3D laser scanner methods by [5] and[6], stereo vision methods by [7]and Staniek [8], and visualization using Microsoft Kinect sensor by Joubert et al. and Moazzam etal. [11-12].

2. 3D Laser Scanner Methods

The 3D laser scanner uses a technique that employs reflected laser pulses to create accurate digitalmodels of existing objects. In the study by[7],the accurate 3D point cloud points with their elevations were captured during scanning and extracted focusing on specific distress features by means of a grid-basedProcessing approach. The experimental results indicate that the severity and coverage of distress such as potholes can be accurately and automatically quantified to calculate the needed amounts of filled materials.

Li et al. introduced a real-time, low-cost inspection system to detect distress features such as rutting, shoving and potholes using high-speed 3Dtransverse scanning techniques consisting of an infrared laser line projector and a digital camera [6]. To improve the accuracy of the system, a multi-view coplanar scheme is employed in the calibration procedure so that more feature points can be used and distributed across the field of view of the camera. Laser scanning systems can detect potholes in real time. However, the cost of laser scanningequipment'sstill significant at vehicle-level and currently these works are focused on the local accuracy of 3Dmeasurement.

3. Stereo Vision Methods

Wang did feasibility study to conduct comprehensive survey of pavement condition using stereovision technology [10]. In this method, two digital cameras are used to cover a pavement surface. Thefirst step is to analyses 2D images from each of the twocameras to detect and classify any cracks. The results fromanalyzing two image sources of the same pavement are then combined so that cracks missed by one analysis arestill counted, therefore potentially achieving higher accuracy. Also, the pair of images on the same pavement surface is used to establish 3D surface model with longitudinal and transverse profiles through geometricmodelling. To recover the 3D properties from given pairs of 2D images on the same pavement surface, the sequence of steps such as camera calibration, distortion correct, matching stereo points, 3D reconstructs, and profile reportshould be performed.Hou et al. presented a method of applying thestereovision technique into pavement imaging toreconstruct the 3D pavement surface from a pair ofimages [7]. A total of four cameras were used in two pairsto collect pavement surface images across a meter-widepavement (each pair of images covers 2 meters of theroad). In this method, 4 steps such as calibration, distortion adjustment, matching and 3D reconstruction was involved. As an experiment platform, DHDV (Digital Highway Data Vehicle) which is a multi-system road condition survey vehicle developed by University of Arkansas and Way link Systems Co. Also, they presented preliminary results for the feasibility of applying stereovision into pavement imaging. The resolution in 3Dreconstruction can only be made as 2mm in the still environment and more than 5mm in the dynamic moving environment.

They mentioned that as the next step, application of very high-precision gyro system is needed for vertical motion. Staniek suggested the stereo vision techniques for the measurement of pavement condition with a stereovision system attached to a vehicle for recording of the road network conditions[8]. A detailed description of the proposed solution was found in this article. As field experiments, the road section was measured on a local road with the length of 650m.

The author concluded thatthe proposed stereo vision method might be used for evaluation of the road network conditions in Poland. Stereo vision methods need a high computational effort to reconstruct pavement surface through the procedure of matching feature points between two views so that it is difficult to use them in a real time environment. Also, both cameras should be vary accurately aligned since the cameras may misalign and affect the quality of the outcome if there is the vibration by the vehicle motion.

4. Kinect Sensor

Proposed a low-cost sensor system using Kinect sensor [10] and a high-speed USB camera to detect and analyses potholes. At the time of this study, the project was still in its early stages. Some tests were done to determine the viability of using Kinect to examinepotholes.Recently, [11] used a low-costKinect sensor to collect the pavement depth images andcalculate the approximate volume of a pothole. Using alow-cost Kinect sensor, the pavement depth images were collected from concrete and asphalt roads. Meshes were generated for better visualization of potholes. Area ofpothole was analyzed with respect to depth. The approximate volume of pothole was calculated using trapezoidal rule on area-depth curves through pavement imageanalysis. Although it is cost effective as compared to industrial cameras and lasers, the use of infrared technology based on Kinect sensor for measurement isstill a novel idea and further research is necessary forimprovement in error rate.

III. VISION-BASED POTHOLEDETECTION

Vision-based methods include 2D image-based approaches by Koch and Brilakis[12] and Buza et al. [13]and video-based approaches by Jog et al. [14], Lokeshworet al. [15] and Koch et al. [12].

1. 2D Image-Based Approaches

Koch and Brilak is presented a method for automated pothole detection in asphalt pavement images[12]. Under the proposed method, the image is first segmented into defect and non-defect regions. The potential pothole shape is then approximated according to the geometric characteristics of a defect region. Next, the texture of a potential region is extracted and compared with the texture of the surrounding non-defect region. If the texture of the defect region is coarser and grainier than the one of the surrounding surfaces, the region of interest is assumed to be pothole. In order to test the proposed method, it was implemented in MATLAB utilizing the Image Processing Toolbox,

The resulting accuracy was 86% with 82%precision and 86% recall. Recently, Buza et al. proposed a new unsupervised vision-based method which does not require expensive equipment, additional filtering and training phase [13]. Their method deploys image processing and spectral clustering for identification and rough estimation of potholes. The proposed method is divided into threesteps such as image segmentation, shape extraction using spectral clustering, and identification and extraction. The proposed method was implemented in MATLAB and tested on 50 pothole images which were selected from Google image collection. The accuracy for estimation of pothole surface area was about 81%. So, this method canbe used for rough estimation for repairs and rehabilitation of pavements.

2. Video-Based Approaches

2D image-based approaches have been focused on only pothole detection and are limited to single frames it cannot determine the magnitude of potholes for assessment. To overcome the limitation of the above method, video-based approaches were proposed to recognize a pothole and calculate total number of potholes over a sequence of frames. Presented a new approach based on 2Drecognition and 3D reconstruction for detection and measurement (width, number, and depth) of potholes using a monocular camera mounted on the rear of a car[14]. The method of 2D recognition built upon the previous work of [12], and the method of 3D sparse reconstruction built upon the previous work of [16], and 3D dense reconstruction and mesh modeling was based on the dense 3D point cloud reconstruction of [16]and thepoison surface reconstruction approach. The proposed method was validated on several actual potholes using a CanonVixia HD camera (20fps at 20mph).

Inthe proposed method, first captured video clips are segmented automatically into two different types offrames category (frames with distress and frames withoutdistress) using DFS (Distress Frames Selection)algorithm. Then, database of frames with distress isprocessed with CDDMC (Critical Distress Detection,Measurement and Classification) algorithm whichconsists of image enhancement, image segmentation, visual properties extraction, detection and classification by decision logic, and quantification. Also, the decision logic for potholes, cracks and patches were developed by three main distinctive visual properties of these distresses such as the visual texture (standard deviation), the shape(circularity), and the dimension (average width). Adatabase of 1275 video frames with distress was selected randomly from the results obtained after applying DFSalgorithm to various video clips. As results, an overall accuracy of 97% with 95% precision and 81% recall in detecting frames with potholes, overall accuracy of 94%with 93% precision and 98% recall in detecting frames with cracks, and overall accuracy of 90% with 8.5%precision and 19% recall in detecting frames with patches.

If few objects such as bleedings, manholes, black coloredroad markings and discoloration spots appear very similar to potholes, cracks and patches, the proposed method could not deliver high accuracy. The method by [12] was limited to single frames and therefore cannot determine the magnitude of potholes in the frame of video-based pavement assessment. In order to complement and improve the previous method, Koch et al. presented an enhanced pothole-recognition method which updates the texture signature for intact pavement regions and utilize vision tracking to track detected potholes over a sequence of frames [18].

The proposed method was implemented inMATLAB and tested on 39 pavement videos containing10,180 frames. The resulting total recognition precision and recall were 75% and 84%, respectively. Consequently, compared with the previous method, the texture-comparison performance was increased by 53%,and the computation time was reduced by 57%. They assumed that only one pothole enters the viewport at a time, and therefore additional work is needed for considering multiple potholes in the viewport.

IV. METHODOLOGY

Our system uses a Vision Based Tracking System or as we call it VBTS and IMU based Detection. IMU based detection uses the raw values taken from the accelerometer and gyroscope in the IMU and processes it to give a precise value of the angle at which the vehicle is, giving the values in 3 axis.In addition to the IMU based Detection, we have incorporated the VBTS as it increases the reliability of the output data. VBTS is an accurate way of detecting potholes. This is due to extent of the number of functions one could use to refine the detection at each step.

Due to the usage of a camera, we have a massive field of view (78^{o}) which gives us the liberty to detect object, or in this case potholes, accurately inside and outside the path of the vehicle.
All this data from the camera and IMU is sent to the Raspberry Pi and is further processed. The video taken by the camera is sent, in packets, to the Pi and for each amount of time it separates the video into separate frames. We then run an Object Detection algorithm; the MATLAB algorithm and process are explained below:

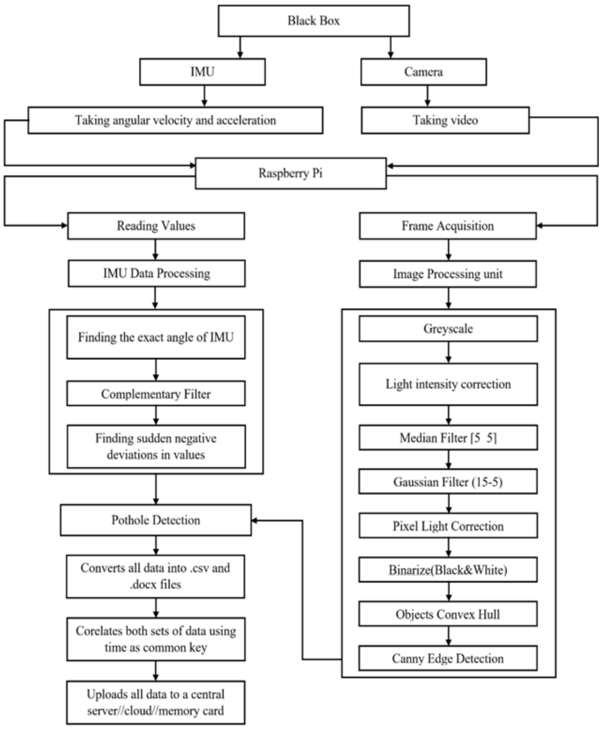


Figure 2 Flow chart of Processing Algorithm

1. Image Pre-Processing

1.1 Image Resizing

The original pothole image captured has high resolution and hence more information stored. Using original pothole image may take more computational time. So, the image must resize into lower resolution for faster processing and optimal segmentation. The main challenge in resizing the original image is to obtain a lower resolution image without losing its required properties and not losing its quality. So, finding the resizing resolution is the first step for achieving better and faster results in image segmentation process. In resizing we should not have a fixed resizing resolution for example [200,200], because it may affect the aspect ratio of the image. If the aspect ratio is changed it badly affects the results. So, we must resize without finite resizing resolution for example [NaN,200], it won't affect the aspect ratio of the image and provide a resized image with original shape properties.

1.2 Grayscale Conversion

The next step required for pre-processing is to convert RGB-image (original pothole image) into grayscale image using standard techniques to restrict the images to a single plane before image segmentation process.

1.3 Median-Filtering [5 5]

The Median filter was used to remove random noise in grayscale image and give a smoothed output image. Also, median filter maintains the integrity of image regions and boundaries.

2. Difference of Gaussian-Filtering (DoG)

The *DoG*- Filter was applied as a pre-processing filter to original pothole image for better edge detection with reduced noise. It finds the difference between two sigma values of two Gaussian profiles and find the edges in the grayscale image, refer [19]. It is given by (1),

$$\mathrm{DoG}_{\sigma}(x,y) \stackrel{\mathrm{def}}{=} \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) - \frac{1}{2\pi(0.5\sigma)^2}\exp\left(-\frac{x^2+y^2}{2(0.5\sigma)^2}\right) \quad (1)$$

3. Image Segmentation Methods

After image pre-pre-processing the next important step for pothole detection is image segmentation. The image segmentation uses different techniques for separating pothole area and non-pothole road area from the original pothole image.

4. Imflatfield technique

J = imflatfield(I, sigma) applies flat-field correction to the gray scale or RGB image I. The correction uses Gaussian smoothing with a standard deviation of sigma to approximate the shading component of I. The corrected image is returned in J. Applies flat-field correction to image I only where the binary mask is true. Where the mask is false, the output image J contains the unmodified values of image I. J = inflate field (___,'Filter Size',filter Size) specifies the size of the Gaussian smoothing filter.

5. Thresholding technique based on Otsu's method

Otsu's thresholding is an image segmentation process basedon grey level intensity value of pixel in image. It involves segmentation of isolated objects by converting the grayscalepothole image into a black and white image. Imagethresholding is an effective way of partitioning an image into aforeground and background. Image thresholding is mosteffective in images with high levels of contrast [20], [21], [22].

6. K-Means based Image clustering technique

The K-Means based image segmentation was done by taking a least square partition and cluster into a k-groups ofobjects. The clustering was grouped based on the n-observationand k- clusters of the nearest mean [20].Observation are taken as a set of d-dimensional real vector(x1, x2......., xn), where clustering was done based onobservationinto k (<n) sets of S= {S1, S2…., Sn} as achieve cluster sum of square to minimum. It is given by (2),

$$arg\min_{S} \sum_{i=1}^{k} \sum_{x \in S_i} \|x - \mu_i\|^2 \qquad (2)$$

- Random points are assigned for clustering at initialstage. The mean value was obtained for each clustering.
- The distance was calculated for each point from eachcluster and assigned to each point to nearest to the meanvalue obtained from the corresponding cluster.
- The iteration continues until the sum of squared within group errors cannot be reduced anymore. The groupware obtained based on the geometrical compactness around their respective mean value.

7. Fuzzy C-Means based Image clustering technique

The Fuzzy C-Means based image segmentation was done by taking a degree of belonging to clusters. It allows clustering of one object which belong to two or more clusters. Thus, the edge object in a cluster may be present more than the object presents in the canter of cluster. In fuzzy c-means the means of all point is the canter of cluster, weighted by their degree of belonging. At point x theset of coefficients that gives the degree of belonging in the *kth* cluster- wk(x). The degree of belonging is inversely related to the distance canter of cluster to the point x and given by the parameter m which measure the weight of the nearest canter. The minimization is done based on (3),

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\|x_i - C_j\right\|^2 \qquad (3)$$

Where m is a real number <1, cj is the d-dimension canter of the cluster, uij is the degree of membership of xi in the cluster j, xi is the itch of the d- dimension measured data, and‖*‖is the norm of measured data and the canter.Let X= {x1, x2, …, xn} be the set of data points and V= {v1,v2,….., vc} be the set of centres. The centres of the cluster '*c*' are randomly selected.

- The fuzzy membership 'μ_{ij} 'arecalculated using (4),

$$\mu_{ij} = 1/\sum_{k=1}^{c}\left(d_{ij}/d_{ik}\right)^{(2/m-1)} \qquad (4)$$

- The centres of fuzzy *'vj'* are calculated using (5),

$$v_j = \frac{\left(\sum_{i=1}^{n}(\mu_{ij})^m x_i\right)}{\left(\sum_{i=1}^{n}(\mu_{ij})^m\right)},\ \forall_j = 1,2,\ldots\ldots c \qquad (5)$$

- The iteration is repeated until the minimum 'J' value isachieved i.e. as in (6),

$$\left\|U^{(k+1)} - U^{(k)}\right\| < \beta \qquad (6)$$

where, 'k' is the iteration step number,
'β' is the termination criteria between [0,1].
'U = (μ_{ij})n*c' is the fuzzy membership matrix.
'J' is the objective function.

8. Pothole Identification and Counting

8.1 Black and white-Convex hull

It was used for generation of convex hull image from binary image. It computes the convex hull of each connected component of black and white individually. The convex hulling helps in shaping the connected black and white components i.e. pothole segmented area which provides better results for pothole detection.

8.2 Number of Black and white-connected components

By find the number of connected components in binary image i.e. the segmented image we can find number of pothole present. Eight neighbourhood pixels where considered for identifying connected components [22].

8.3 Red-mask pothole detection

After detection of pothole to highlight the pothole area, perimeter of the black and white connected components is obtained. By changing the perimeter detected pixel as true in red-plane of the original RGB-image provides the red mask around the detected potholes [23].

9. Performance Measures For Validation of Image segmentation

After image segmentation the performance of the different segmentation techniques where evaluated. The following performance measures given in the literature [19]where considered for our study namely accuracy (Acc) as in (7), sensitivity (Se) as in (8), and specificity (Sp) as in (9) and computation time.

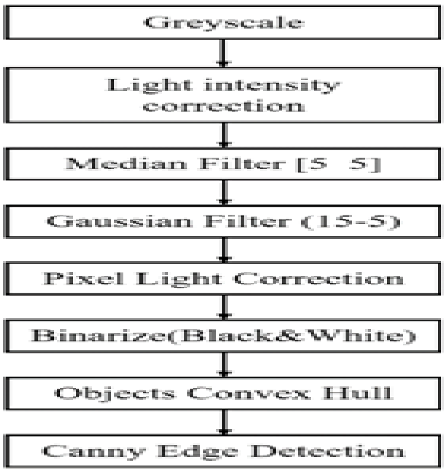


Figure 3 MATLAB Algorithm Flow.

$$Accuracy(Acc) = \frac{(TP+TN)}{N} \qquad (7)$$

$$Sensitivity(Se) = \frac{TP}{(TP+FN)} \qquad (8)$$

$$Specificity(Sp) = \frac{TN}{(TN+FP)} \qquad (9)$$

Where,TP-number pixel that are correctly identified, TN-number pixel that are correctly rejected,FP-number pixel that are incorrectly identified,FN-number pixel that are incorrectly rejected,N-Total number of pixels, it is given by (10),

N = TN + TP + FN + FP (10)

V. RESULTS AND DISCUSSION

1. Original Pothole image sample

The original pothole images, i.e. both single pothole and multiple pothole images are converted intogrey scale which is shown below:

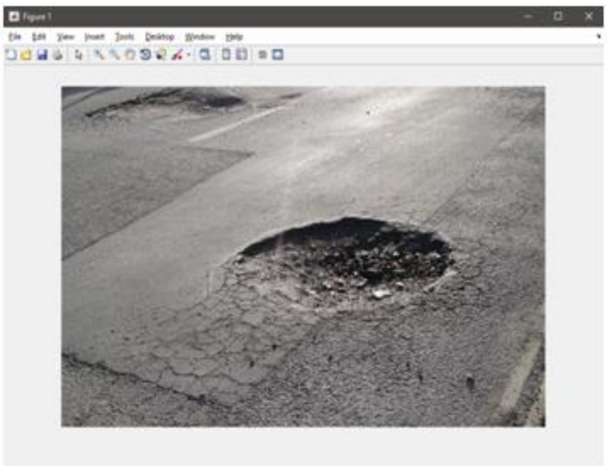


Figure 4 Original Images.

2. Manually Segmented image sample

The manually segmented images, i.e. the images have noise which denoises the image with the help of median filter and Gaussian filter are shown below:

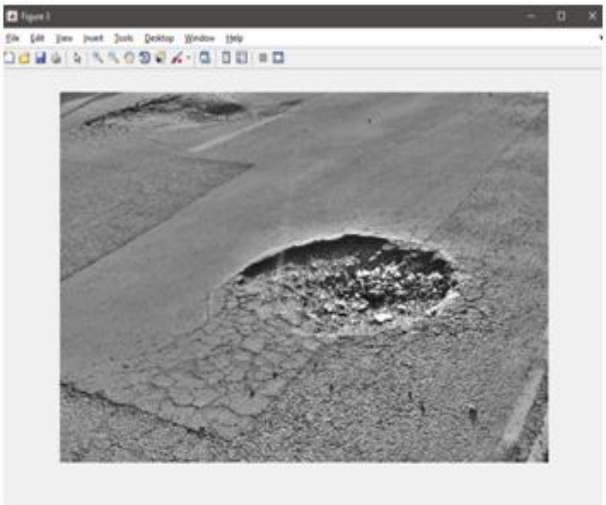


Figure 5 RGB to Grey scale.

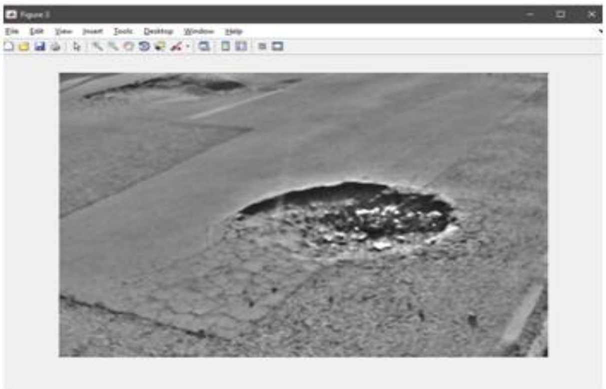


Figure 6 Imflatfield

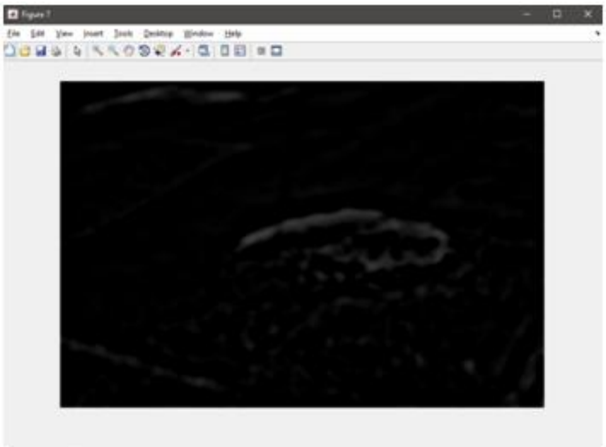


Figure 7 Gaussian Filter.

3. Edge segmented and pothole detected image sample

The edge detection based segmented image using sobel edge detector, the pothole counted and detected image are shown:

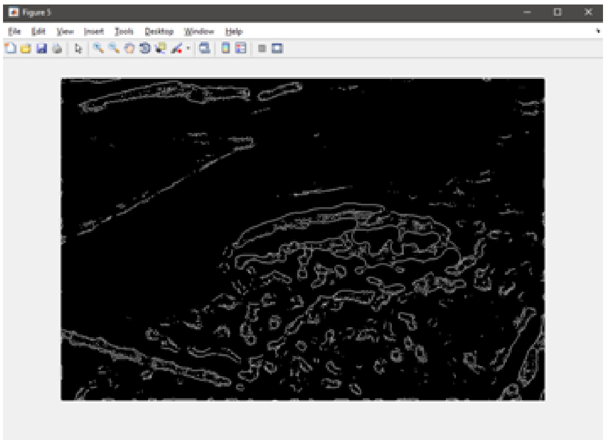


Figure 8 Sobel Edge Detection.

4. Threshold segmentation

The threshold based segmented image is way of partitioning an image into a foreground and background and most effective in images with high levels of contrast is shown below:

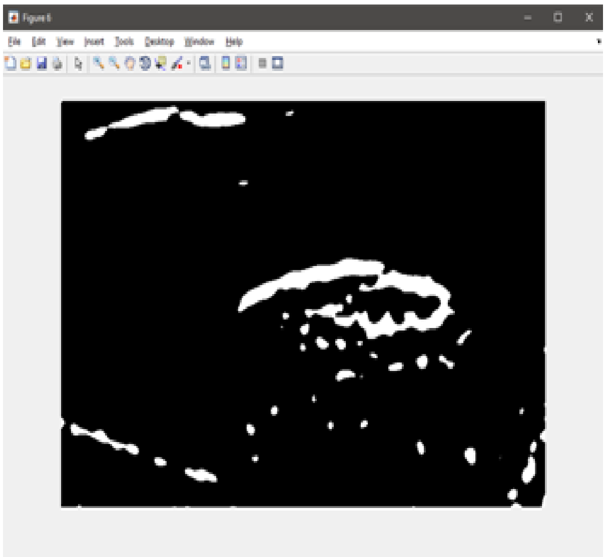


Figure 9 Ostu Method.

5. K-Means Clustering

The K-means clustering to partition the observations of the *n*-by-*p* data matrix X into k clusters, and returns an *n*-by-1 vector (idx) containing cluster indices of each observation the image is shown below

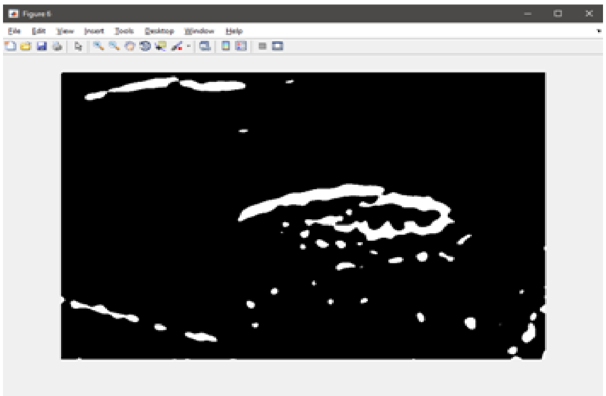


Figure 10 K-means.

6. Fuzzy C-Means based Clustering

The Fuzzy C-means is a data **clustering** technique wherein each data point belongs to a cluster to some degree that is specified by a membership grade is shown below:

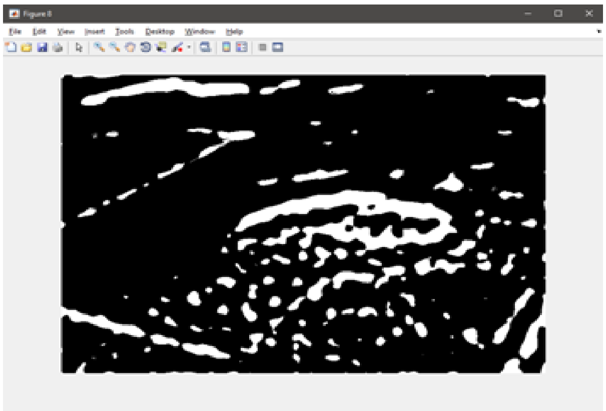


Figure 11 C-means.

7. Convex Hull

The convex hulling helps in shaping the connected black and white components i.e. pothole segmented area which provides better results forpothole detection is shown below:

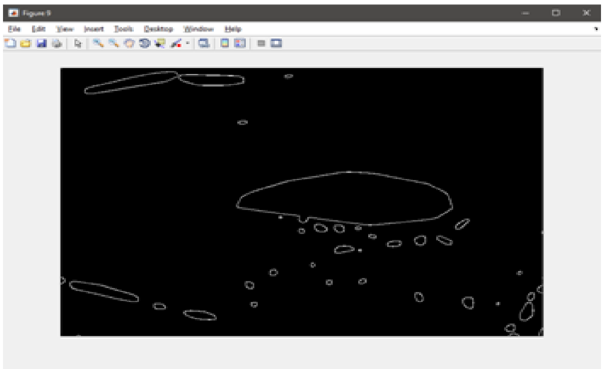


Figure 12 Convex Hull.

8. Red-Masking

The detected pixel as true in red-plane of the original RGB-image provides the red mask around the detected potholes is shown below:

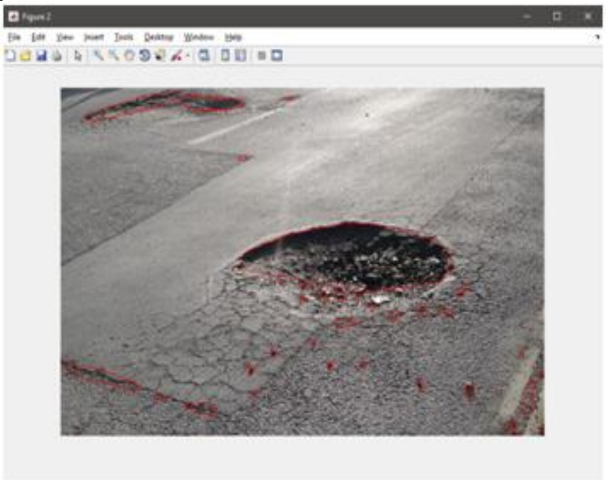


Figure 13 Red Masking.

The same detection method happens for even in night, this is a unique feature where we have also figured out a way the night image are followed more noise, so we made a algorithm which reduce the noise and follow the same methods the day algorithm and give us the detection.

Figure 14 Night Detection.

VI. CONCLUSION

The result of the image processing helpedto gives out accurate pothole detection in both day and night with 85% for photos. We have even input live video pothole detection which has showed about 74% accuracy with is a great way for the project. With help all the field experts like administrator, manufacturing and consumer we have made data in word file which show not raw data but data which they required to fill up the pothole.

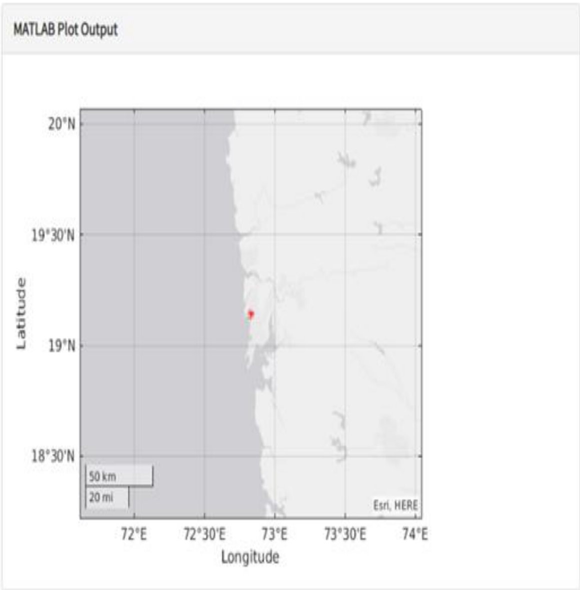


Figure 15 Geo-Mapping.

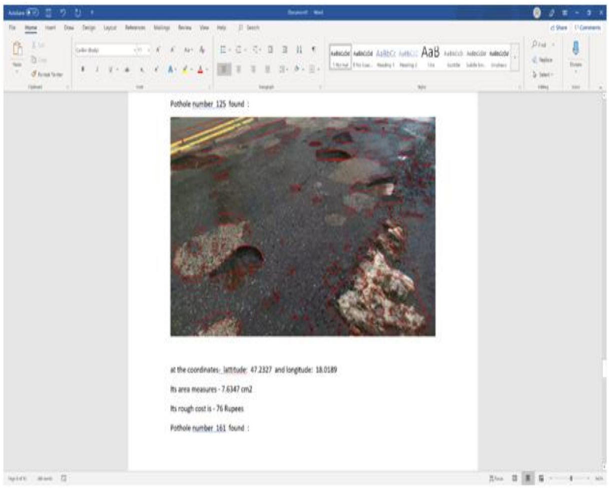


Figure 16 Word File give size, shape, volume, cost needed to fill pothole.

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