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## Recognition and Depth Approximation of Dry & Filled Potholes

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**ABSTRACT:** The proper planning of repairs and rehabilitation of the asphalt pavement is one of the important tasks for safe driving. The most common form of distress on asphalt pavements are potholes. While travelling through roads in India, a person frequently finds potholes which could be either dry or water-filled. Therefore, to asseverate safe driving, its highly essential to detect / recognise potholes along with estimating their respective depth & area independent of their condition. One of the major reasons of improper road track happens due to unawareness of government towards the condition of road. Timely repairing potholes is crucial in safety, quality of driving, and reducing the cost of vehicle maintenance. Road pothole detection system will detect the potholes and also estimates its depth, area and count of potholes using Matplotlib, OpenCV and Machine Learning trained model respectively. The system will generate 3D plot for estimating the depth of the pothole thus making it easier to visualize it. The proposed system acquires potholes images through camera using Android application. After checking the redundancy of the image, it will be directly send to the official site of higher authorities along with dimensions / parameters and estimated material for repair. Using latitude and longitude information from the images, potholes are geotagged on the selected map.

**KEYWORDS:** Pothole, Depth, 3D Plot, Pothole Detection, Matplotlib, OpenCV, Machine Learning, Geotagged.

### I. INTRODUCTION

In recent years, with the increase in world's population there has been increasing load on the infrastructure. Roads have been flooded with vehicular traffic. One of the major problems roads are facing is corroded road conditions. According to a survey one of the major reasons for road accidents is potholes [1] As indicated by the review report "Road Accidents in India, 2017", by the Ministry of Road Transport and Highways, an aggregate of 1.47 lakh individuals had lost their lives because of road accidents. According to most recent figures by a few state governments, potholes across the nation has claimed 3,597 lives in 2017, an over half ascent in the toll than a year ago. Around 30 deaths happen day by day on streets because of potholes.[2] The simplest approach we have chosen is to collect photos of road pothole taken by the participants and to upload them to a central server using the android application. The server is going to calculate different parameters of pothole such as count of pothole, area by image processing and most importantly depth from single image by generating a 3D graph.

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## II. RELATED WORK

### 2.1 Potholes Detection Based on SVM in the Pavement Distress Image

Jin Lin, et al [3], recommended a solution for recognition of potholes, constructed on Support Vector Machine which differentiated potholes from different deformities present on the road, for example splits or cracks etc. In order to detect the presence of potholes, the Support Vector Machine (SVM) was trained with a group of images of different pavements. The limitation of this model is that the model which is trained failed in detecting the defects on pavement if the pictures of the pavement are not properly taken or are not properly enlightened.

### 2.2 Metrology and Visualization of Potholes using the Microsoft Kinect Sensor

Moazzam, et al [4] recommended a solution which was economical for examining 3D pavement distress images that were captured. The cost of computation here is reduced by composite utilization of a low-cost Kinect sensor which aided by giving the undeviating depth measurement. The sensor used in the device consists of an RGB camera and an IR camera which would capture the depth images and RGB pictures that are put under examination using the MATLAB environment by extracting the characteristic and the metrological features to determine the exact depth of the potholes present in the image.

### 2.3 Pothole Detection and Warning System

Sudarshan S. Rode, et al [5], proposed to warn the vehicles nearby, vehicles furnished with Wi-Fi, collects data regarding the surface of road and transmit the data to Wi-Fi access point which broadcast to other vehicles. For that vehicles with Wi-Fi devices and adequate access point needs to be set up which was expensive.

### 2.4 An Intelligent System to Detect, Avoid and Maintain Potholes: A Graph Theoretic Approach

Sandeep Venkatesh, et al [6] recommended a solution to would detect along with which it would also avoid potholes making use of laser line striper along with a camera. The system consists of a database which is of central distribution wherein the location of the potholes was stored and maintained, along with this the system also sends a warning or an alert to the neighbouring transportation vehicles informing them about the presence of potholes utilizing Dedicated Short-Range Communication Protocol.

### 2.5. Pothole detection and severity measure-ment using laser imaging

Yu and Salari [7], implemented a system that uses laser imaging for detecting potholes. Pavement distress such as pothole is detected when the laser source deformation is observed in the captured images. Different techniques such as multi-window median filtering and tile partitioning are applied to detect the presence of potholes. These potholes are further classified based on their shapes and severity. Although this is an accurate and efficient method for detecting potholes, the cameras capture shaky images due to uneven road surface, which reduces the efficiency of pothole detection.

### 2.6 Road Hazard Detection and Sharing with Multimodal Sensor Analysis on Smartphones

Faith Orhan, et al [8], presented a piece of work that he created using the android programme for the purpose of recognizing the hazards related to the roads which is composed of three core ingredients; namely Sensing, Analysis and Sharing. The primary component sensing collects unprocessed information with the help of the accelerometer and then synchronizes it with the user interface for making access easier. The data which is gathered with the help of the sensors are used for making the analysis modules in the component. For secondary component sharing: the framework which is constructed is joined with the central application, through which it can directly communicate with each other. Now for processing all the information or data further, the whole of data or information gathered is stored and maintained at the central repository.

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## III. METHODOLOGY

Even though there are other traditional systems for performing pothole detection which are involving vehicles equipped with sensors and camera provide accurate results, but the cost overhead associated with them makes them infeasible. But this paper aims at introducing a system that is highly inexpensive and provides accurate results with maximum precision.

### 3.1 Flow of Operations

First the user logs into his/her account and takes a picture of the pothole along with the current location of the user using the android application and upload the image to the server. The server performs three actions on the image. By image processing the server first finds the number of potholes present in the image, secondly it finds the area of pothole(s) present and finally find the depth by generating a 3D plot.

### 3.2 Image Processing

Firstly we find out the size of the image of the decoded image by using the function of OpenCV known as Numpy.shape, which return the height and width of the current image, this is required to create a mask of the image. As the next step the input image  $i(x,y)$  shown in Figure 2 is converted to grayscale image  $g(x,y)$  as seen in Figure 3 using the `cv2.cvtColor()` function of OpenCV. As the primary input, the function acquires the original form of the image from the user. Further as the secondary input, it acquires the color space conversion code. Considering that our goal is to convert the obtained original image from the BGR color space to grayscale, we tend to utilize the code `COLOR_BGR2GRAY`.



Figure 2: Original Image



Figure 3: Grayscale Image

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Then the grayscale image is converted into binary image. When the value of the pixel is found higher than a threshold value, the result is assigned as one value (which could be white) else it is assigned as another value (which could be black). This is achieved using the OpenCV function `cv2.threshold`. The primary parameter taken is the source image, such image should be a grayscale image. Secondary parameter is the threshold value which is utilized for classification of the pixel values. Tertiary parameter is the `maxVal` that is utilized to represent the value given if the value of the pixel is less than or is sometimes more than the specified threshold value.



Figure 4: Original



Figure 5: Binary

In conversion of original image to binary image the pixels get rearranged in the below given format. Consider an example of the image as Figure 4 when converted to binary, the image gets converted into Figure 5.

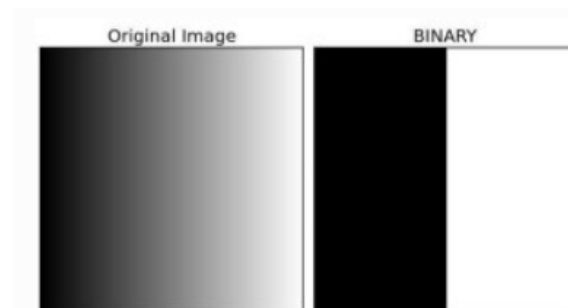


Figure 6: Conversion of Original to Binary

The figure 6 shows the result of converting the original image to binary image. The next step is to get the object of interest, this is done with the help of the GrabCut algorithm. This GrabCut algorithm cuts the background object and removes it from the image which gives us the object of interest on which we perform some processing.

Initially program draws a rectangle around the foreground region (foreground region should be completely inside the rectangle). Then the GrabCut algorithm generates a mask of the object which allows the background and foreground to be separated, once they are separated the algorithm performs segmentation iteratively on the image to in order to get the best possible solution, along with which the center of the image is also marked with the label Centroid print on the resulting image. An illustration of which is shown below, if we have Figure 7 as input from the user then Figure 8 is the output of image.

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Figure 7: Pothole captured using camera



Figure 8: Masked Pothole

Once the object of interest is extracted, then the area of the pothole is found. For the area of pothole the function of OpenCV is used, the function `cv2.contourArea()` works by finding the number of counters in an image. To find the area first moments are found using `cv2.moments()`, which performs computations of all the moments until the third order of a polygon or rasterized shape while it tries to determine the center of the blob. Image Moment is a specific weighted average of pixel intensities present in the image, through the help of which we would be able to find some properties associated to the image, for example area, radius, centroid etc. Similarly to find the centroid of the original image, we normally convert the image to binary format and later detect its center. The centroid is represented by the:-

$$C_x = \frac{M_{10}}{M_{00}}$$

$$C_y = \frac{M_{01}}{M_{00}}$$

$C_x$  represents the x coordinate &  $C_y$  represents the y coordinate of the centroid along with  $M$  denoting the Moment. After finding out the moments we calculate the area of object using the centroid already found. The function used for computing the area of the contour is `cv2.contourArea()`. Homogeneous to moments, computation of the area is done by the utilization of the Green formula. Thus, the result is the area returned along with the count of the non-zero pixels present. Since the image is made from a group of pixels, so the area calculated using the function is in pixels, therefore the area calculated is converted from pixels to square cm.

### 3.3 Deep Learning CNN Model

Deep learning is the field of artificial intelligence is essentially when machines can do tasks that typically require human intelligence. It encompasses machine learning, where machines can learn by experience and acquire skills without human involvement. Deep learning is a subset of machine learning in artificial intelligence (AI) that has networks capable of learning unsupervised from data that is unstructured or unlabeled. Technology behind driverless cars, which enables them to recognize a stop sign, or to distinguish a pedestrian from a lamppost is deep learning. There might be hundreds of such specialized visual recognition AI that all feed their opinions into an AI that interprets

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driving events. In theory, a single car could use the opinions of thousands or even millions of individual AI as it navigates a street. It is the key to voice control in consumer devices like smartphones, tablets, laptops, TVs, etc. Human level performance can be exceeded sometimes by using deep learning with state-of-the-art accuracy model. Large set of labeled data and neural networks architecture are used to train models which contains many layers without the use for manually extracting the data feature. One of the most popular types of deep neural networks is known as convolutional neural networks or CNN. [9] This system too uses the Convolutional Neural Network (CNN), an example of which is shown in figure 9. In CNN we have used SqueezeNet Architecture for identifying whether the object of interest is present or not.

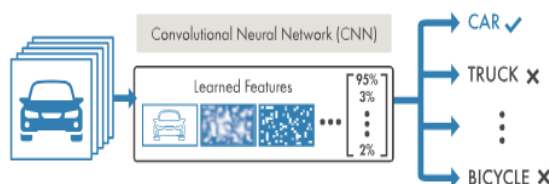


Figure 9: Example of CNN

The architecture used in the system is given below in figure 10.

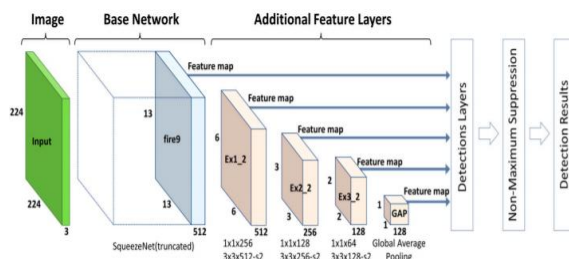


Figure 10: SqueezeNet Architecture

The above architecture takes 224x224 px inputted image, and then uses the architecture of SqueezeNet (Shorten) with the addition of multiple layers to extract details of image. The detection is performed by using the features from the five layers namely Three convolutional layers (Ex1\_2, Ex2\_2, Ex3\_2), a global average pooling layer (GAP), and the last fire module in the SqueezeNet (fire9). With SqueezeNet as the base network and append several additional layers. Significantly reduces the computational cost of the proposed model, using image dataset a model is trained. [10] The model which is proposed in this system is used for identifying if there is a pothole or multiple potholes in the given image. If pothole(s) is / are found then a rectangle is drawn around it and the accuracy is displayed on the top of it. In figure 11 and 12 we can see that after the image is inputted from the user, the trained model identifies the number of potholes in the image and provides the output.

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Figure 11: Multiple pothole

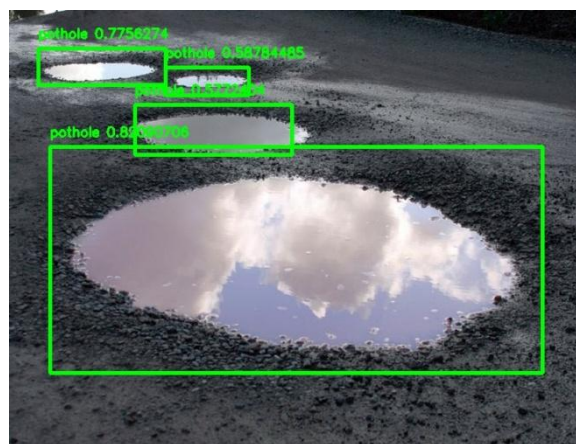


Figure 12: Potholes(s) Identified using CNN Model

### 3.4 Matplotlib 3D Depth Plot

The Matplotlib is a more contemporary plotting bundle that has been gaining consequential traction in the Python clique. It is known for providing a very quality rich and substantial environment for plotting. The amalgamated Graphical User Interface (GUI) elements along with emerging plot panels appeal to be much more modernistic, with the added advantage that the plotting panel could also be blended into variegated other applications of GUI, comparatively than living in a separate window to Gnuplot. For the Graphical User Interface it can use various generic GUI toolkits (wxPython, Qt or GTK). One of the features of matplotlib is that it offers next to the object-oriented API an additional procedural interface (the pylab interface) that is closely modelled to bear a resemblance to that of MATLAB. The coalescence of both, the matplotlib along with the NumPy therefore could be utilized as a complementary, easy and a modern way to familiarize oneself with the substitution of the package/ packages.[11] When using Matplotlib Axes object is used for axes projections, similarly an Axes3D object is created just like any other axes using the projection = '3d' keyword. This makes the a 2D image into a 3D projection, that is the images gets converted from two axes (x & y) and achieves the third axes (z) making it a 3D image and is then projected onto the 3D axes. In the proposed system we take the image of the pothole and project it on the 3D axes by which we are able to detect the depth of the pothole. Since

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pothole(s) are uneven surface object, therefore we consider the lowest / the most deepest point from the 3D plot as depth of the pothole. From Figure 13 we can see that the 2D image of a pothole is inputted by the user & processed, a 3D projection is generated from it. If the original 2D image of pothole sent by the user is taken to form a 3D projection then we get a 3D plot with lots of noises present in the it. Therefore we have applied gaussian blur to the original image and then is processed for forming the 3D plot which reduces the noises present in the plot and which results in a better values of depth. Here the z axes gives us the depth.

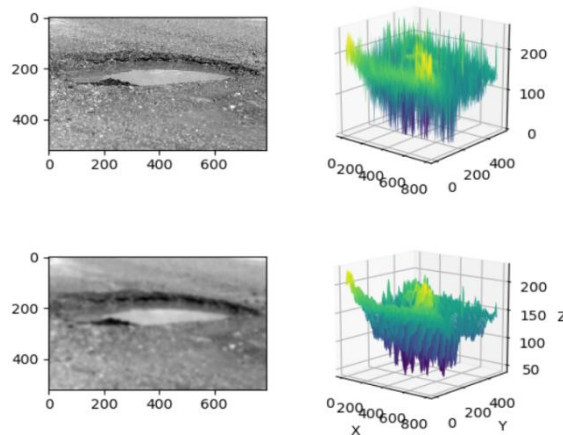


Figure 13: Depth Analysis

## IV. IMPLEMENTATION

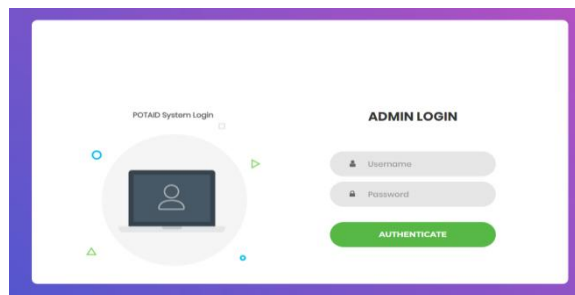
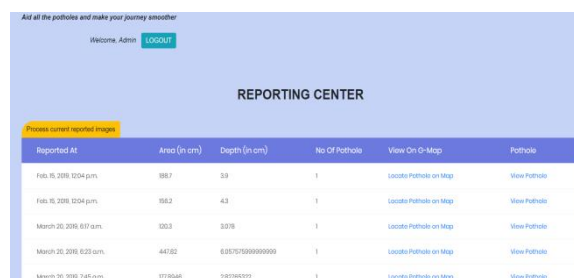


Figure 14: Admin Login

This will be the admin login page which will be operated by the user authorised through the administrator.



Reported At	Area (in cm)	Depth (in cm)	No Of Pothole	View On O-Map	Pothole
Feb 19, 2019, 10:54 p.m.	88.7	3.9	1	<a href="#">Locate Pothole on Map</a>	<a href="#">View Pothole</a>
Feb 19, 2019, 10:54 p.m.	88.2	4.3	1	<a href="#">Locate Pothole on Map</a>	<a href="#">View Pothole</a>
March 20, 2019, 6:17 a.m.	100.3	3.976	1	<a href="#">Locate Pothole on Map</a>	<a href="#">View Pothole</a>
March 20, 2019, 6:22 a.m.	447.02	6.917019099999999	1	<a href="#">Locate Pothole on Map</a>	<a href="#">View Pothole</a>
March 20, 2019, 7:45 a.m.	177.846	2.8276532	1	<a href="#">Locate Pothole on Map</a>	<a href="#">View Pothole</a>

Figure 15: PotAid Dashboard



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This is the dashboard visible to the system admins through which they will be able to see & operate the following functionalities:

- (i) The date and time at which the pothole was reported.
- (ii) Area of the potholes in the image provided by the user. Area that will be displayed will be in sq cm.
- (iii) Depth of the pothole in cm.
- (iv) Number of Pothole present in the image uploaded by the user.
- (v) The admin will also be able to view the pothole on the Google Map by accessing the link of a particular entry in the table.
- (vi) The dashboard also gives the facility of viewing the pothole to admin which the user had sent using the app.
- (vii) Admin will be also given a button on the top of the table "Process current reported images", which will be used when there are entries made with the word "None" in columns of recently reported potholes. The admin will press the button and will get the measures of the pothole like area, depth etc which had been reported by the user.

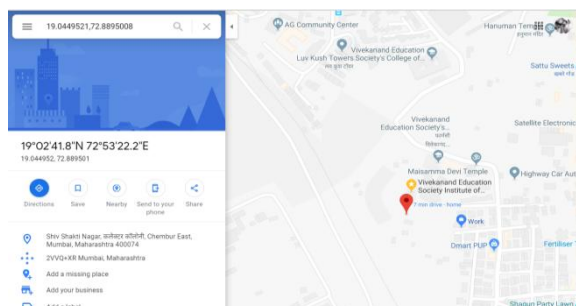


Figure 16: Pothole Location

This will be viewed to admin when he/she tries to locate the pothole. The location from which the user had sent the image will be marked using red marker & shown to the admin on the map.

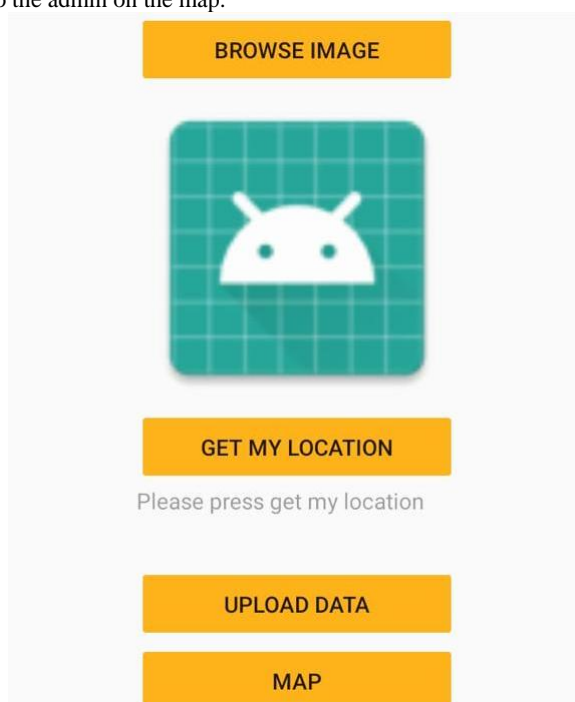


Figure 17: Android GUI

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The android app shown in Figure 17 will be used by the user to report a pothole to the officials. Firstly the user has to capture the image of pothole using the built-in camera of the phone then the image is browsed from gallery, next the user will get his/her location using Get Location button and finally the user will press the upload button. If the upload is successful then Thank You message will be displayed else an error message will be displayed. An example of this is shown below where a user is uploading a pothole image which he / she has captured using his/her phone built in camera, and then clicked the Get My Location button to get the current location in the form of latitude and longitude. Once the location of user is successfully then the user presses the Upload Data button, which sends all the data that is image, latitude and longitude is sent to the server for further processing which has been depicted below in Figure 18.

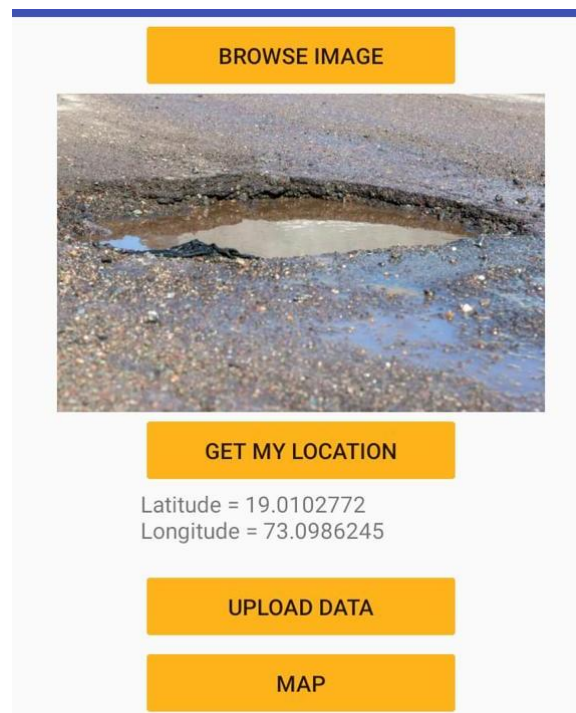


Figure 18: Sample Input

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Figure 19: Map with pothole reported locations

The user has been given one more functionality that will allow the user to be able to view a google map containing all the potholes which had been reported by different users all around the country. Figure 19 shows the different locations within the country at which a pothole has been spotted.

### V. CONCLUSION

We have performed various testing experiments in term of calculating count, area and depth of pothole. The most crucial key is to entirely use the information obtained. Firstly the model with false positive and negative image of pothole is trained to identify whether it's pothole after identifying the count calculated after that the area and then the depth from a single image is obtained by using 3D plot algorithm. Results show that application can detect potholes and reckon all the parameters accurately. The government body are also intimated about the location of the pothole using the latitude and longitude while capturing image and thus the potholes can be recovered soon.

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