A Computer Vision based Framework for Detecting Potholes on Asphalt-Road using Machine Learning Approach

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***Abstract*—**This paper proposes a Pothole Detection Framework which may assist the pedestrian in avoiding potholes on the roads by giving prior warnings. The basic idea of this framework is to detect the pothole on asphalt road by analyzing the image of the road-surface. This proposed framework combines image processing techniques with machine learning methods and primarily explores edges, Histogram of Gradients and Local Binary Patterns of an image frame for extracting features to detect the presence of potholes on the road surface. The experimental results indicate promising potential of the proposed framework for detection of potholes on asphalt-road.

***Index Terms*—**Potholes, Road Defect Detection, Crack Detection, Local Binary Pattern, Computer Vision and Machine Learning..

I. INTRODUCTION

The ever-increasing concern of the road development authorities is one of the major reasons for the increasing road mishaps. Potholes trigger majority of such mishaps. A pothole is defined as a bowl-shaped depression in the pavement surface, and its minimum plan dimension is 150mm [1]. With the frequent changes in climatic condition and extreme weather such as heavy rain, road surfaces are getting more damaged and thus complaints regarding road accidents are increasing. There are internal causes to potholes such as the degradation and responsiveness or durability of the pavement material itself to climate change, such as heavy rainfall and snowfall, and external causes such as the lack of quality management and construction management. It is a very time-consuming process to manually detect and identify the potholes on the road surfaces. Thus, several efforts have been made for developing a technology that can automatically detect and recognize potholes, which may contribute to the improvement in survey efficiency and pavement quality through prior investigation and immediate action. In our framework, 2D road images that have been collected by video recording of road surface and the performance of the proposed method is evaluated for several conditions such as road, recording, and brightness.

II. RELATED WORK

We have tried and used various methods on different perspectives to design a method which can automatically detect and recognize potholes. A detailed survey on methods for pothole detection can be found in Koch and Brilakis [6]. And also, Kim and Ryu [9]. Pothole detection methods can be divided into vibration-based methods by B. X. Yu and X. Yu [1], De Zoysa et al. [4], Eriksson et al. [5], and Mednis et al. [6]; three-dimensional (3D) reconstruction-based methods by Wang [7], Kelvin [8]. Accelerometers are used in vibration-based pothole detection. If we consider the benefits of a vibration-based system, a very little amount of storage is used and can be used in real-time processing. However, wrong results can be provided by the vibration-based systems, for example, that the hinges and joints on the road can be detected as potholes and that potholes in the center of a lane cannot be detected using accelerometers due to not being hit by any of the vehicle's wheels. Real time detection of potholes can also be done by 3D laser scanning. However, the cost of laser scanning equipment is still significant at the vehicle level, and currently these works are focused on the accuracy of 3D measurement. High computational effort is required for stereo vision methods to reconstruct pavement surfaces by the help of feature points matching between two views so that it is difficult to use them in a real-time environment. Recently, Moazzamet al. [9] used a low-cost Kinect sensor to collect the pavement depth images and calculate the approximate volume of a pothole. Although it is cheaper compared to industrial cameras and lasers, the use of infrared technology based on a Kinect sensor for measurement is still a novel idea, and further research is necessary for improvement in error rates. Even though the vision-based methods much cheaper than the 3D laser scanning methods, it is quite tough to detect road anomalies using these methods because of the distorted signals generated by noise in collecting image and video data. Thus, a pothole detection method using various features in 2D images is proposed for improving the existing pothole detection method and accurately detecting a pothole. A 2D image-based approach has been focused only on pothole detection and is limited to a single frame, so it cannot determine the magnitude of potholes for assessment. To overcome the limitation of the above method, video-based approach is explored to detect a pothole and calculate the total number of potholes over a sequence of frames.

Fig. 1. Pothole on Asphalt Road

III. PROPOSED FRAMEWORK

This section discusses our proposed framework in detail. The following figure intuitively demonstrates the overall flow of the proposed strategy. The description of each step of the overall flow is detailed next.

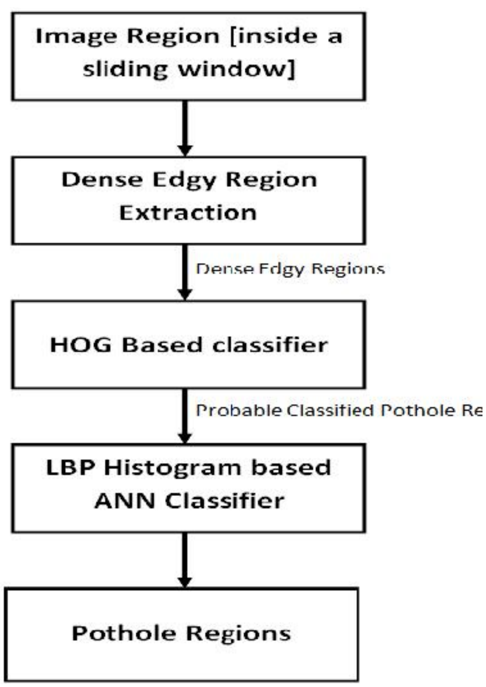


Fig. 2. Overall Flow of the Proposed Scheme

A. Edgy Region Extraction

Roads are often seen with different anomalies. Roads containing potholes corresponds to dense edgy region. From the image processing perspective, cracks/potholes free road surface has no edges, whereas slight cracks and small potholes on road surface contains non-dense edges, on the other hand, regions of the road containing severe potholes have dense edgy regions. That's why, we have used Canny filter for edge extraction. Then we calculate edge density by using a small sliding window, which checks each and every portion of the image for the dense edges. We select the candidate region from the images by checking whether the calculated density of the image pixel is greater than the obtained thresholded image. If the condition satisfies, we select the region as candidate region. The resultant image after applying canny filter is shown in Fig. 3.

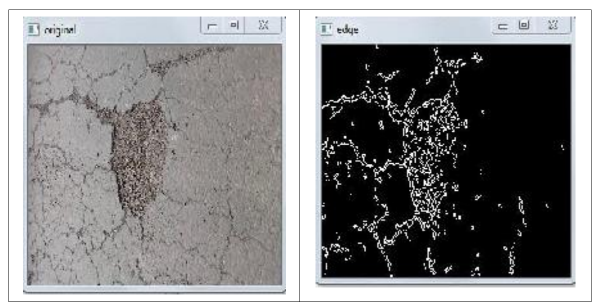


Fig. 3. Edgy Region Extraction

B. Histogram of Gradients based Verification

The histogram of oriented gradients (HOG) is a feature descriptor used in computer vision and image processing for the purpose of object detection. In our proposed working model, we have used HOG based classifier to find out the gradients of the sample images. It has been seen that the portions of the road surface which have potholes, gradients are spread unevenly in different angles (Fig. 4b) whereas portion not having any cracks or potholes have even number of gradient spreads in the image. That's why, we have used Histogram of Gradient (HoG) descriptor to classify (Fig. 4a) the severity of the pothole on road surface.

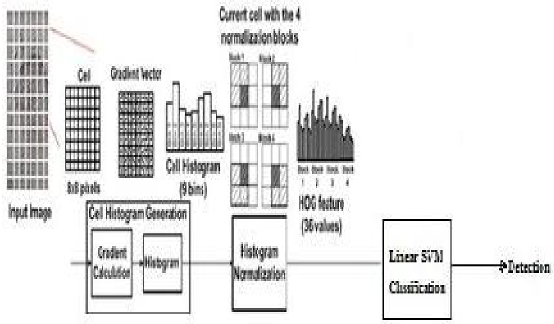


Fig. 4a HOG based verification scheme

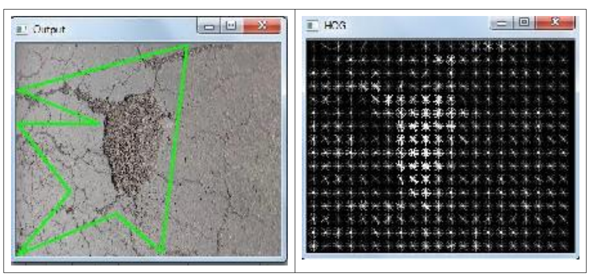


Fig. 4b HOG based verification scheme

C. Local Binary Pattern based Texture Analysis

Local binary patterns (LBP) is a type of visual descriptor used for classification in computer vision. LBP is the particular case of the Texture Spectrum model proposed in 1990. Different road surfaces have their own unique textures. Potholes on plain road surface have their unique kind of textures and gradients. Hence, in our framework, we have used linear binary pattern (LBP) to distinguish the potholes from the other portion of the road, and hence separating the candidate regions. After identifying the unique texture of the potholes, we calculate the histogram of LBP values of the candidate regions.

Illustration of LBP Extraction:

In the following figure, we take the center pixel (highlighted in red) and threshold it against its neighborhood of 8 pixels. The value of the central pixel is compared with the neighbourhood pixel. If the central pixel is greater-than-or-equal to the neighbours, we set the value 0 in that particular neighbourhood position, else we set 1 as the neighbourhood position. So, with the 8 neighbourhood pixels, we have $2^8 = 256$ possible combinations of LBP codes.

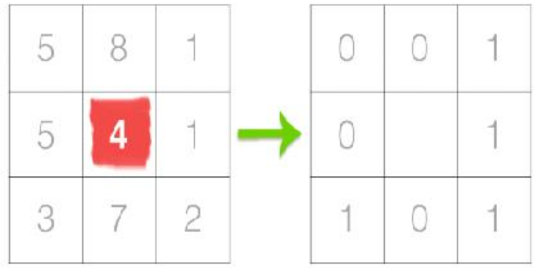


Fig. 5 LBP Thresholding

Next, we calculate the LBP value for the center pixel by considering neighbors in clockwise direction. Given a 3 x 3 neighborhood, the results of this binary test are stored in an 8-bit array and subsequently it is converted to decimal as illustrated in following figure.

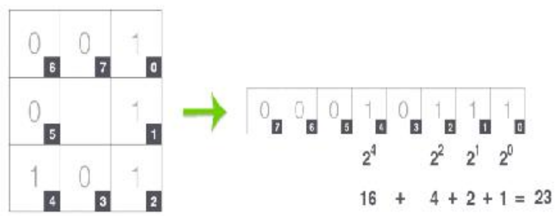


Fig. 6. LBP Value Calculation

The last step is to compute a histogram over the output LBP array. Since a 3 x 3 neighborhood has 2 ^ 8 = 256 possible patterns, our LBP 2-D array thus has a minimum value of 0 and a maximum value of 255, allowing us to construct a 256-bin histogram of LBP codes as our final feature vector.

D. ANN based Verification

The proposed framework verifies HOG and LBP features as potholes using Artificial Neural Network model. An artificial network performs in two different modes, learning (or training) and testing. We calculate the severity of the damage of the road surface from the obtained candidate regions using the help of ANN classifier.

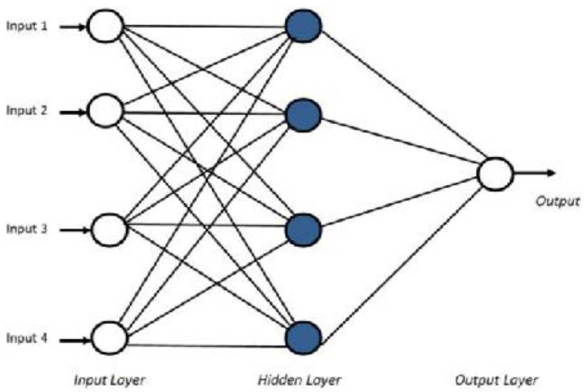


Fig. 7. ANN Model

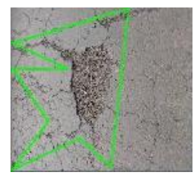
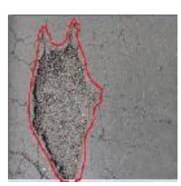
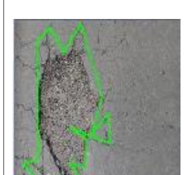
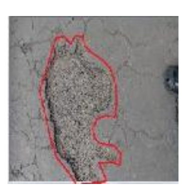
IV. EXPERIMENTAL RESULTS AND ANALYSIS

In order to evaluate the performance of the proposed framework, experiments have been conducted on manually captured dataset. Table 1 lists a set of sample images along with pothole regions as identified by our algorithm. Evaluation of performance is a difficult for such framework, mainly due to the subjectivity of the human vision-based judgment. The merit of such a classification scheme is usually presented in terms of confusion matrix [Table 2]. Intersection over Union (IoU) is an evaluation metric which is widely used to measure the accuracy of an object detector on a particular dataset. This evaluation metric is often used in object detection challenges whereas the accuracy is measured based on True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) values [Accuracy = *(TP + TN) / (TP + TN + FP + FN)*]. IoU is the proportion of the area of overlap between predicted pothole-region (b_p) and ground truth based respective pothole-region (b_t) to the overall area. If IoU exceeds 0.5 then the detection is considered as true prediction (TP) in our proposed model. As per our observation, the proposed framework seems to perform reasonably well with overall accuracy nearly 96.5%.

$$IoU = Area(b_p \cap b_t)/Area(b_p U b_t)$$

Table 1. Confusion Matrix

GROUND TRUTH	DETECTION (%)	
	POTHOLE	NON-POTHOLE
TRUE POTHOLE	95	5
TRUE NON-POTHOLE	7	93

Ground truth bounding box	**Predicted bounding box**	**Accuracy (IoU)**
		82.35%
		78.9%
		73.29%
		85.62%
		83.25%
		80.67%
		86.39%

V. CONCLUSION

In this study, a pothole detection method based on 2D road images was proposed for improving the existing method and designing a pothole detection system to be applied to road management system. For experiments, 2D road images were collected by video recording of road surface and the performance of the proposed method is evaluated for various road-conditions. The proposed method reaches an overall accuracy of 96.5% which is reasonably acceptable performance. However, there are some limitations in the proposed method. Potholes may be not be detected due to water-logged state and broad variances of textures of the potholes. Thus, in order to more accurately detect potholes, it is necessary to use images from not only a single sensor but also additional sensors.

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