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Machine Learning for Automated Pothole Detection

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Abstract: Road conditions during the rains are aggravated, even after frequent reconstruction and maintenance, and are not repaired on time due to lack of information. Potholes cause problems such as over-inflated tires, wheel damage, damage to the underside of the vehicle, collisions and serious accidents. Therefore, accurate detection of potholes is a necessary task to determine the appropriate system of road management strategies. Several efforts have been made to overcome this problem. In this study, a pothole detection method that takes 2D images into account proposes a pothole detection system which uses convolutional neural networks which increased the accuracy significantly and is cost efficient. The information extracted from the proposed method is used to determine the preliminary maintenance of a road management system and to take immediate action on repair and maintenance.
Keywords: Machine learning, convolutional neural networks(CNN), potholes, image processing.

I. INTRODUCTION

A pothole is defined as a depression in the surface of the pavement and its minimum dimension in the plane is 15 cm. With climate change, like heavy rains in India, damaged pavements like potholes increase. Thus, complaints and prosecutions for pothole accidents increase. Potholes have internal causes, such as the degradation of the pavement material and external causes, such as the lack of management of quality and construction. The potholes are an important indication of the structural defects of the paved road and their precise detection is a crucial task in determining the proper road maintenance and rehabilitation strategies. However, manual detection and evaluation methods are expensive and time-consuming. Therefore, several efforts have been made to develop a technology capable of detecting and automatically recognizing potholes, which could help improve the efficiency of the survey and the quality of the pavement through previous research. The existing methods for the detection of potholes can be divided into methods based on vibrations, three-dimensional methods (3D) and methods of reconstruction. These models are not profitable, nor does this method effectively inform the authorities for road repair. In general, these systems are mounted on very expensive cars and do not involve potential road repairs. The proposed system uses machine learning to learn the patterns of a pothole and the images and videos of traffic cameras to detect potholes. Once these holes are detected using the location of the camera, the maintenance and administration authorities are informed of the highway of the cutting road and its location to take the necessary measures.

II. LITERATURE SURVEY

The detection of potholes is necessary for the safety of the itinerant population. (Hyunwoo Song and et al) have proposed a low-cost 3D roadmap analysis model, which uses a low-cost kinetic sensor that provides direct depth measurements, which reduces computational costs. Lin and Liu have proposed a pothole detection method based on SVM (Support Vector Machine).

(Kwok Yu Mak et al) of NYU have developed a project using a methodology that distinguishes potholes from other defects, such as cracks. This project focused on the construction of an easy to remove and easy to use device that specializes in the detection of potholes in addition to the detection of short-range obstacles. This project uses blinking LEDs and vibrations for user safety.

In “Pothole Detection System using Machine Learning on Android” a research paper (Aniket Kulkarni and et al) have proposed a system and an associated algorithm to monitor the conditions of road potholes to track the location of potholes in Google Maps using Android devices. (Hsiu-Wen Wang et al) propose in a research paper a pothole detection method based on mobile detection. The generated accelerometer data is normalized by calculating the Euler angle and then adopted in the pothole detection algorithm to obtain information about potholes. In addition, the spatial interpolation method is used to reduce location errors in the data collected by GPS. (Jinting Ren et al) drafted a conference document that proposes a reliable pothole detection system using machine learning to facilitate the detection of potholes and the maintenance of road conditions. The proposed system provides a low latency in the detection of potholes and the reduction of the time necessary for road maintainers to identify defective roads and also reduce the monetary costs for the development of the system.

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III. PROPOSED WORK

A pothole detection system is designed to collect images of the road through a camera and detect a pothole from the data collected using the proposed algorithm. The camera collects data about potholes and the collected data is sent to a pothole detection algorithm. The pothole detection algorithm works based on CNN.

CNN:

The proposed methodology can be divided into three stages:

A. Segmentation of the image.
B. Extraction of the region of interest.
C. Decision

First, a histogram and the operation of closing a morphological filter are used to extract the dark regions for the detection of holes. Therefore, the candidate regions of a hole are extracted using different characteristics, such as size and compactness. Finally, it is decided whether the candidate regions are unequal or not by comparing the characteristics of the hole and the bottom with the pothole data set. The segmentation phase consists of separating a region from the hole of the background region by transforming an original color image into a binary image using the histogram of an input image.

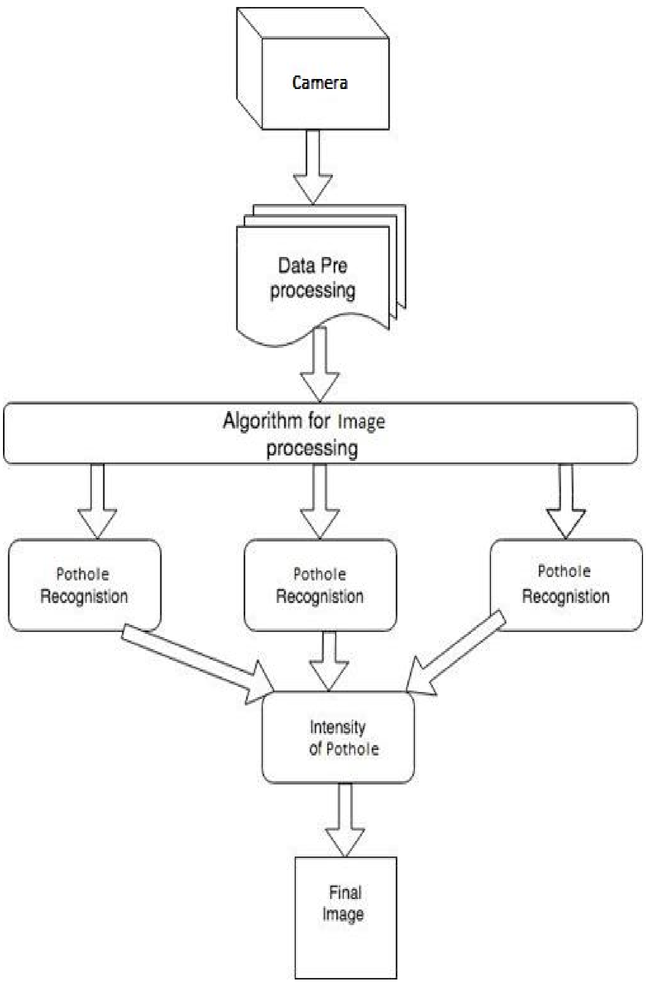

Fig 1: Flow Chart for Detection of pothole

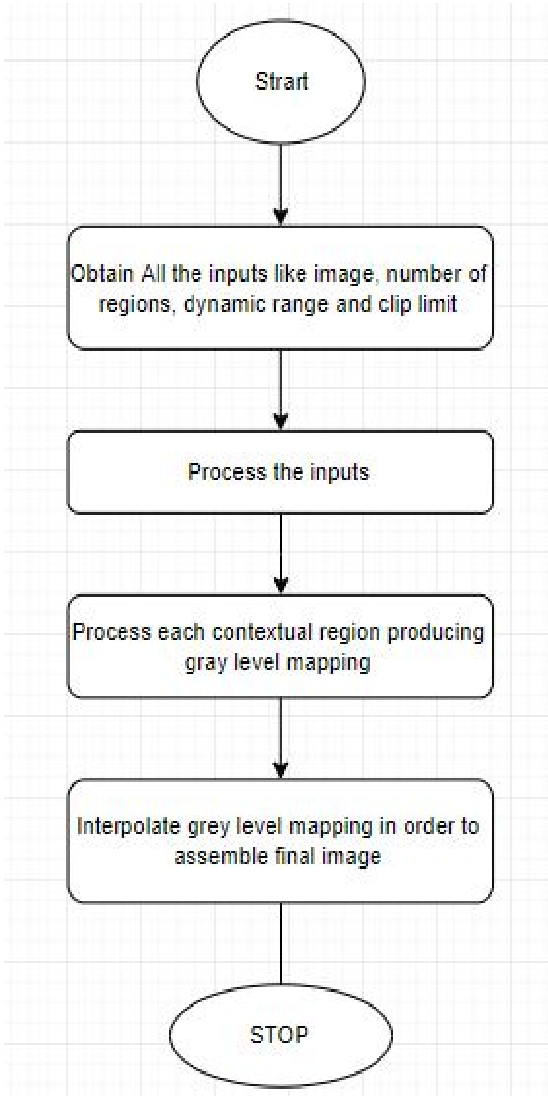

Fig 2: Component Diagram

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IV. RESULTS AND DISCUSSION

The paper proposed a new pothole detection system with an optical camera and a unique pothole detection algorithm. The convolutional neural network algorithm is simulated on a desktop computer and uses the inputs of an optical camera.

The proposed pothole detection CNN algorithm is designed and implemented taking into account the limited computing capacity of existing systems. Experimental results potentially show that the proposed algorithm can correctly eliminate different types of similar objects, such as patches, records, tents and moving vehicles. By doing so, the regions of the hole are detected correctly. The general sensitivity and accuracy is approximately 90% to 99%, respectively. As a result, the CNN algorithm is considerably robust for similar objects. In some cases, however, the proposed system does not detect particularly bright or flat holes. When the intensity of sunlight changed rapidly, false detections occurred. We intend to improve this algorithm with a minimum increase in the complexity of the system in general.

Therefore, the CNN algorithm remains a bit problematic. However, we confirm that a pothole detection system using a typical traffic camera can be potentially used as an automated and intelligent pothole maintenance system for road maintenance authorities.

Implementation Details:

A. Software and tools: Python 3.7.0, Git 2.21.0, Anaconda.
B. Editor: Jupyter.
C. Libraries: Tensorflow, Mobilenet CNN.

MobileNet is a a small efficient convolutional neural network. "Convolutional" just means that the same calculations are performed at each location in the image. We used a pre-trained convolutional neural network Mobilenet 0.5_224 for our system. The system uses Python's TensorFlow library for machine learning. We got our pothole dataset from Cranfield University's Online Research Data(CORD) to train our system.

1) *Training:* We train our dataset on top of the Mobilenet convolution neural network. The input resolution we take is 224 pixels in order to increase the data accuracy. The relative size of model is 0.5 to the original image in terms of fraction to reduce the input size. Also the dataset is trained according to colors, edges, features, curves, shape etc. We do the training in 500 steps that is we run a testing image on top of the CNN for 500 times in order to increase the accuracy. The training runs all the images on top of the convolution neural network and checks for validation accuracy, train accuracy, cross entropy. The bottleneck files are created for all the images.
2) *Testing:* Once we train our classifier in order to recognize a pothole, we input test cases and the bottleneck of this image is tested against the bottle neck of all the bottleneck dataset that was stored and the closest bottlenecks are selected. Thus we can determine the images fractional participation as per the available dataset. This fraction determines the existence of pothole in the image.

Fig 3 Raw Image without Detection

Fig 4: Raw Image without Detection

```
rishabh@rishabh-Aspire-4736: ~/Desktop/tensorflow-for-poets-2
File  Edit  View  Search  Terminal  Help
INFO:tensorflow:2019-03-26 16:34:38.656261: Step 400: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:38.656575: Step 400: Cross entropy = 0.018595
INFO:tensorflow:2019-03-26 16:34:38.723612: Step 400: Validation accuracy = 99.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:39.355362: Step 410: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:39.355674: Step 410: Cross entropy = 0.003252
INFO:tensorflow:2019-03-26 16:34:39.418398: Step 410: Validation accuracy = 99.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:40.035346: Step 420: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:40.035957: Step 420: Cross entropy = 0.005250
INFO:tensorflow:2019-03-26 16:34:40.101871: Step 420: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:40.703418: Step 430: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:40.703732: Step 430: Cross entropy = 0.002401
INFO:tensorflow:2019-03-26 16:34:40.767142: Step 430: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:41.383516: Step 440: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:41.383809: Step 440: Cross entropy = 0.008217
INFO:tensorflow:2019-03-26 16:34:41.443781: Step 440: Validation accuracy = 98.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:42.044937: Step 450: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:42.045225: Step 450: Cross entropy = 0.007070
INFO:tensorflow:2019-03-26 16:34:42.108220: Step 450: Validation accuracy = 98.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:42.716386: Step 460: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:42.716693: Step 460: Cross entropy = 0.002976
INFO:tensorflow:2019-03-26 16:34:42.781931: Step 460: Validation accuracy = 99.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:43.417130: Step 470: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:43.417667: Step 470: Cross entropy = 0.004353
INFO:tensorflow:2019-03-26 16:34:43.487684: Step 470: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:44.123842: Step 480: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:44.124136: Step 480: Cross entropy = 0.004740
INFO:tensorflow:2019-03-26 16:34:44.189488: Step 480: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:44.808978: Step 490: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:44.809261: Step 490: Cross entropy = 0.002862
INFO:tensorflow:2019-03-26 16:34:44.875417: Step 490: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2019-03-26 16:34:45.435942: Step 499: Train accuracy = 100.0%
INFO:tensorflow:2019-03-26 16:34:45.436252: Step 499: Cross entropy = 0.005087
INFO:tensorflow:2019-03-26 16:34:45.501354: Step 499: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:Final test accuracy = 99.1% (N=438)
INFO:tensorflow:Froze 2 variables.
Converted 2 variables to const ops.
rishabh@rishabh-Aspire-4736:~/Desktop/tensorflow-for-poets-2$
```

Fig 5 Pothole Detected

V. CONCLUSION AND FUTURE SCOPE

In this article, we propose a unique pothole detection system with an optical camera, and we have also implemented a CNN algorithm. The algorithm was simulated on a desktop computer and using the inputs of an optical camera.

The proposed pothole detection algorithm was designed and implemented taking into account the limited computing capacity of existing systems. The experimental results show that the proposed algorithm can correctly eliminate different types of similar objects, such as patches, registers, stores and moving vehicles. By doing so, the regions of the hole can be detected correctly. The general sensitivity and precision reached 60% and 90% respectively. Therefore, the algorithm is considerably robust for similar objects. In some cases, however, the proposed system did not detect particularly bright or flat holes.

Extensive research is needed in a variety of climatic conditions. In addition, we will collect more video data from holes in later evaluations. When the intensity of sunlight changed rapidly, false detections occurred. We intend to improve this algorithm with a minimum increase in the complexity of the system in general.

Therefore, the proposed terrain detection algorithm remains problematic. However, we are confident that a well detection system using a new system has the potential to be used as an automated and intelligent pothole detection system.

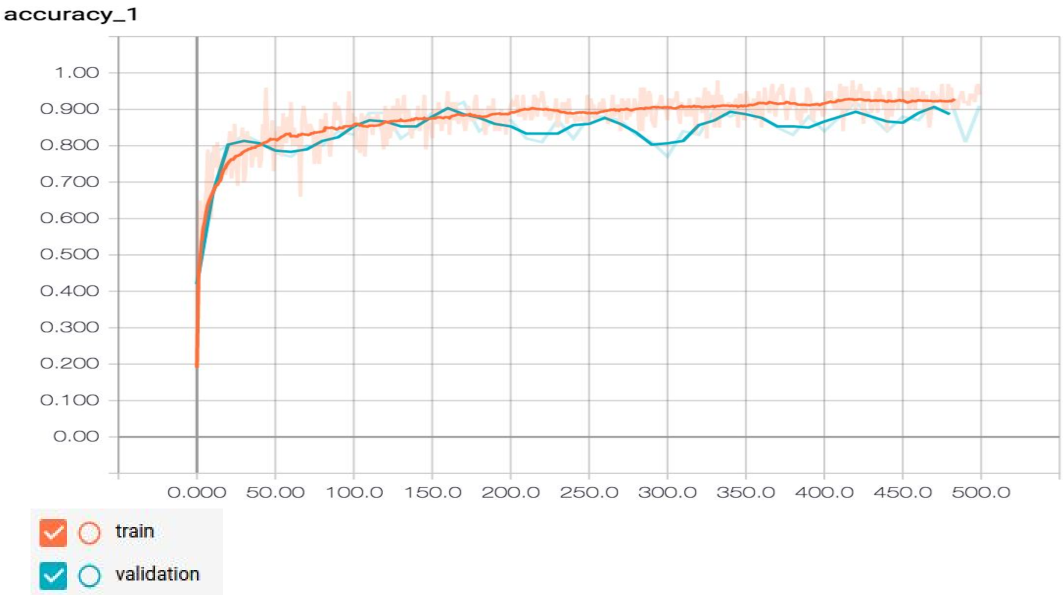

Fig 5: Accuracy Graph

A. In the Future, the System

1) It can be integrated with the surveillance system present in cities.
2) It can be integrated into any CCTV camera.
3) It can be more integrated with car cameras.
4) Can be trained to recognize roads vulnerable to flooding.
5) Can be integrated with drones and other optical devices.

B. Driving Social Benefits Such As

1) Decrease the number of traffic accidents.
2) Bring transparency to government business.
3) Reduce the risk of flooding in the future.
4) It will influence in maintaining the aesthetics of the roads.

VI. ACKNOWLEDGEMENT

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