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Pothole Detection using Computer Vision and Raspberry Pi

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Abstract: One of the main reasons for the number of potholes rising overtime is the poor road-maintenance system along with aging roads with no maintenance. This then jeopardizes road safety as well as transport efficiency, resulting in being the lead cause of car accidents. To address the problems associated with potholes the size and location should be determined. Efficient road-maintenance strategies require a pothole database, incorporating a specific pothole detection system that can collect information at low cost and cover a wide area. However, pothole detection encompasses prolong manual steps of detection. Recently made, pothole detection systems using vibration or laser scanning are not only unstable but result in accurate detection as well as are expensive respectively. Thus, in this paper, we introduce a newly efficient way for pothole detection A Night Vision camera not only detects potholes over a wide area at low cost but also owns a novel pothole detection algorithm that has been specifically designed to work with the embedded computing environment of the camera. Our system shows experimental results which prove that our system successfully detects potholes in real-time.

Keywords: Pothole; Raspberry-Pi; Computer Vision; Image Processing; Night Vision Camera; Machine Learning; Disturbance Sensor; TensorFlow.

1. Introduction

Our project aims to find the solution to one of the major transportation barriers known as 'Potholes'. Potholes are known to be depressions on a road surface, usually, asphalt pavements where because of water lying in the underlying soil structure the surface becomes soft causing erosion of the surface (rocks) as traffic passes over. This results in imbalanced roads, slowing down the traffic and being the cause of accidents as well. The project is the creation of a combination of 'Web Application', 'Data Science' and 'Image Processing'. With the increasing population, the number of vehicles are increasing correspondingly. Culminating in an intensive increase in the surfaces of roads being damaged i.e. Potholes. The potholes are scattered all over the roads causing barriers such as a reduction in vehicle speed and road accidents. We aim to create a system that would detect these potholes and transfer the required data to the respective organizations. Informing them of the location (coordinates) of these potholes so that they can work on getting them fixed. Concerning the current work in the field, IoT) is one of the leading branches in the field of Computer Science/Software Engineering. Concluding with the statement that with everything being technologically advanced and especially with the increase of development of smart cities such projects are being developed and deployed globally.

2. Literature Review

In the past several designs have been proposed for the detection of a pothole. [1] Detected potholes by using image analysis and spectral clustering method, in this method, they first took pictures of defective frames and then compared those images to histogram data using spectral clustering. [2] used a sensor approach to detect potholes in their research they first took the sensor reading and afterward they fed this data to the v3 inception classifier to classify potholes from the given data. [3] Used a black box camera mounted on the front windshield of the vehicle for the detection of potholes. [4] Detected potholes using the Artificial intelligence approach. [5] Used machine learning on Android to detect potholes. [6] used a robust stereo vision-based pothole detection system, this system consists of a disparity map modeling algorithm and disparity transformation algorithm. [7] Used an accelerometer and GPS to detect potholes. [8] Used deep learning algorithms like the convolutional neural network to detect potholes. [9] Detected potholes using image processing techniques and further estimated the diameter of potholes using different edge detection algorithms. [10] made use of an Accelerometer and ultrasonic sensors to detect potholes, an Ultrasonic sensor detects the depth of the pothole and an accelerometer detects the jerking of the vehicle.[11]Introduced laser imaging for pavement distress inspection, the pavement images are captured regions corresponding to potholes represented by a matrix of square tiles, and the estimated shape of the pothole is determined.[12] Proposed a model which performs 3D analysis of pavement distress images using a Kinect sensor and calculates the direct depth of potholes with very few calculations.

3. Process and Workflow Diagram

On disturbance of Distance from the sensor readings, we are capturing the images, marking contours on them through image processing. This pre-processed image is sent to TensorFlow having two classes describing whether there is a pothole present in the image or not. The process is executed on a Raspberry Pi, running TensorFlow. We are not using it in real-time due to the lesser computing power of Raspberry Pi Microcomputers. The length and width can be estimated by using the pixels of the bounding box, however, the exact length and width of the pothole can be done by using efficient techniques and learning algorithms. The idea of depth is integrated using a sharp sensor. For ease of understanding, we have made a TKINTER desktop application to test all the modules individually. For Geo-tagging the exact position of the whole we have used a Global Positioning System Module GPS (Neo-6M) for getting the latitudes and longitudes of the current position. The numerical and pictorial data can be further processed in case of calculation of relevant material to fill up the damages.

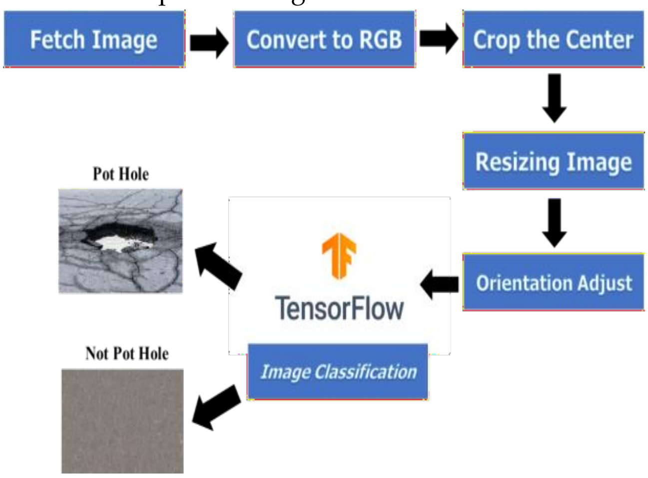

Figure 1. Block Diagram of the Image Processing and Classification Structure

As the above figure shows, A Night Vision-Camera will be capturing images after every interval of 40secs and storing them in or sending them onto the cloud which is directly proportional to the availability of the network connection. Further onwards the GPS-Module links and is responsible for providing locations of all the potholes to the system. This is then uploaded to the cloud that starts off the Pre-Processing firstly the image is cropped so that the pothole can be seen, followed by basic image processing procedures such as threshold conversion, gray scaling, line, and edge segmentation and ultimately using the pothole detection algorithm to confirm pothole detection. After which now comes the Image-Processing methods, now as the pothole has finally been detected it goes through several procedures to get a distinctive length, breadth, and area of the pothole. The output of which and the location received is then utilized in our Repair maintenance System which not only prioritizes our pothole but generates a final report along with the potholes fixation cost, all of which is then updated onto Google Maps [16-17].

4. Methodology

In our prototype, we are capturing images of different potholes based on disturbances in readings of distance. The sharp sensor GP2Y0A02YK0F having a range from 20cm – 150cm is fitted at the bumper of the vehicle. The camera will get activated on disturbance of the normal threshold reading set in your Python script. For capturing the image, we've used the NoIR Camera Raspberry Pi, 5 MP 70 degree with infrared LEDs recording 1080p video at 30 frame rate per second. The working principle of the distance sensor is similar to laser distance meters, we calculate the distance based on the angle of incidence.

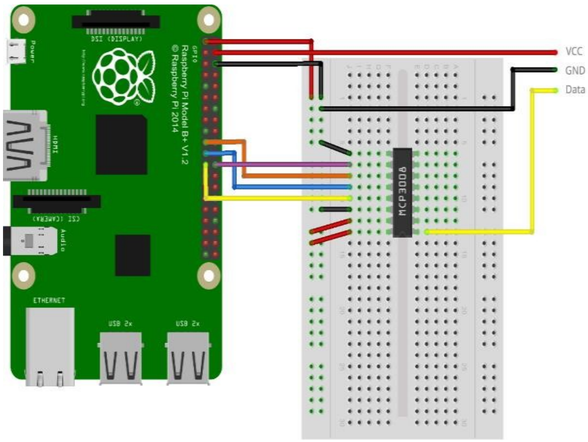

Figure 2. Connection Diagram of ADC MCP3008 and Raspberry-Pi

As we have analog signals the MCP3008 (Analog to Digital converter) is used with the circuit. The SPI bus of Raspberry Pi is controlling the device and has eight channels to translate analog voltages. These are divided into 2^20 so 1024 areas (0-1023). If the MCP3008 is connected to 3.3V, a signal of 1 means 0.00322V (3.22mV). Since the SPI bus of the Raspberry Pi works on 3.3V, no more power should be applied, otherwise, it will result in the damage of GPIO pins of Raspberry Pi. In our distance sensor, the data pin is connected to MCP3008, the pi's SPI bus couldn't receive more than 3.3 volts as mentioned in the datasheet.

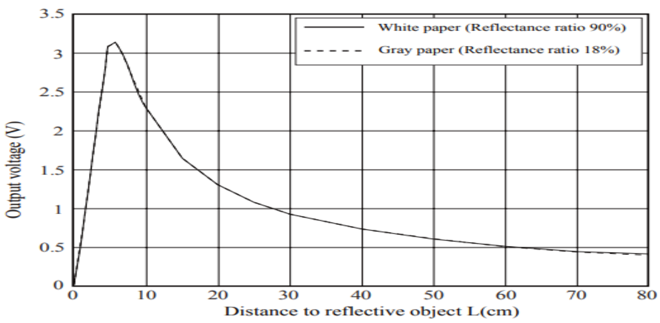

Figure 3. Output Voltage and Distance to the Reflective Object

Table 1. Comparison of earlier approaches and proposed solution

Sr.	Feature	Previous work	Proposed Approach
1	Processing System	[9]have used an Arduino as the main processing unit to interface with the sensors.	We are using a Raspberry pi for processing to capture, process & detect potholes
2	Sensor	[13] have used a Kinect sensor for depth estimation. This sort of hardware is both expensive and prone to calibration errors.	We are using a sharp sensor which is cheaper and has a faster response time.

3	Image processing	[9] have used MATLAB software for image processing and detection of potholes.	We are using an open-source library called OpenCV for image processing and then using it in tandem with TensorFlow to detect potholes.
4	Training & runtime effectiveness	[14] [18] Used a Deep CNN, YOLO v2 which is computationally a more complex neural network and therefore requires a high amount of onboard computing power.	Our model uses a mobile net SSD neural network built on top of TensorFlow Lite which allows it to be trained more easily and to deliver substantially fast real-time outputs with good accuracy.
5	Methodology	[15] have used an unsupervised learning method based on image processing and spectral clustering	Our approach uses a supervised learning and basic image processing approach.

5. Applications of the Prototype

- This Prototype is suitable for all kind of vehicles as it is very compact in size and can be easily installed on any vehicle.
- The Developed Prototype is very useful for the authorities responsible for the repair and maintenance of roads as they can find the location of pothole by using their cell phones.
- This prototype works fine in the night as well and gives accurate results because of the night vision camera.
- The data from the prototype can be analyzed and integrated into google maps to provide information regarding which routes to take to avoid ones that have high counts of potholes.
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6. Future Enhancements

The research work is widely open to scientific contributions. In the future, we aim to make the following enhancements: the landmark of potholes will also be visible on Google Maps. Further onwards, currently, we are using the ideology of general shapes and their respective equations to calculate the volume of the potholes, whereas in the future we aim to make our machine learning system efficient enough so that the volumetric calculations can be based on complex equations and perfect accuracy could be attained. Another improvement would be the development of an IoT based network wherein data can be collected from multiple vehicles and thus improving the reliability of the system.

7. Conclusion

Our work summed up together, the pothole detection system is a well-trained system that works in the following way: The Prototype is attached under the very front-bumper of the car comprising of a sharp-sensor, a night vision camera, GPS-module and most importantly a Raspberry Pi all connected on chipboard aiming to capture pictures of all the potholes within its range. This data will then be processed so that the pothole can be identified, length and breadth of the pothole is detected, along with the sharp-sensor and GPS-module detecting its depth and coordinates respectively. Ultimately all this data will be backed up on the firebase-cloud through a connection to which it would be visible on our Android device. The final product will be a summarized form of the pothole's dimensions, location, and fixation cost.

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