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Road Feature Extraction From High Resolution Satellite Images Using Neural Network

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Abstract - *Road transportation is the main form of transportation in any given region. The main problem in developing countries is the maintenance of the road. The maintenance includes the potholes on the road which is the major cause of the road accidents. Whereas the road damages that occur due to the natural disasters or the ill maintenance of the roads, will eventually lead to the delay and also results in the horrible travel experience, which may not be suitable in certain situations. This paper deals with the detection and notification of potholes on roads using raspberry pi as the controller. In this project we propose a method to detect the damages on the road surface using the image of roads in different regions. As precautionary measure, a warning message will be displayed so that the traveller can choose an alternate route. And the presence of the pothole is notified to the government office automatically through cloud network. This project is designed to reduce the road accidents.*

***Key Words*: Road surface damage, Potholes, warning message, openCV, Android, CNN**

1. INTRODUCTION

India is the most populated country in the world, does not have proper maintenance of the road, over 95%of the people uses road transportation. Due to this peak usage of road transports, there are many possibilities of potholes on roads, which become the reason for several life drinking accidents.

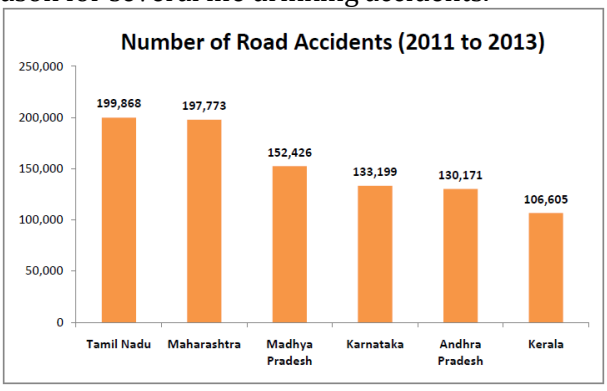

Chart-1: Road accidents

Road transport is the most common and complex network as it covers a wide range, physically convenient, highly flexible and usually the most operationally suitable and readily available means of movement of goods and passenger traffic over short, medium and long distances. The potholes occur due to heavy rain or due to the heavy vehicles on the road. These potholes become the main reason for the road accidents.

In road pothole is a kind of structural damage. Pothole detection plays an important role in highway administration and the maintenance department. Traditionally, pothole detection mainly relies on manual work, which is labor-consuming, time consuming, imprecise and dangerous. Some systems use automatic algorithms for pothole detection, however high success in terms of classification rate has not been achieved due to lighting conditions, various in road texture and other difficult environmental conditions.

Therefore, it is necessary to propose a kind of fast and effective method to improve the efficiency of detection. There have been many thoughtful studies on pothole auto recognition. In image pre-processing stage, many researchers have paid great attention. For example, histogram equalization and spatial filtering have been used to achieve the image enhancement. For image segmentation, a suitable threshold is needed, in a solution is proposed which is to break the image into tiles.

The block size is a very important parameter. It should be large enough to contain both the crack and background regions while representing only the local information. After binary image processing, as noise and texture existed, there will be some isolated dots, burrs and small connected domains. Mathematical morphology is introduced into the applications of road image analysis and processing. But the result of them is not very well due to different lighting conditions and surface texture. Usually, even mathematical morphology method could not solve the problem that there are many breakpoints in the potholes. However, the algorithm is complex and time-consuming. In this project a novel method is introduced which carried out

in two stages. First stage, the pre-processing stage is image segmentation and noise removing. The second stage is to detect the breakpoints of the potholes.

2. METHODOLOGY

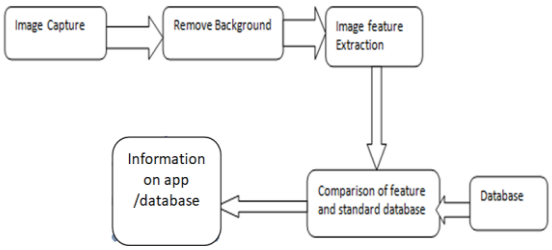

Fig- 1. Block Diagram of road damage detection

The above specified methodology first starts from the acquisition of the image. The image can be acquired by many means of platforms. The resolution of the image the height of the acquisition device from the road plays an important role in the image processing. Whereas, the resolution gives the clarity of the image, the height determines the length of the road covered. For shorter road lengths the images can be captured from low heights, for the longer lengths of the roads, the images of the roads should be taken from the high altitudes. Satellite images depend on length, height, altitude, area coverage, etc.

Once the image is acquired, it is subjected to the pre-processing. This pre-processing involves various aspects such as the removal of the unwanted regions within the images, such as the surrounding vegetation, or the environment. This step is done to minimize the executing time of these regions during the processing, which may delay the processing and correspondingly contribute to the lengthened executing time. As acquired color image consist of 3 planes (Red, Green, and Blue); it is difficult to process it in quick time. So, it is first converted into Grayscale image. After color to grayscale conversion, pre-processing stage uses some enhancement techniques to eliminate challenges created by noise, blurring effect and uneven lighting. Where the pixel range is reduced, the hue and the saturation region are removed and the luminance of the image is retained by converting the image from the true color image to the grayscale.

2.1 CNN FOR FEATURE EXTRACTION:

Convolution is the first layer to extract features from an input image. Convolution preserves the relationship between pixels by learning image features using small squares of input data. It is a mathematical operation that takes two inputs such as image matrix and a filter or kernel.

- An image matrix (volume) of dimension **(h x w x d)**
- A filter **(f_h x f_w x d)**
- Outputs a volume dimension **(h - f_h + 1) x (w - f_w + 1) x 1**

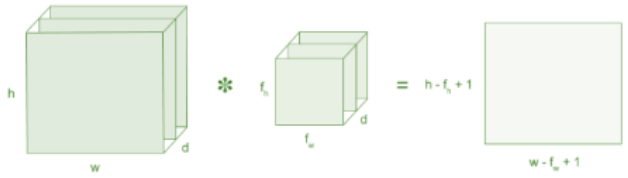

Fig-2. Image matrix multiplies kernel or filter matrix

Consider a 5 x 5 whose image pixel values are 0, 1 and filter matrix 3 x 3 as shown in below

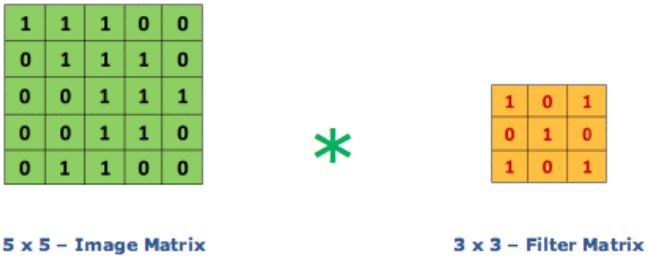

Fig-3. Image matrix multiplies kernel or filter matrix

Then the convolution of 5 x 5 image matrix multiplies with 3 x 3 filter matrix which is called "Feature Map" as output shown in below

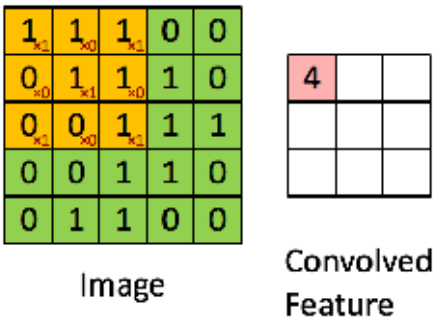

Fig-4. 3 x 3 Output matrix

Convolution of an image with different filters can perform operations such as edge detection, blur and sharpen by applying filters. The below example shows various convolution image after applying different types of filters (Kernels).

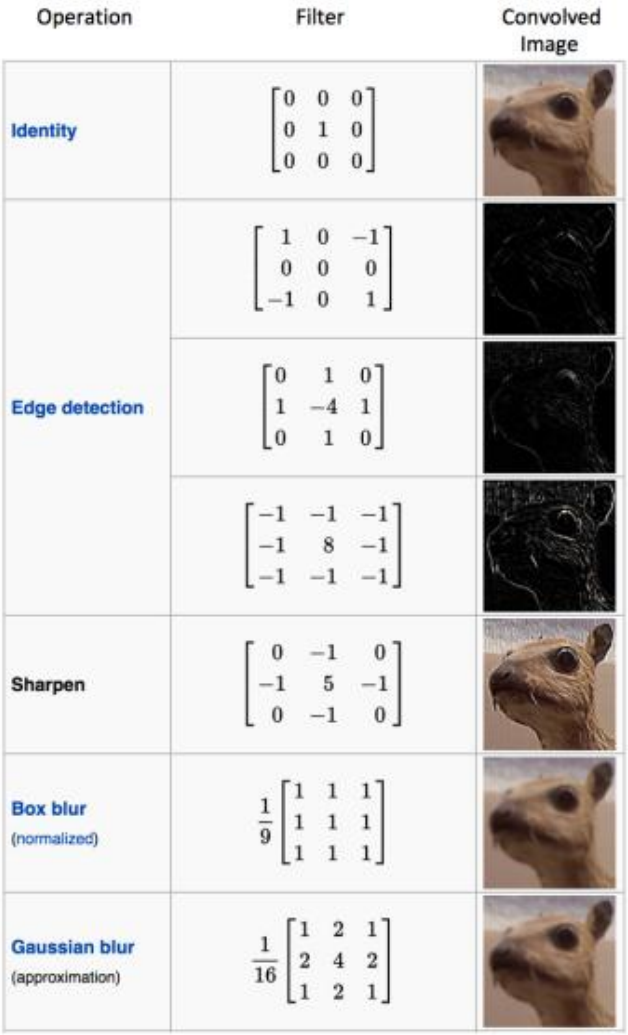

Fig-5. Some common filters

2.1.1 STRIDES:

Stride is the number of pixels shifts over the input matrix. When the stride is 1 then we move the filters to 1 pixel at a time. When the stride is 2 then we move the filters to 2 pixels at a time and so on. The below figure shows convolution would work with a stride of 2.

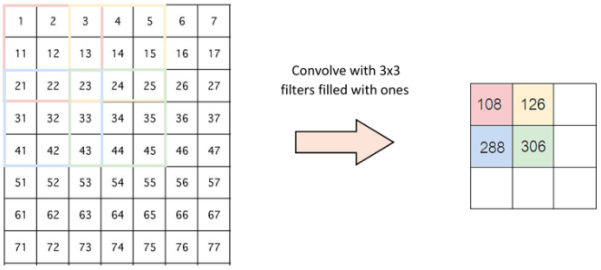

Fig-6. Stride of 2 pixels

2.1.2 PADDING:

Sometimes filter does not fit perfectly fit the input image. We have two options:

- Pad the picture with zeros (zero-padding) so that it fits
- Drop the part of the image where the filter did not fit. This is called valid padding which keeps only valid part of the image.

2.1.3 NON LINEARITY (RELU):

ReLU stands for Rectified Linear Unit for a non-linear operation. The output is $f(x) = \max(0, x)$.

Why ReLU is important: ReLU's purpose is to introduce non-linearity in our ConvNet. Since, the real world data would want our ConvNet to learn would be non-negative linear values.

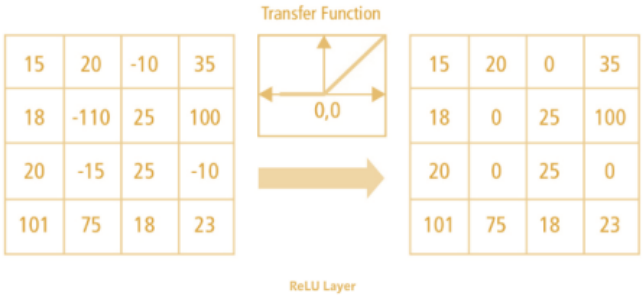

Fig-7. ReLU operation

There are other non linear functions such as tanh or sigmoid can also be used instead of ReLU. Most of the data scientists uses ReLU since performance wise ReLU is better than other two.

2.1.4 POOLING LAYER:

Pooling layers section would reduce the number of parameters when the images are too large. Spatial pooling also called subsampling or downsampling which reduces the dimensionality of each map but retains the important information. Spatial pooling can be of different types:

- Max Pooling
- Average Pooling
- Sum Pooling

Max pooling take the largest element from the rectified feature map. Taking the largest element could also take the average pooling. Sum of all elements in the feature map call as sum pooling.

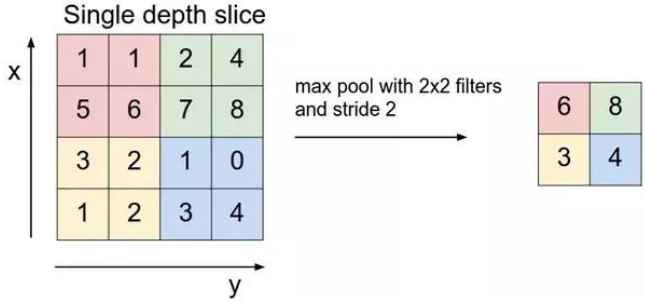

Fig-8. Max Pooling

2.1.5 FULLY CONNECTED LAYER:

The layer we call as FC layer, we flattened our matrix into vector and feed it into a fully connected layer like neural network.

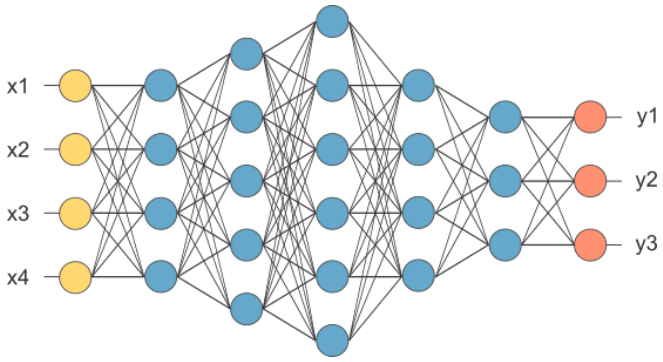

Fig-9. After pooling layer, flattened as FC layer

In the above diagram, feature map matrix will be converted as vector (x1, x2, x3, …). With the fully connected layers, we combined these features together to create a model. Finally, we have an activation function such as softmax or sigmoid to classify the outputs as cat, dog, car, truck etc.,

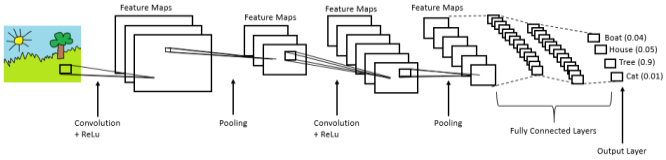

Fig-10. Complete CNN architecture

SUMMARY:

- Provide input image into convolution layer
- Choose parameters, apply filters with strides, padding if requires. Perform convolution on the image and apply ReLU activation to the matrix.
- Perform pooling to reduce dimensionality size
- Add as many convolutional layers until satisfied
- Flatten the output and feed into a fully connected layer (FC Layer)
- Output the class using an activation function (Logistic Regression with cost functions) and classifies images.

2.2 STEPWISE PROJECT WORKING/ ALGORITHM:

1. Start raspberry pi
2. Download dataset
3. Sort dataset as pothole images and no potholes images
4. Train dataset using CNN to get model
5. Save model
6. Get input image
7. Pass input image to model.predict () function to get prediction class
8. Show results
9. End

3. RESULTS

Above algorithm is executed and damage was detected in the image. The results shown below:

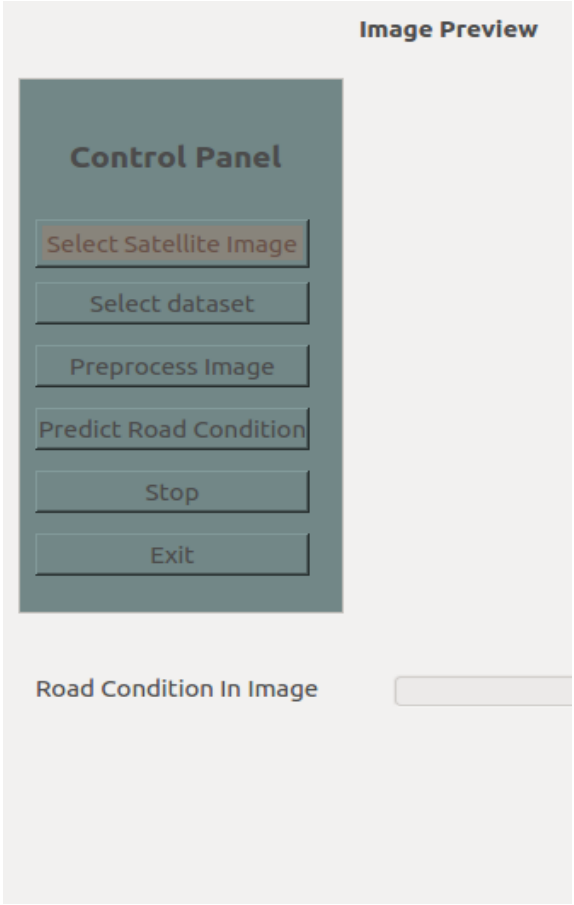

Fig-11. User Interface

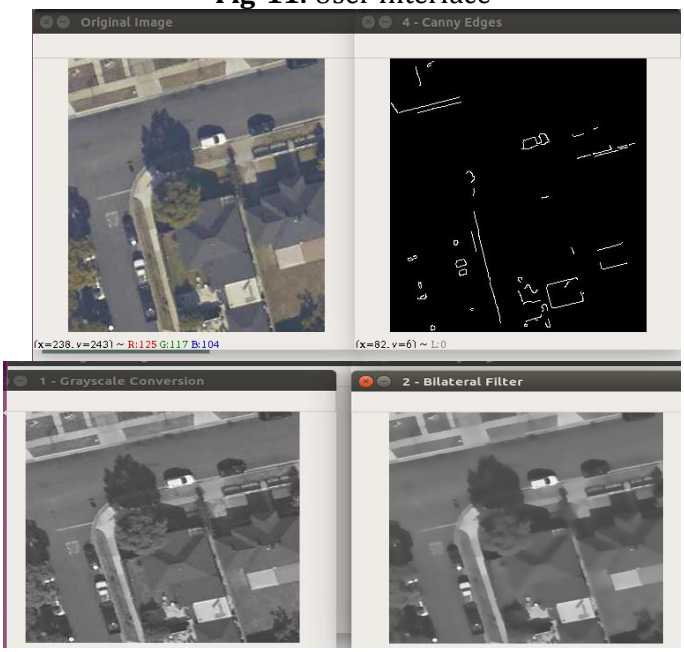

Fig-12. Image Processing

After extracting the feature condition of road is detected as below:

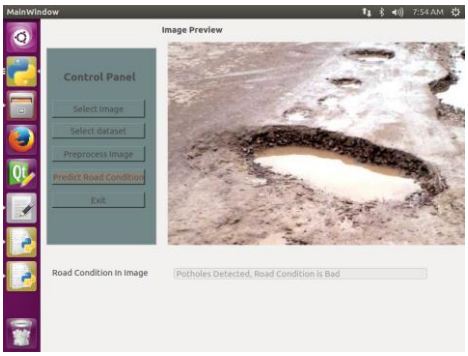

Fig-13. Road condition

Presence of the pothole is notified to the government office automatically through cloud network.

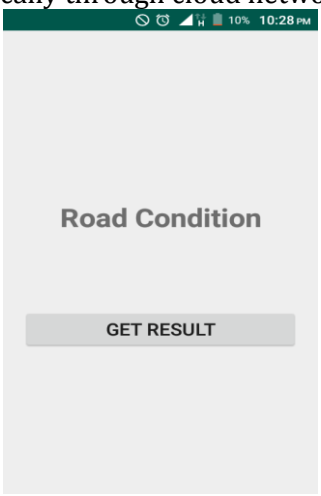

Fig-14. Android app for result

4. CONCLUSIONS

This Project will serve as a useful approach to automate pothole detection and reporting. It will enable to create and maintain updated database of detected potholes. It serves as a helpful approach for the government authority. It reduces the time taken to manually search and locate potholes. It reduces the manpower required. It provides accurate information about the location.

The system can be made useful as a part of smart city campaign. Also by applying machine learning techniques in classifying data can help the system to adapt changing factors like nature of the road and vehicle type the users use. And the data collected can be sent to the government so that they can take the care for improving the road condition.

5. REFERENCES

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