An Intelligent Pothole Detection System using Deep Learning

Harun Joe[1], Joseph Blessingh[2], Joel Cherian[3]

[1,2,3]*Student, Dept. of Computer Engineering, Fr. C. Rodrigues Institute of Technology, Vashi, Maharashtra, India*

Abstract - *Potholes on roads constitute a major problem for citizens acting as pedestrians as well as vehicular drivers. Government bodies which consist of engineers and workers are responsible to detect damages on roads. Manually assessing every single part of the road is highly time-consuming, requires a lot of manpower and hence it cannot be done efficiently. The method to fix this issue by automating the detection. The study focuses on collecting and analyzing the dataset of potholes to train a convolutional neural network. The object detection system tiny YOLOv3 is used for detecting the potholes. The design of a system is identified which can be used for developing a mobile application for detection and presenting a visualized view of the potholes.*

Key Words: YOLOv3, Deep Learning, Pothole, Object Detection, API, NoSQL

1. INTRODUCTION

Transportation by roads has been fairly easy and cost saving, although the condition of road decides the comfort of the ride. Potholes on roads are a major cause of inconvenience for the people travelling by vehicular modes of transport. They are caused by the expansion and contraction of ground water after the water has entered into the ground under the pavement. Potholes are therefore becoming a sizable threat to drivers as they face accidents and damage to the vehicle. In 2017, Union Ministry of Road Transport and Highway in India reported 2,000 pothole-related deaths [1].

The potholes have a need to be repaired to make the ride comfortable and rule out dangers. The responsibility to repair these potholes lies under the Municipal Authorities of the city, but the current method of inspecting the roads for potholes and other irregularities are manual or through complaints registered by citizens affected [2]. This makes it difficult to comprehend the severity and urgency of roads that require immediate attention if it is not detected and informed to the authorities.

The paper shows the work done on the dataset used by analyzing and preparing it for the training phase. The dataset consists of images from majorly two sources, first being an open dataset available in Kaggle [3] and the second source being images of the current state of roads captured from Mumbai city. Images from both these sources give a diverse set of data for training the model for detection. YOLOv3, an object detection model to detect the potholes is trained using the dataset. The focus is also on creating a system design which is capable of operating on mobile to detect potholes. The aim is to provide a solution to automate the manual challenges of finding the potholes by the municipal body. It constitutes a Deep learning model which can be used to detect potholes and visualize them on map using a mobile application. The road to setting up the entire system includes a mobile being mounted on the dashboard inside a vehicle belonging to the municipal authority. When the vehicle is in motion, the mobile application begins recording the video of the road ahead of the vehicle. The video feed is simultaneously processed to capture images based on distance intervals. Images are fed to the pothole detection model to detect potholes. The data pertaining to the pothole is stored, which is then retrieved to be able to visualize it on a Map. This information can be used by the Municipal Authority to repair the potholes.

2. RELATED WORKS

Different real time pothole detection systems were studied to gain an insight over the various algorithms and techniques used in it. The location of pothole is an important aspect. In [4], space interpolation method is used to obtain exact location of the pothole, the distance between the start point and the pothole followed by the distance between end point and the pothole is obtained by using a GPS module on the mobile. A system to detect the pothole using an optical device mounted on the vehicle is explained by [5]. This approach uses candidate region extraction to identify the pothole and it is first segmented by various techniques like Otsu, Histogram shape-based thresholding. This proposed system gave an accuracy of 73.5 percentage with a precision of 80 percentage, the location and severity of the pothole is given to the center i.e. pothole alert service and road management system.

A simulation-based method was developed by Sudarshan et al. [6] to construct mobile nodes equipped with WiFi and a single access point between the roads to alert drivers i.e. mobile nodes about pothole on roads is achieved by a software called Qualnet 4.0. The alert is sent by packet transmission from the access point to the nearby nodes and collision avoidance by RTS/CTS or CA. Youngtae et al. [7] employed a Cascade detector method to distinguish pothole from similar types of shades and road patches. This method makes use of a black box camera fitted on top of a vehicle which removes objects like shades that changes its shape irrespective of a pothole. As our proposed system uses tiny YOLOv3, the basic understanding of the model was studied from this paper [8]. This model makes use anchor boxes with a score for each object identified with the help of logistic regression.

3. POTHOLE DETECTION SYSTEM

The pothole detection system aims to provide a solution for both municipal authority and the citizens to reduce the number of potholes by developing an application for mobiles. The entire design of the system is based on the integration of various libraries and frameworks. A mobile application, APIs to provide insights from data gathered, an object detection model to precisely detect the potholes and a cloud storage solution to store and handle various forms of data. The application has two major functionalities: First, for detection and gathering of data mainly for the local municipal body's usage and the other is the view of the gathered data on a map which is helpful for both the authorities responsible for maintenance and also for citizens of the locality to be aware of their surrounding roads.

3.1 Design of the System

The Fig -1 shows the basic structure of the system. The flow of the working is represented through the diagram.

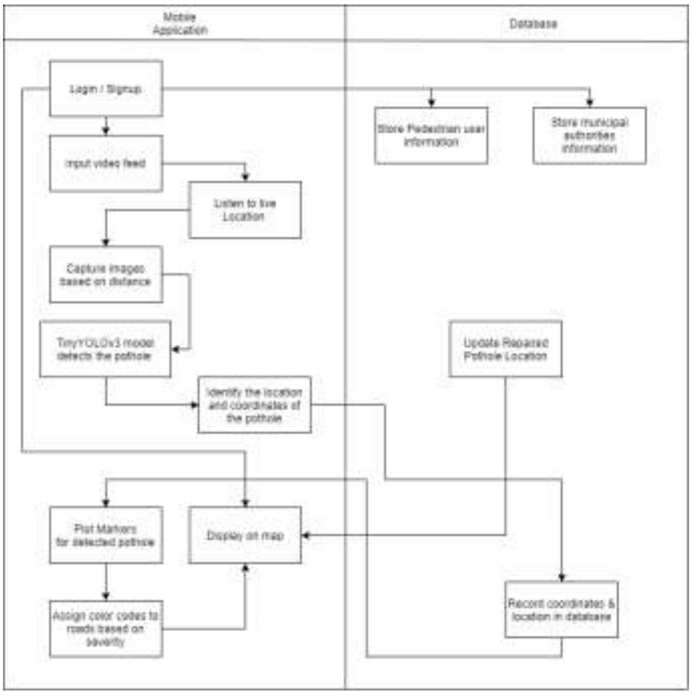

Fig -1: Block Diagram

3.1.1 Mobile Application

With the processing capability of mobile devices sky rocketing compared to its preceding years, computational workload that can be handled by the device has also increased. This makes the mobile devices to be able to handle machine learning task easily. With the help of libraries for integration of CNN to an application it is thus made possible to run an object detection model in the mobile device itself. Along with that, a constant listener can run in the background that updates the user's location. With the location updated, the distance is calculated and the image is captured. The captured image is then fed into to the Neural Network and the potholes are recognized as co-ordinates in the images.

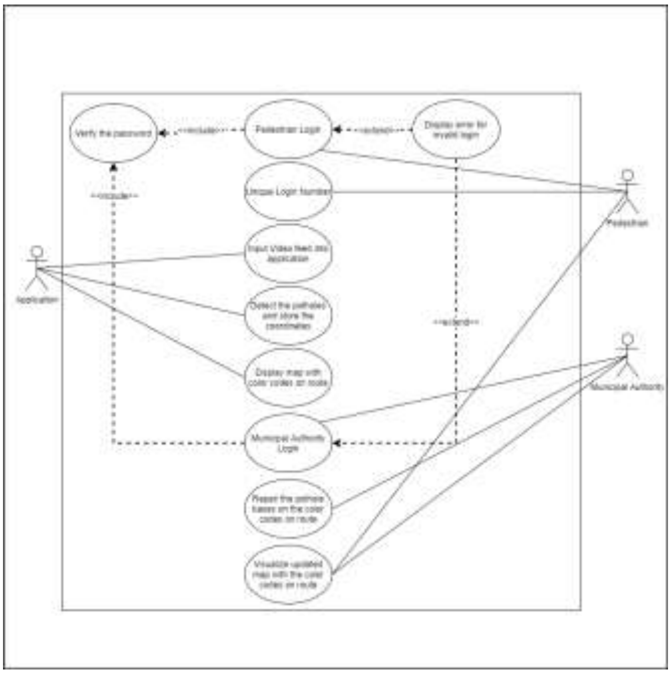

Fig -2: Use Case Diagram

A constant listener runs on the background that updates the location. With the location updated, the distance is calculated and the image is captured. The captured image is then fed into to the Neural Network and the potholes are recognized as co-ordinates in the images.

The use case diagram of the application is as shown in Fig -2.

3.1.2 Database

Data gathered through all the mentioned procedures are not in a structured format, i.e. data can be in a variety of forms and thus cannot be predefined and inserted in a set of rows and columns. This make the traditional form of databases like MySQL not useful in this type of scenario. NoSQL form of databases can deal with huge amount of data faster than MySQL [9]. Firebase is a cloud Storage solution provided and hosted by Google which is NoSQL form of database that stores data in a JSON file format [10]. To have reliable synchronization within the server to feed in live data, such as the images of roads with potholes, number of potholes, locations as latitude and longitude etc. APIs provided from Firebase itself allow to make HTTP requests to the cloud storage which helps in performing various operation on the database such as insert, update, delete. Also, integration with Firebase using Flutter or other mobile development platforms becomes effortless since both the platforms are created by the same parent organization.

3.2 Study of Dataset

The main engine behind this application and database is the dataset, the dataset is trained using the YOLOv3 model. The study of dataset is divided into three parts:

1) About the Dataset
2) Description of Dataset
3) Analyzing the Dataset
4) Object Detection using YOLOv3 and Darknet

3.2.1 About the Dataset

The dataset for training constitutes 1,500 images for training and 350 images for testing the model developed. Kaggle provides an open dataset of roads which contain potholes called Nienabar Pothole dataset [3]. This dataset consists of repetitive images which needs to be filtered out such that images in the final dataset is unique and of different features. But, certain factors in this dataset is constant such as colors of roads, illumination, and pothole vicinity do not help in making the model well versed with various real-life scenario. Using python and OpenCV, we also reduced the resolution of images to remove the constant part of images in the dataset like dashboard and the sky.

Fig -3: Captured Image for Dataset

The Fig -3 shows the self-captured image from the streets of Mumbai containing pothole which is combined with the Nienabar Pothole dataset as shown in Fig -4 to give the dataset a wide spectrum of images. To make the dataset unique and versatile, web scraping is performed. Using various keywords for search, 1000 images were extracted. But, since searches using different keywords provides same images sometimes, manual identification and removal of such images were performed. The scraped images were merged with the dataset. LabelImg [11] was used to label the potholes from images according to the YOLO requirements.

Fig -4: Image from Nienabar Dataset

3.2.2 Description of Dataset

There are 2 categories in the dataset namely positive and negative. Positive denotes the fact that the road contains one of multiple potholes whereas negative will denote that the image doesn't contain any kind of potholes in it. But training a model in YOLO does not require partition of images in the dataset and hence a 70-30 ratio of images from the positive and negative images were taken from the files into the final dataset.

3.2.3 Analyzing the Dataset

Python is used to collect and process the final pothole dataset for our system. The scraping of images from the web is done as the images were in different file formats. A common file format is used to convert all the scraped images into same extension. Since, the dataset had scraped images from web it consisted of multiple repetitive images in a row, images in the final dataset have been taken from an interval of 17 images. This ensures that the final dataset is free from redundancy. The images selected has a common characteristic in them i.e. the dashboard and the sky from the Nienabar Pothole dataset. So, to filter out the other unwanted parts of the image, cropping of images is done using a simple python program.

Fig -5: Pothole Detected using YOLOv3

3.2.4 Object Detection using YOLOv3 and Darknet

With multiple images being captured, it becomes essential that the object detection model detects potholes in the least amount of time. YOLOv3 (You Only Look Once ver.3) improves operation speed which meets real time requirements for detection [8]. Darknet is a framework for YOLO implemented using C/CUDA. To make the object detection model mobile friendly, the model is converted to a TensorFlow lite model, which compresses the neurons in the neural network. This will make the model run efficiently in the mobile devices. Fig -5 shows the detection of pothole which has been implemented.

4. CONCLUSION

The paper showcases our work performed to train an object detection model capable of detecting potholes. The collection of images for dataset to train the model consists of a mixture of Nienabar Pothole Dataset and self-captured images of pothole. Tiny YOLOv3, a CNN which is capable to function on a mobile device is trained to be used as the object detection model. Furthermore, a design was introduced for the Pothole Detection System which uses a mobile application to detect potholes and represent on maps using markers with APIs from Google and other third-party resources. Using the application with the plotted information, the responsible civic body can repair the pothole with the gained insights.

5. FUTURE SCOPE

The system's continued work includes the development of the mobile application and the integration of the object detection model with the application. Also, integrating the system to the cameras present in the new generation vehicles to give a real-time analysis of roads. With the data gathered through this analysis, providing the vehicle drivers on roads with an alert or prompt regarding the current state of the roads they are travelling on.

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