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IOT Based Pothole Detection System Using YOLO V4 Algorithm

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Abstract—The widespread issue of potholes on roadways poses a big threat to road security. According to the Ministry of Road Transport and Highways. The report shows a rise in accidents caused by potholes - from 3564 in 2022 to 3625 in 2023. Our primary goal is to develop a specialized pothole detection system that smoothly integrates the YOLO (You Only Look Once) algorithm, specifically YOLO v4, with an innovative Internet of Things (IoT)- based strategy. This integration is helped through the usage of Raspberry Pi, a versatile single-board computer, to boost the real-time capabilities and connectivity of the pothole detection system. To complement our system, mobile applications have been developed to effectively transmit detected potholes. The IoT-based pothole detection system, empowered by Raspberry Pi, uses an integrated camera to capture live footage and extract pictures for precise pothole detection. Identified potholes are dynamically highlighted in real-time using bounding boxes, reminiscent of recognized object detection systems. The resulting system achieves a remarkable accuracy rate of 95.9%, offering a strong and effective way of detecting potholes to only prevent potential accidents on the road. This innovative integration with IoT, especially leveraging Raspberry Pi, not only improves the real-time capabilities of our pothole detection system but also enables smart communication with mobile applications. When a pothole is detected, this technology alerts the driver with audible warnings like a buzzer, and also it gives passengers in nearby cars visual notice, A blue LED light is also turned on the back of the Vehicle.

Keywords: YOLO (You Look Once), IoT (Internet of Things), CNN (Convolution Neural Networks), NMS (Non-Maximum Suppression Threshold).

1. Introduction:

India, emerging as one of the fastest-developing nations following China, has achieved commendable progress in various sectors. Despite these accomplishments, the country faces a significant deficit in its roadway infrastructure. Roads stand as the primary mode of transportation in India; however, they are characterized by narrowness, congestion, poor quality, and inadequate maintenance. The sub-optimal road condition acts as a catalyst for increased traffic congestion and a higher incidence of road accidents. Motivated by these challenges. I found a compelling reason to develop an effective system aimed at enhancing the safety and well-being of transportation in my country.

Potholes, described as holes or dips in street areas, result from a combination of weather elements and the wear and tear inflicted on roads by continuous. heavy-duty vehicle traffic. They are prominent on busy roads facing high traffic volumes, particularly manifesting during periods of heavy rainfall followed by intense heat. Despite their seemingly harmless appearance, these structures pose significant obstacles to daily well-being. Over recent years, significant advancements have been made in the detection and identification of potholes.

Fig1: Conditions of roads with Potholes

The primary aim of these developments is to ensure safe driving conditions, addressing the major causes of fatal accidents resulting from road unevenness caused by path holes. Large holes can disturb the balance of traveling vehicles, leading to serious accidents. The model presented in this document prioritizes human well-being by facilitating the detection and identification of potholes on road areas. To achieve this, we have employed the YOLO (You Only Look Once) v4 algorithm, a contemporary approach widely used for object detection. YOLO v4 includes an embedded Open CV (Open-source Computer Vision) library function, renowned for its versatility in various machine learning applications, including face recognition, behaviour and object detection, motor tracking, emotion tracking, and handwriting detection.

In the following sections of this document, we elucidate the operational procedures and systematically detail the construction of our proposed model. This entails a comprehensive exploration of the model training process, ensuring its capability to generate satisfactory responses and communicate the anticipated outcomes effectively.

2 Literature Review:

In a paper called 'Deep Learning Based Pothole Detection and Reporting System (IEEE 2020)', they used an accelerometer and ultrasonic sensor thoroughly mounted in the bottom of a car, drove the car at 25 km/hr, and also utilized a GPS to find the location.[1] The microcontroller detects the pothole and gives the location to the control room. The microcontroller (ATmega328) Starts the GPS and gives us the Coordinates. we use a Methodology of Comparative study between CNN, KNN (k-Nearest Neighbours), and Kirchoff's Theory Method.[2] In the manuscript, 'A Modern Pothole Detection Technique Using Deep Learning (IEEE 2020)', they have put a camera on the car and then find the potholes and mark the location using the app that is formed so the car which does not have the camera can get the information about the pothole using the application and give the driver the required +alerts.[3] They have not talked about the accuracy of their project period The methodology used was F-RCNN (faster region-based Convolutional neural network). Additionally, In the paper 'Development and Analysis of Pothole Detection and Alert based on Node MCU (IEEE 2020)', one could depict the depth and danger along it. GPS module and IFTTT (if this, then that) servers are used to find the locations, to the emails of the maintenance authorities who can take the necessary actions. The methodology used was a model designed using node MCU, GPS module, Ultrasonic sensor, IFTTT Webhooks exclamation mark. [4] In the paper 'Smart Detection and Reporting Potholes via Image-Processing using Raspberry-Pi Microcontroller (IEEE 2018)', The whole system was successively implemented using the Raspberry-Pi microcomputer with a 100% reporting success rate, it was. The methodology from a moving car was able to locate and report potholes, the system used image processing, and the integration which was used to produce an algorithm from Python Language from the OpenCV library to detect and report potholes automatically. The reported image of the pothole and its location was stored and viewed through a Mobile Application.[5]

3. Methodology:

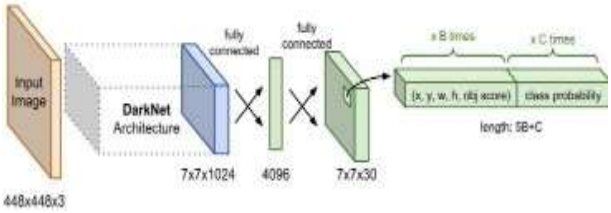

Fig 2: YOLO V4 Architecture

(i) Input Image: The Algorithm takes a input image of arbitrary size. YOLOv4 can handle pictures of different resolutions effectively without impacting its accuracy significant.

(ii) Backbone Network: YOLOv4 uses a backbone network, which serves as the feature extractor. In YOLOv4, the Darknet framework architecture is used, which includes a combination of CNN (Cross Sage Partial Network) and the Darknet framework. This architecture enhances feature extraction capabilities, contributing to better object detection performance.

(iii) Neck Architecture: The neck architecture follows the backbone and includes PANet (Past Aggregation Network). PANet aids in aggregating information across different scales, enabling the model to capture context and details from various levels of the image.

(iv) YOLO Head: The YOLO head is responsible for generating predictions. It operates on the feature maps obtained from the backbone and neck. The head involves multiple detection heads, each responsible for predicting bounding boxes, class probabilities, and confidence scores for objects within a specific scale range.

(v) Anchor Boxes: YOLOv4 uses anchor boxes to assist in predicting bounding box dimensions. Anchor boxes represent prior knowledge about the average sizes and aspect ratios of objects in the data set. These anchor boxes are used during training and inference to refine the bounding box predictions.

(vi) Detection at Multiple Scales: YOLOv4 performs detection at multiple scales by incorporating predictions from different detection heads. This allows the model to detect objects of various sizes effectively.

(vii) Post-Processing: After obtaining the raw predictions from the YOLO heads, post-processing is applied to filter and refine the results. Non-maximum suppression (NMS) is commonly used to remove redundant and low-confidence bounding boxes, ensuring that only the most confident predictions are retained.

4. Technical Components of Proposed System

(i)Hardware Requirements:

a. Camera: A camera is integrated with a system to capture images or videos specifically focused on detecting potholes on road surfaces. This specific setup is designed to identify and record visual data related to the presence of potholes, aiding in the assessment and management of road conditions.

Fig 3: Camera Module

NEO-6M GPS Module:

Fig 4: NEO-6M GPS Module

The NEO-6M module utilizes GPS technology to determine accurate geographical positioning, and provide information such as latitude longitude, altitude and time.

C. Raspberry Pi:

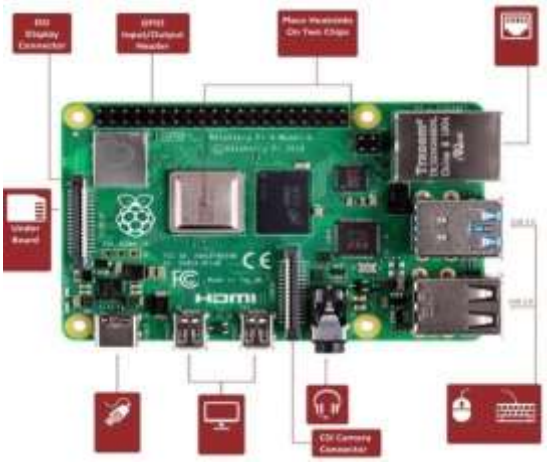

Fig 5: Raspberry pi

The Raspberry Pi: The Raspberry Pi is a series of small, single-board computers developed by the esteemed Raspberry Pi Foundation. These compact and highly affordable computers are specifically designed for educational purposes, various DIY projects, and even for embedded system applications.

Software Requirement: IDLE (Integrated Development Learning Environment) is integrated development environment (IDE) exclusively for the Python programming language. It comes bundled with the standard installation of Python, making it readily available for users. IDLE provides a simple and user-friendly interface for writing and texting python.

5. Implementation:

In the vast landscape of Indian Traffic Control (ITC), enhancing traffic safety emerges as a pivotal concern. This proposed cutting-edge initiative entails implementing a pothole detection system that capitalizes on machine learning and image processing, utilizing the YOLO (You Only Look Once) Algorithm. The primary objective lies in identifying potholes on road surfaces and subsequently providing warnings to drivers. When a pothole is detected, this technology alerts the driver with audible warnings like a buzzer, and also it gives passengers in nearby cars visual notice, A blue LED light is also turned on back of the vehicle.

This innovative system is poised to significantly contribute to enhancing roadway safety and aligns with the aspiration to harness technology for the betterment of humanity.

The data pre-processing stage plays a critical role in the data mining process, which encompasses manipulating, removing, or adding data before its utilization to ensure and improve overall performance. In the realm of data mining and machine learning endeavors, the adage "garbage in, trash out" holds particular relevance. Though our YOLO V4 Model was originally trained with a limited set of images or videos, the transition to a real-time detection system marks a noticeable shift. In this context, images are automatically extracted from live recordings via the camera, and the YOLO v4 Algorithm is subsequently applied for further processing.

The successful implementation of this advanced technology promises to revolutionize how traffic associated with potholes on roadways! Exciting times lie ahead as we witness the fusion of cutting edge technology to create safer roadways for all! Can we truly quantify the positive impact this innovative system will have on traffic safety in the Indian Traffic Control sector? Only time will tell.

6. System Flow Chart:

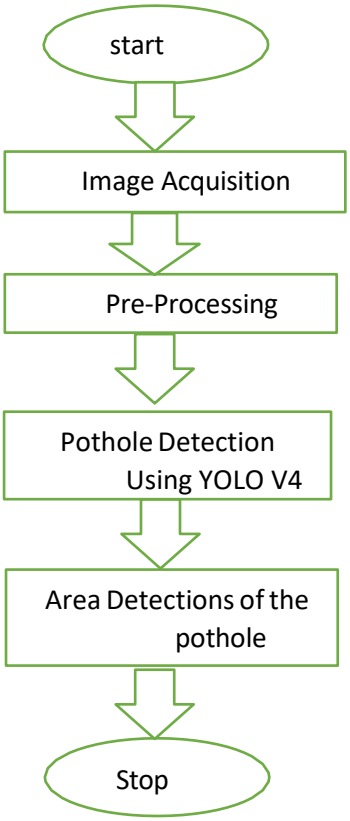

Fig 6: Flow chart of the model

7. Result:

Fig 7: Detected Poth Hole Accuracy95.9%

Fig 8: Location of pothole

Confusion Matrix:

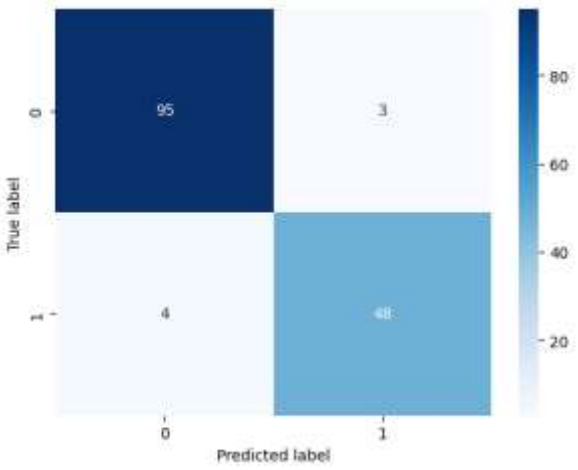

Fig 9: Confusion Matrix

1. Accuracy : TN+FP/TN+FP+FN+TP
   = 95.9%
2. Precision : TP/TP+FP
   = 0.96
3. Recall : TP/TP+FN
   =0.96

8.Conclusion:

This paper extensively explores a pothole detection system that has been implemented through the effective utilization of the cutting-edge YOLO V4 Algorithm. The decision to employ YOLO V4 proves to be highly advantageous, primarily owing to its exceptional speed; capable of processing an impressive 45 frames per second. YOLO's outstanding proficiency in understanding generalized object representation positions it as one of the premier object detection algorithms around, rivaling the performance of other algorithms like R- CNN and others as well. The system's notable advantages include heightened operational speed and the ability to function with reduced man power. The training and testing phases of our model, which have been executed with the implementation of YOLO V4, have been successfully done. Significantly, the system now exhibits an enhanced accuracy rate of approximately 95%, which is a huge improvement from the previous versions.

Additionally, we are in the process of developing a user-friendly mobile application that seamlessly integrates with the pothole detection system. This app aims to provide a convenient interface for users, enhancing accessibility and real-time monitoring capabilities, thereby contributing to an even more robust and efficient solution for all users who need this Great job team.

References:

[1] E. J. Reddy, P. N. Reddy, G. Maithreyi, M.
B. C. Balaji, S. K. Dash, and K. A. Kumari authored a paper titled "Development and Analysis of Pothole Detection and Alert based on Node MCU".

[2] A collaborative effort by E. J. Reddy, P. N. Reddy, G. Maithreyi, M. B. C. Balaji, S. K. Dash, and K. A. Kumari resulted in a paper titled "Development and Analysis of Pothole Detection and Alert based on Node MCU".

[3] G. Singal, A. Goswami, S. Gupta, and T. Choudhury presented a paper titled "PITFREE: Potholes Detection on Indian Roads Using Mobile Sensors".

[4] S. Barnwal presented "Vehicle Behavior Analysis for Uneven Road Surface Detection".

[5] Ch. Koch, I. k. bricks, "Improving Pothole Recognition through Vision Tracking for Automated Pavement Assessment".

[6] Chandan G, Ayush Jain, Harsh Jain, Mohana "Real-Time Object Detection and Tracking Using Deep Learning and OpenCV" 2018 IEEE Xplore Proceedings of the International Conference on Inventive Research in Computing Application.