SafePath:Advanced Obstacle-Aware Cruise Control System

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Abstract— This project combines Adaptive Cruise Control (ACC) with Object Detection (YOLOv8) to create a self-pothole detecting system, revolutionizing vehicle safety. Using LiDAR for depth estimation, it dynamically adjusts vehicle speed based on pothole severity, enhancing comfort and safety. By categorizing potholes into classes and adjusting speed accordingly, it minimizes discomfort and reduces the risk of accidents. The system operates by scanning for potholes using a camera and continuously measuring sensor values with LiDAR. Detected potholes are classified and displayed, with vehicle speed adjusted accordingly, promising to enhance road safety and driving experience.

Keywords - Cruise Control, YOLOv8, Vehicle safety, Pothole

I. INTRODUCTION

In today's fast-paced society, the persistent threat of automobile accidents remains a critical concern, particularly in countries like India where road transport is predominant. Despite notable advancements in automotive technology, there's a pressing need for comprehensive solutions that not only bolster safety measures but also actively prevent accidents. Shockingly, road traffic injuries claim approximately 1.3 million lives annually worldwide, with nearly 70% of highway accidents attributed to insufficient braking distances between moving vehicles. Potholes, prevalent on Indian roadways, significantly contribute to accidents due to heavy traffic and inadequate maintenance. Efforts to mitigate potholes include government initiatives, technology utilization, and heightened public awareness.

Adaptive Cruise Control (ACC) represents a significant advancement in automotive technology, dynamically adjusting vehicle speeds to maintain safe distances from other vehicles, thereby enhancing road safety. Integrated with other technologies like lane-keeping assistance and automatic emergency braking, ACC is increasingly prevalent in mainstream vehicles, reflecting a growing demand for advanced driver assistance systems (ADAS). Object detection software, particularly YOLOv8, plays a pivotal role in modern computer vision applications, offering real-time processing capabilities and accuracy, thus underscoring its significance in enhancing road safety and driving convenience. This project aims to harness the power of Adaptive Cruise Control (ACC) and seamlessly integrate it with other cutting-edge features to create a versatile device that can use the power of Adaptive Cruise Control for detecting and avoiding severe potholes on roads. This project takes a novel approach of combining the detection capabilities with the cruise control system to make the vehicle a self-pothole detecting system. By doing so, we seek to revolutionize the way vehicles interact with their surroundings, ultimately reducing accidents and saving lives.

II. METHODOLOGY

The proposed initiative aims to revolutionize vehicle safety and driving efficiency by integrating Adaptive Cruise Control (ACC) with Object Detection (YOLOv8) technology. This integration aims to develop an intelligent vehicle capable of identifying potholes, assessing their severity, and autonomously determining the optimal action for safety and comfort. Through the amalgamation of ACC and YOLOv8, the vehicle will automatically detect and respond to potholes. YOLOv8 will continuously scan the road surface, accurately identifying potholes, while advanced algorithms will promptly analyse their depth and dimensions in real-time. These potholes will be categorized into three classes: safe, moderate, or hazardous, based on their severity.

Subsequently, the ACC system will adjust the vehicle's speed and trajectory accordingly to ensure safety and minimize potential damage. Minimal adjustments will suffice for safe potholes, while moderate and hazardous ones will prompt speed reductions or route alterations to avoid them. This endeavour holds immense promise in significantly enhancing road safety and driving comfort by mitigating the risk of accidents and vehicle harm. Furthermore, it will alleviate driver stress and fatigue, particularly on poorly maintained roads. The integration of ACC and YOLOv8 signifies a significant advancement in automotive technology, offering the prospect of safer roads, reduced maintenance costs, and an improved driving experience. This innovation aligns with broader endeavours to advance autonomous driving and intelligent transportation systems, marking a substantial stride towards safer and more efficient road networks.

III. IMPLEMENTATION

The proposed system has been implemented as a model with two systems:

1. Pothole Detection and Depth Estimation system
2. Cruise Control system

A. POTHOLE DETECTION

After meticulously curating a diverse dataset of 500 pothole images, the dataset underwent annotation using LabelImg and YOLO format, with 70% allocated for training, 20% for validation, and 10% for testing. Training the YOLOv8 model was conducted in Google Colab, utilizing A100 GPU acceleration for efficient processing. With 100 training epochs, the model's performance metrics such as loss, accuracy, and mean Average Precision (mAP) were monitored on validation data. Upon completion, the trained model weights and configuration files were packaged for deployment, followed by evaluation on a separate test set to gauge its generalization ability.

Fig. 1: Test Batch

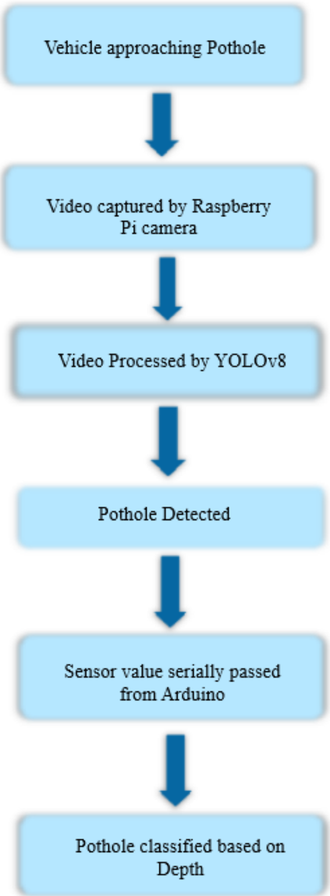

Fig. 2: Block Diagram of Pothole Detection and Depth Estimation System

Following the training of the YOLOv8 model for pothole detection, a comprehensive array of performance metrics has been generated, including confusion matrix, recall confidence curve, F1 confidence curve, precision-recall curve, and precision confidence curve. These graphs collectively illustrate the model's efficacy in identifying potholes, providing insights into its precision, recall, and overall performance across different confidence thresholds. The analysis of these metrics offers valuable information for further refining the model and optimizing its performance, thereby enhancing its practical utility in real-world applications aimed at road maintenance and safety improvement.

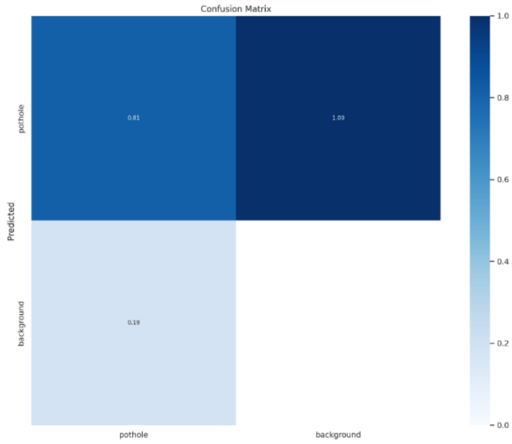

Fig. 3: Confusion Matrix

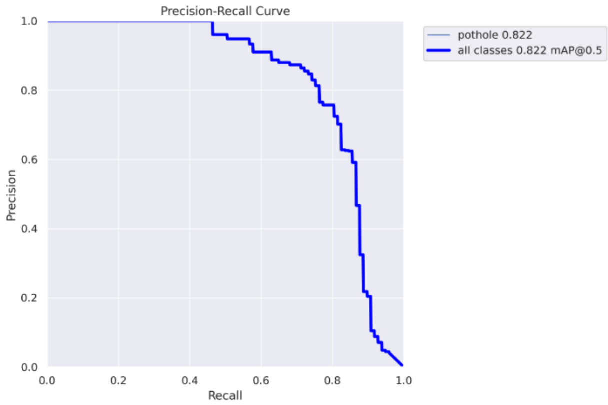

Fig. 4: Precision Recall Curve

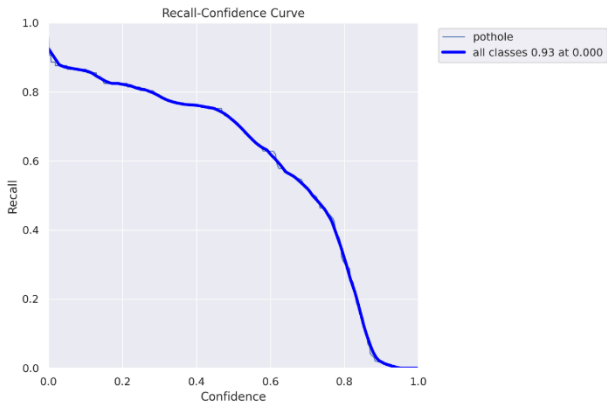

Fig. 5: Recall-Confidence Curve

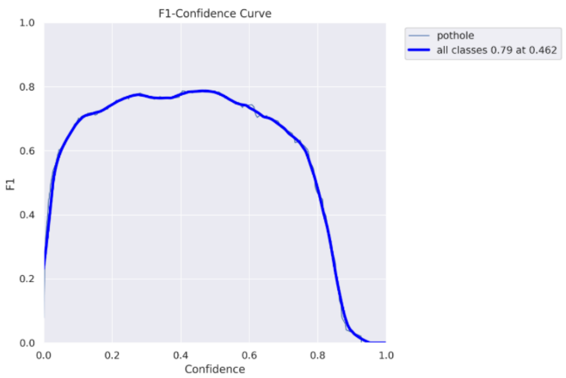

Fig. 6: F1-Confidence Curve

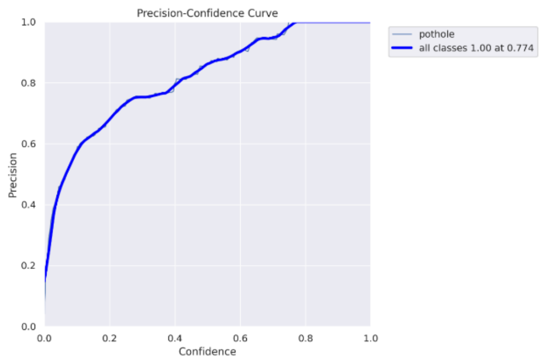

Fig. 7: Precision-Confidence Curve

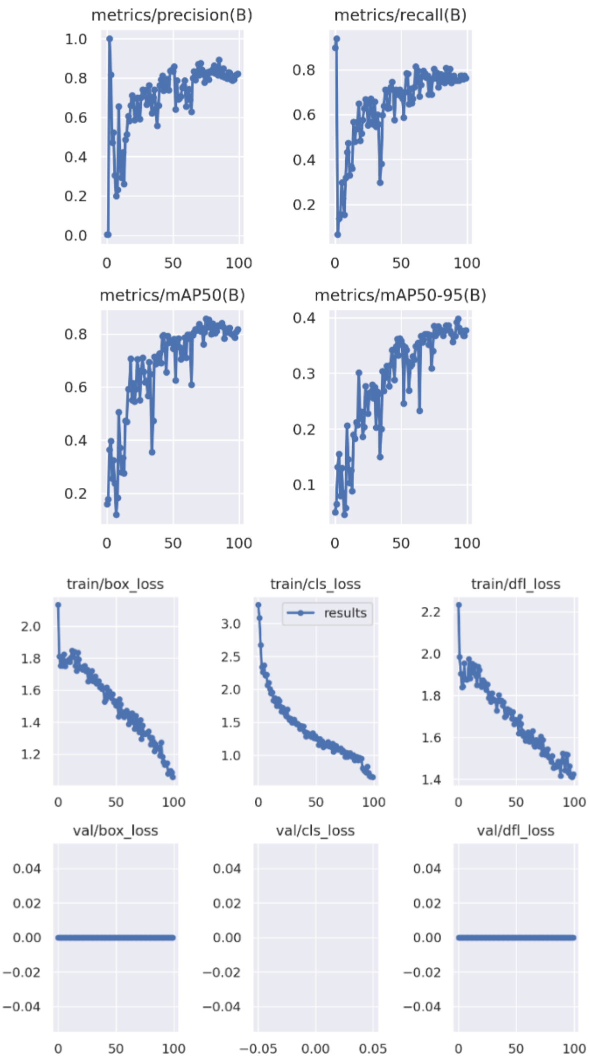

Fig. 8: Performance Metrics

B. POTHOLE DEPTH ESTIMATION

Pothole depth estimation relies on a LIDAR sensor affixed to vehicles, emitting laser pulses towards the road surface. These pulses meticulously gauge the distance to various points along their path, maintaining a consistent distance from the ground. Upon encountering a pothole, the distance between the sensor and the road surface increases as the laser pulse reflects off the pothole's bottom instead of the road's surface. This disparity in distances enables the calculation of pothole depth. Based on this disparity, potholes are categorized as Safe, Medium, or Risk.

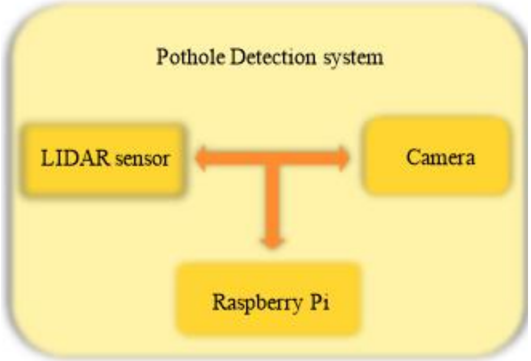

Fig. 9: Pothole Detection System Block Diagram

Fig. 10: Pothole Depth Estimation

C. CRUISE CONTROL

By incorporating pothole depth estimation into cruise control systems, the goal is to improve both driving comfort and safety. This system dynamically adjusts speed based on pothole depth, reducing passenger discomfort and minimizing vehicle suspension and tire damage. As a result, drivers experience smoother rides, leading to lower maintenance costs. The cruise control system categorizes potholes into different classes and adjusts vehicle speed accordingly. Initially maintaining a safe distance from the leading vehicle, it then reduces speed for safe-class potholes, further decreases for medium-class, and halts for high-risk-class potholes.

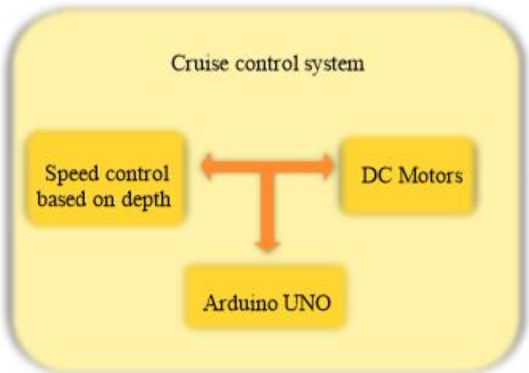

Fig. 11: Cruise Control System Block Diagram

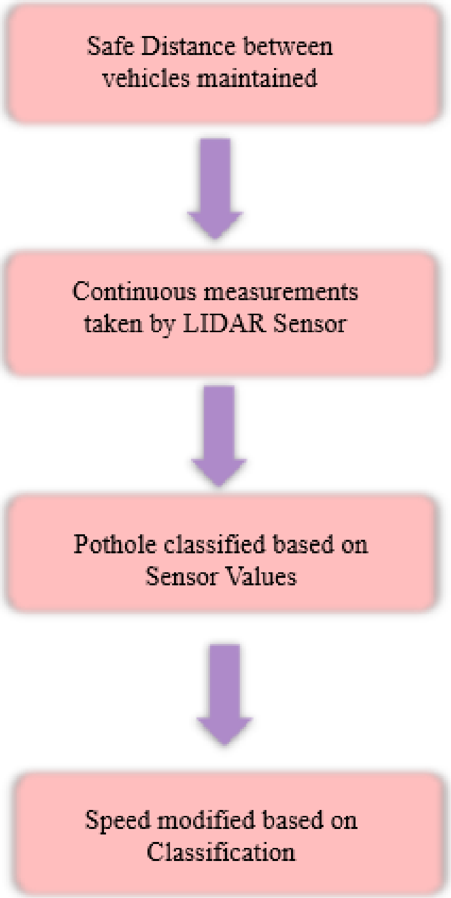

Fig. 12: Block Diagram of Cruise Control System

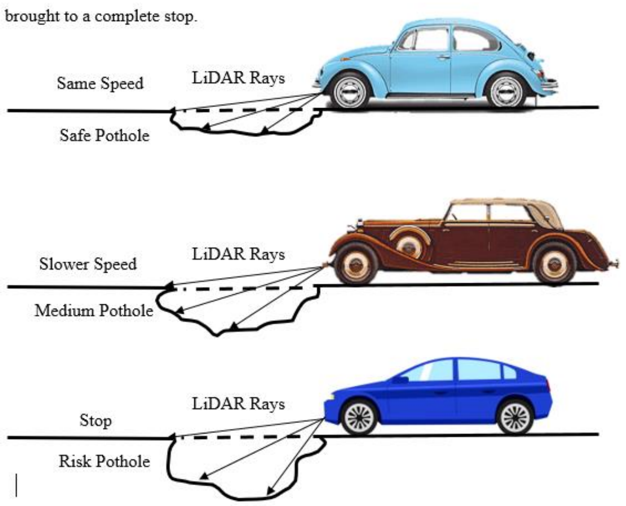

Fig. 13: Different Level Depth Estimation

D. *RASPBERRY PI IMPLEMENTATION*

The Raspberry Pi 4 serves as the central hub, encompassing all necessary components for seamless operation. Utilizing Real VNC Viewer, the display is streamed by linking the laptop and Pi over the same Wi-Fi network. Thonny IDE orchestrates program execution, facilitating the installation of crucial libraries like NumPy and OpenCV, as well as additional software such as Arduino, via the terminal. Direct interface between the Raspberry Pi camera and the Pi enables immediate activation for pothole scanning upon program initiation. Once detected, the LiDAR sensor continuously gathers sensor data, contributing to precise pothole classification. This information is transmitted from Arduino to the Python program through the Pi's serial port, where the detected pothole and its class are visually represented within a bounding box. Subsequently, vehicle speed adjusts dynamically to ensure safe traversal of identified road hazards. This integrated system showcases efficient collaboration between hardware and software components to enhance road safety measures.

IV. RESULTS

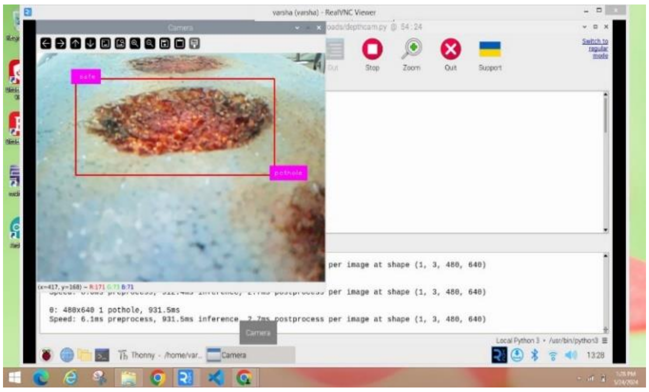

Fig. 14: Detection of Pothole (Safe)

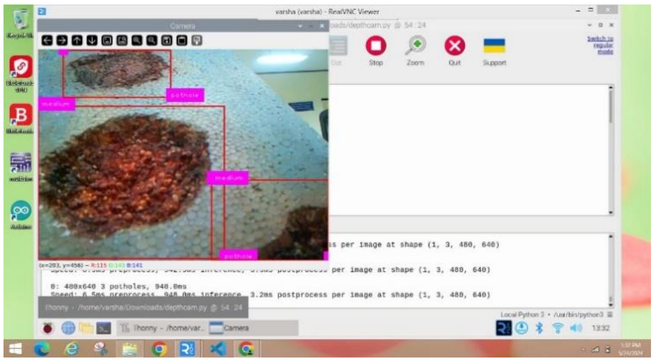

Fig. 15: Detection of Pothole (Medium)

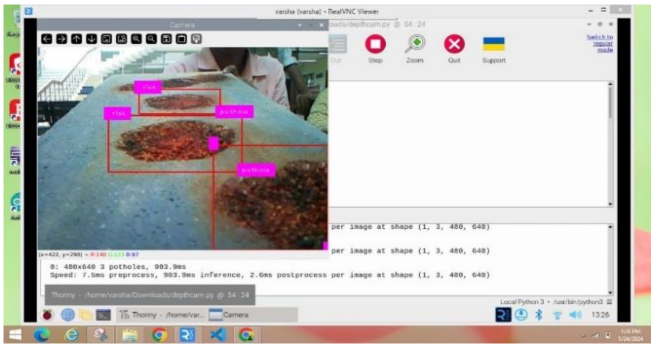

Fig. 16: Detection of Pothole (Risk)

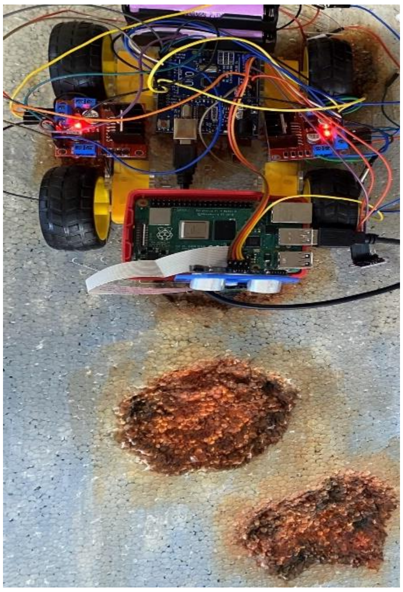

Fig. 17: Model Demo

V. CONCLUSION

This project amalgamates two forefront automotive technologies: object detection for early pothole identification and depth detection for hazard avoidance. Leveraging Raspberry Pi and YOLOv8, this amalgamation has proven highly efficient. Scaling this model to address various obstacles beyond potholes is entirely viable. The subsequent phase entails seamlessly integrating this model into a fully autonomous system, thereby enhancing overall road safety and efficiency. This cohesive integration not only underscores the potential for broader applications but also signifies a significant step forward in advancing autonomous driving technologies.

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