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Pothole Detection System For Indian Roads With Increased Road Safety Driving

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Abstract: Potholes are a nuisance, especially in the developing world, and can often result in vehicle damage or physical harm to the vehicle occupants. Drivers can be warned to take evasive action if potholes are detected in real-time. Moreover, their location can be logged and shared to aid other drivers and road maintenance agencies. This paper proposes a vehicle-based computer vision approach to identify potholes using a window-mounted camera. Existing literature on pothole detection uses either theoretically constructed pothole models or footage taken from advantageous vantage points at low speed, rather than footage taken from within a vehicle at speed. The main objective of this system is to design a Pothole Detection System which assists the driver in avoiding potholes on the roads, by giving him prior warnings. Due to weather conditions, improper construction, and overloading of vehicles, the roads are getting damaged. The scope of this research work lies, where the irregularity of the road affects public people. This can be used in 4-wheelers, especially for ambulance drivers so that they could save many lives in time.

I. INTRODUCTION:

Potholes in road surfaces are mostly caused by water (CSIR, 2010) and regular road maintenance is vital to prevent the decaying process. The manner in which a pothole forms is dependent on the type of bituminous pavement surfacing. The volume of traffic and the axle load experienced by the road are example factors that lead to fatiguing of the road surface, resulting in the formation of cracks. These cracks allow water to seep through and mix with the asphalt. When a vehicle drives over this area, this water will be expelled through the crack with some of the asphalt, and this will slowly create a cavity underneath the crack. Eventually the road surface will collapse into the cavity, resulting in a visible pothole. If regular road maintenance is neglected, the aforementioned cracks are not repaired before they cause substantial damage to the road. This paper discusses a method for detecting potholes (via image processing) that does require a bit of machine learning, but is based on an algorithmic approach that is rooted in the fundamental properties of potholes. Due to the visual nature of the approach, it is self-evident that the solution is dependent on lighting conditions, obstructions in the line of view, rain and any other factors that visually impair the ability to see potholes. The work presented is therefore limited by this aspect and so does not provide an all-encompassing solution. The next section will briefly summarize the current pothole detection literature. Thereafter, the proposed methodology will be discussed in detail. An implementation including preliminary results will be presented and a clear conclusion on the effectiveness will be drawn from the results. This proposed system has attained an accuracy of 86.7%, with 83.3% precision, and 87.5% recall.

The remainder of this paper has been organized as follows. Section I is for the introduction. Section II briefly explained about the proposed methodology of this proposed work. Section III provides experimental results and analysis. Section IV is the conclusion followed by the future scope of the proposed work, in Section V respectively. Section VI provides some references related to this research work.

II. METHODOLOGY:

In this research work, a visual approach is proposed that uses a machine learning algorithm along with YOLOv5 dataset which is a popular method to train model using object detection, it detects potholes and also road bumpers using a rectangular box. Through the trained models by YOLOv5 we have successfully detected the potholes and as well as speed breakers for preventing any kind of accidents in the roads.

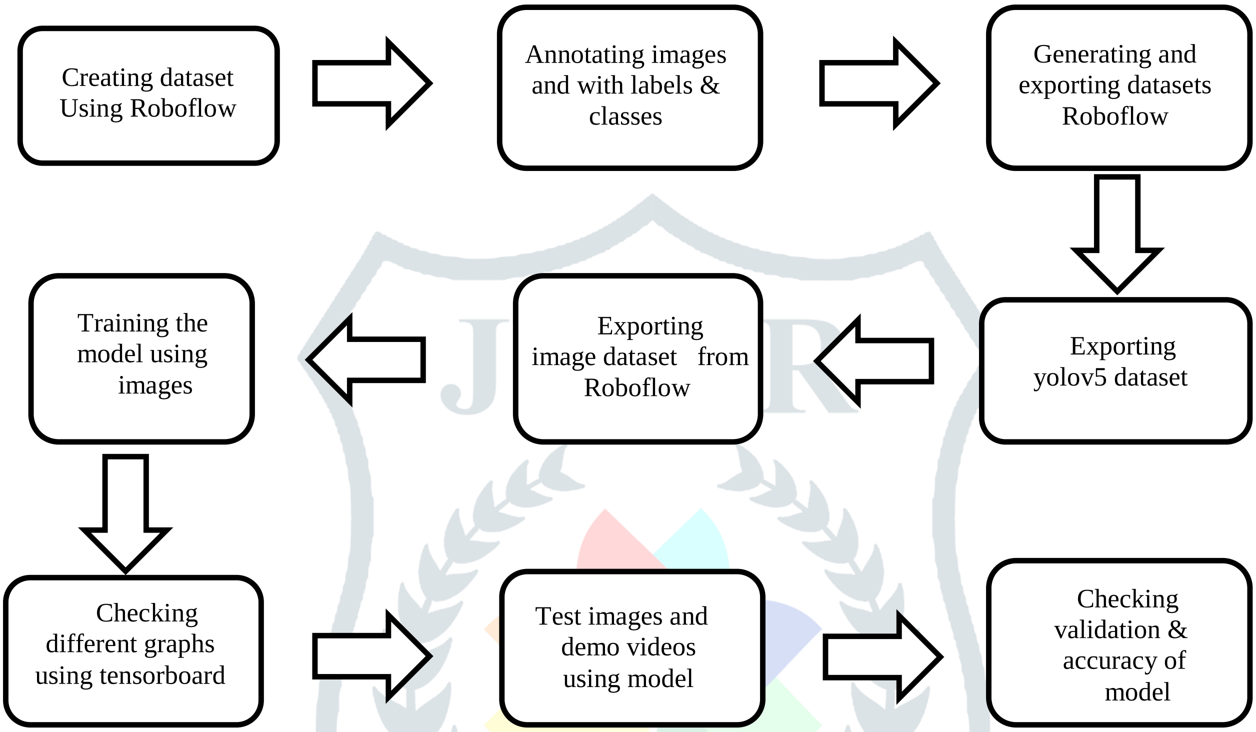

Fig 1: The working diagram of the proposed model

The YOLOv5 algorithm is a state-of-the-art object detection algorithm that can be used for various tasks, including pothole detection. First, we collect and annotate a dataset of images that contain potholes and label them with bounding boxes around the pothole regions. Split the dataset into training and testing sets. Then we initialize the YOLOv5 network with pre-trained weights or train from scratch. During training, the network learns to predict bounding boxes and class labels for various objects, including potholes, by minimizing a loss function that compares the predicted outputs with the ground truth annotations. Next, we pass the preprocessed input images through the network. The network processes the images through multiple convolutional layers to extract features at different scales and performs object detection at each scale. YOLOv5 utilizes anchor boxes, which are predefined bounding box shapes with specific aspect ratios, to predict object locations and sizes. The network predicts bounding box coordinates relative to the anchor boxes at each scale. YOLOv5 predicts bounding boxes and associated class probabilities for potential potholes at each scale. The final output of the YOLOv5 algorithm is a list of bounding boxes around potholes, along with their associated class probabilities.

It's worth noting that the YOLOv5 algorithm can be further customized and fine-tuned based on specific requirements and datasets. The algorithm's performance can be improved by adjusting various hyperparameters, training on larger datasets, or incorporating additional techniques such as data augmentation or transfer learning.

A.Flowchart:

For a real-time pothole detection system, the block diagram of the proposed methodology is shown in Figure 2. Annotation for each image is performed explicitly after the collection of the dataset. The annotated data are split into training and testing data before passing it to deep learning models such as the YOLO family and SSD for custom model training.

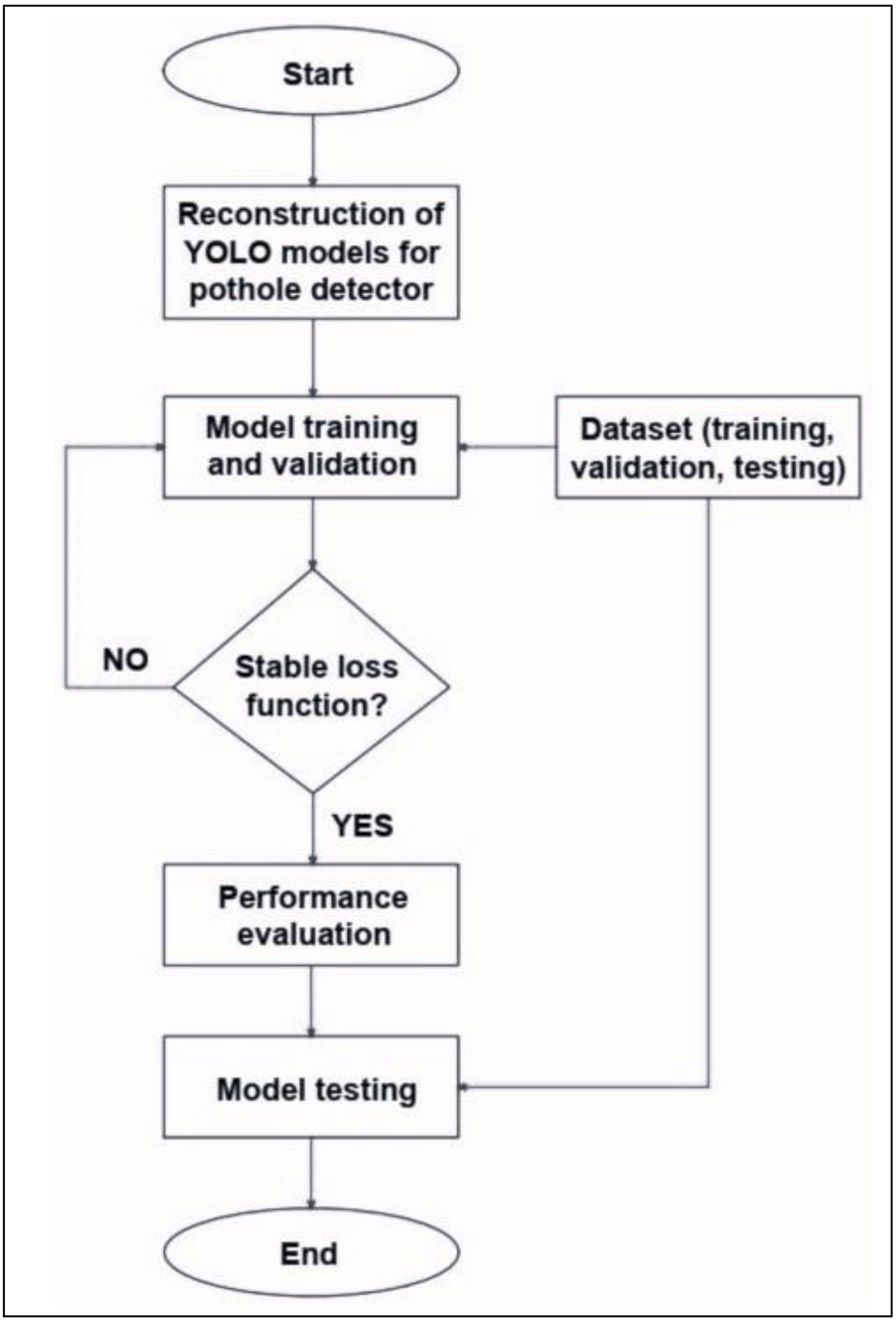

Fig2: Flowchart of the proposed model

III. EXPERIMENTAL RESULT AND ANALYSIS:

The module detects all potholes with an absolute accuracy of 86.7%, precision of 83.3% and a recall of 87.5%. In the following figures the images show the difference before implementing the algorithm and the result after detection of the image. It marks all the detected potholes using a rectangular shaped box.

Fig 3: Before detection of potholes

Fig 4: After detection of potholes

In the figure on the left side i.e.in Fig 3, we can see the road with full of potholes in it and on the right side of the page i.e.in Fig 4, we find the road with detected potholes in it which is detected by red rectangular boxes.

In the Confusion matrix, we find the measurement of the performance of classification models, which aim to predict a categorical label for each input instance. So, in the following diagram we discuss the performance of our model about potholes which is detected as 'pothole' and the speed breakers as 'lombada' in the confusion matrix.

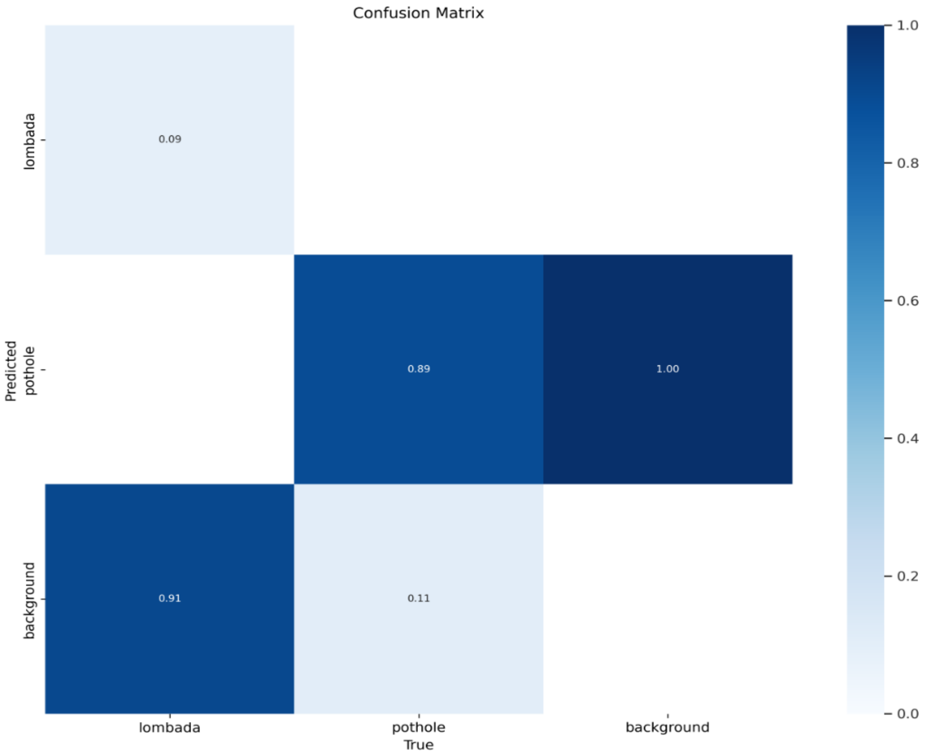

Fig 5: Confusion Matrix

In the Precision matrix, Precision tells what proportion of positive predictions was actually correct and how accurate the prediction is. Here, in the following diagram we can observe that the faded black line is the accurate output and the bold black curve is our predicting output based on the accurate one as shown in the dataset and the corresponding graph figure (fig 7).

A	B
epoch	metrics/precision
0	0.0014381
1	0.0020158
2	0.0020299
3	0.0028338
4	0.0039634
5	0.0033758
6	0.0090842
7	0.55111
8	0.60674
9	0.61553
10	0.65701
11	0.30381
12	0.18468
13	0.31105
14	0.31233
15	0.29433
16	0.28896
17	0.35248
18	0.36135
19	0.36305

Fig 6: Dataset for precision matrix

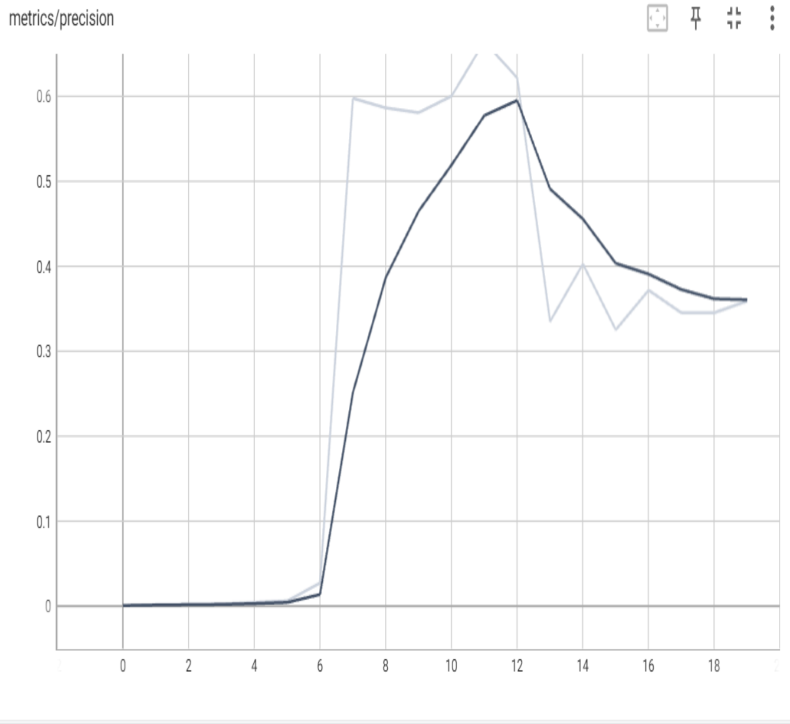

Fig 7: Precision Matrix

We have compared our results with other state-of-the-art techniques, showing that our YOLOv5 trained model has performed better in detection with minimum inference time. Shaghouri et al. [16] used a pothole image dataset with 75.63% mAP using YOLOv4; the trained YOLOv4 has achieved 85.48%, which is 9.85% more accurate; whereas [17] used self-collected dataset and achieved mAP@0.5 of 18.5% with higher inference time using SSD-Mobilentv2. Researchers in [18] used YOLOv5 on the PID and achieved the mAP@0.5 of 74.48% which is in difference of 20.52% as compared to our trained YOLOv5.

IV. CONCLUSION:

This paper presented a good preliminary method for pothole detection using a single optical camera that can detect potholes within a range of ≈ 2 m - 30 m. It was found that the algorithm execution speed is adequate given a vehicle speed of less than 80 km/h although the actual maximum distance at which the pothole can be detected needs to be improved to account for the driver reaction time. The main advantage of this system is that they do not require the use of specialized sensors or equipment, and they can be used with existing cameras. They can be used to monitor large areas of roads, and they can be easily deployed in new locations. But among all the advantages, the major drawback is that it faces some serious issue in detecting potholes in foggy weather due to improper vision and light.

V. FUTURE SCOPE:

The future scope for this work on pothole detection system is highly promising, as it addresses a significant issue in infrastructure maintenance and road safety. With advancements in technology, the project can leverage cutting-edge techniques such as computer vision, machine learning, and sensor integration to develop a robust and efficient system. The system can be further enhanced by incorporating emerging technologies like LiDAR (Light Detection and Ranging), which provides accurate depth measurements, and GPS (Global Positioning System), enabling precise geolocation of detected potholes. The system can be integrated into vehicles, enabling real-time monitoring of road conditions and automatic identification of potholes. Moreover, the data collected can be aggregated and analyzed to generate comprehensive maps of pothole locations, allowing municipal authorities to prioritize repairs and allocate resources effectively. The project also opens avenues for collaboration with smart city initiatives, where the pothole detection system can be integrated with existing infrastructure to create a self-healing road network that proactively addresses road surface degradation. Additionally, the potential for integration with autonomous vehicles holds tremendous promise, as it can enhance their navigation systems and enable them to take preventive measures to avoid potholes, leading to increased safety and reduced maintenance costs. Overall, the future scope for a pothole detection system project is vast, with opportunities for technological advancements, partnerships with municipalities, and integration into smart city initiatives and autonomous vehicles, all contributing to safer and more efficient road infrastructure.

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