Pothole Detection Using ML and DL Algorithms

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Abstract - *Potholes are a persistent problem in transportation infrastructure, causing vehicle damage and hazards for drivers. Manual detection methods are time-consuming and costly. Computer vision and machine learning offer potential solutions for automating pothole detection. These technologies can improve road maintenance and safety by accurately identifying potholes. This paper presents an integrated approach for pothole detection and classification using YOLOv7, SVM, and segmentation techniques. A user- friendly web application is developed using Streamlit for easy interaction. The YOLOv7 model accurately detects and classifies potholes based on annotated training datasets. Segmentation techniques refine pothole regions, enabling precise boundary extraction for accurate analysis. The SVM model is trained on labeled pothole images to classify different pothole types. The web application allows users to upload images, detect and classify potholes, and visualize results. It aids road authorities and maintenance crews in identifying problematic areas and planning repairs, contributing to safer road conditions.*

Keywords: Computer vision, machine learning, pothole detection YOLOv7, SVM, segmentation techniques, web application, Streamlit, pre-processing, object detection, classification

1. INTRODUCTION

Efficiently detecting and classifying potholes on roadways is vital for ensuring road safety and effective maintenance. This paper presents an integrated approach that utilizes the YOLOv7 object detection model for accurate pothole detection and classification. Additionally, a user-friendly web application is developed using Streamlit to provide an intuitive interface for interaction and result in visualization**.**

The detection process relies on the YOLOv7 model, which is trained on annotated datasets to precisely locate and classify potholes in road imagery. The model's robust object detection capabilities make it well-suited for identifying potholes with high accuracy.

To enhance user experience and facilitate result visualization, a web application is built using Streamlit.The application allows users to easily upload road images and applies the YOLOv7 model to detect and classify potholes. The detected potholes are then presented to the user in an accessible and user-friendly format.

By combining the YOLOv7 object detection model and the Streamlit-based web application, our integrated approach provides an efficient solution for accurate pothole detection and classification. This empowers road authorities and maintenance crews to swiftly identify and address potholes, ultimately contributing to safer road conditions and more effective maintenance practices.

2. LITERATURE SURVEY

In a study conducted [1], various image pre-processing and segmentation methods were explored to improve the accuracy of pothole detection. The study specifically implemented the difference between Gaussian-Filtering and clustering-based segmentation methods andcompared their results. The findings revealed that the K-Means clustering-based segmentation method was the most efficient in terms of computing time, while edge detection-based segmentation was the most accurate.The study aimed to identify a superior method for pothole detection compared to traditional methods, and this objective was achieved by using performance measures to evaluate the different techniques reviewed. Their research paper [2] discussed a pothole detection model using computer vision and machine learning. The study involved collecting road images from BMC Mumbai and applying various computer visionoperations such as pre-processing, morphological operations, canny edge detection, and decision tree algorithms to detect potholes. The proposed model aimed to identify potholes and report them to relevant authorities while utilizing machine learning techniques to enhance prediction accuracy. Despite the availability ofsmart technologies like IoT, machine learning, and artificial intelligence, there is a lack of effective techniques for detecting and preventing road anomalies such as potholes. The model also utilized GPUs to accelerate deep learning processes, albeit at the cost of significant power and energy consumption. Additionally, data from vibration and GPS sensors were utilized to evaluate road surface quality. By leveraging image processing techniques, the system successfully detected potholes from input images, enabling effective identification of such road hazards.

In their study [3], researchers aimed to develop a pothole detection method using a combination of pothole and normal road image data. The study involved collecting and preprocessing the data by resizing and rescaling the images. MobileNetV2 was utilized for feature extraction, and dimensionality reduction techniques such as PCA,LDA, and t-SNE were applied to reduce the feature dimensions. Five machine learning classification algorithms were employed to train the system, including Support Vector Machine (SVM), Logistic Regression, Random Forest, Elastic Net, and Decision Tree. The results were analyzed, and it was observed that Logistic Regression, Elastic Net, and SVM performed better than the other algorithms. A comparison of the top- performing algorithms concluded that Support Vector Machine (SVM) achieved the highest accuracy, reaching 99%.

In their research [4], the focus was on detecting potholes to prevent road accidents by utilizing a combination of hardware and software technologies. The researchers employed a Pi Camera for capturing images, benefiting from its high clarity and the ability to connect it to the Raspberry Pi for remote access. An interface was developed to facilitate remote access to the Pi Camera. The system architecture involved taking input from the Pi Camera, sending it to the processing unit via a TCP server for networking, and utilizing a Neural Network Model for pothole detection. Once potholes were detected, the direction of an RC car would be modified accordingly. The study also employed Image Threshold segmentation for visualizing the potholes and Canny Edge Detection for detecting the edges of the images. Theimages were initially converted into grayscale and OpenCV libraries were utilized for edge detection.

In their study [5], researchers aimed to design and develop an Automatic Pothole Detection and Alert System that incorporates an ultrasonic sensor, accelerometer, stereo camera, and Global Positioning System (GPS) integrated with Raspberry Pi. The system's primary objectives were to detect potholes, alert riders, and create a location database of existing potholes. By enhancing rider awareness, the system has the potential to reduce accidents and vehicle maintenance costs. Experimental results demonstrated a 90 percent accuracy rate in pothole detection. The estimated cost of the system is approximately 8000 INR, and it can lead to a reduction of 35-50 percent in average vehicle maintenance expenses. The system is capable of promptly sending GPS location information to the database and alerting the rider within 4 seconds. The database generated by the system is organized on a city- wise basis and has the potential for future expansion to cover the entire nation.

In their study [6], researchers focused on developing an algorithmic approach for pothole detection that does not rely on machine learning. Unlike traditional methods that utilize simulated pothole models or footage from advantageous vantage points, this study utilized an image library, a pothole model, and basic image processing techniques to detect potholes from within a vehicle. The algorithm aimed to identify various road features, including lane markings, road signs, and potholes, with the goal of enhancing road safety. The study aimed to improve pothole detection capabilities and make a contribution to overall road safetyimprovement.

In the study conducted [7], the focus was on the effective management of potholes in complex road environments to ensure driver safety and smooth traffic flow. Traditional visual inspection methods for pothole detection are being replaced by automated approaches that utilize sensors and signal processing. The study categorizes these automated methods into vision-based, vibration-based, and 3D reconstruction-based approaches. It compares the strengths and weaknesses of each method and discusses the detection processes and technologies used in recent research. Additionally, the study outlines future plans for technology development to improve pothole detection and management. Overall, it provides a comprehensive overview of automated pothole detection methods and their potential for future advancements.

The studies mentioned here focused on various techniques and methods for pothole detection using image processing, machine learning, and sensor-based approaches. The studies utilized different types of sensors, algorithms, and image-processing techniques to detect potholes, assess road conditions, and alert drivers of potential hazards. Some studies focused on identifying the most efficient and accurate segmentation methods, while others developed algorithms for pothole detection using machine learning techniques. The studies also discussed the potential benefits of automated pothole detection systems in terms of reducing accidents and vehicle maintenance costs. Overall, the studies provide a comprehensive overview of the current state of pothole detection technology and its potential for future advancements.

3. METHODOLOGY

For a system that can find potholes in real-time, the suggested method looks for potholes with a custom-trained YOLOv7 model, SVM machine learning algorithm, and image segmentation. Like the other modules, YOLOv7 gets information from the webcam or live camera and sends the pictures through the trained model. Each picture is annotated after the dataset has been collected. Before giving it to deep learning models like the YOLO family to train custom models, the labeled data is split into training and testing data.
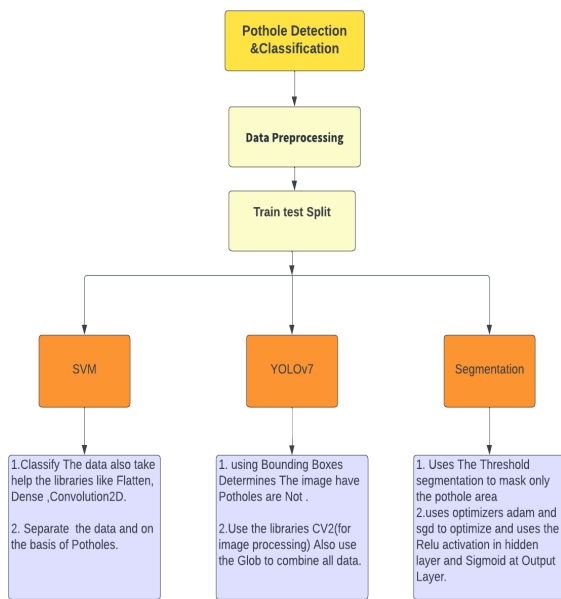
Fig1:- Proposed System

We chose YOLOv7 as the main framework for our proposed solution because YOLOv7 is faster and more accurate than its earlier versions (YOLOv6, YOLOv5, etc.), pushing the state of art in object detection to new heights. The methodology is discussed in detail in the following sections.

3.1 Data Collection and Pre-processing

How well the models work and how reliable they are based on the dataset used to train them. The data set must have pictures of real potholes. So, the most recent pothole image dataset that is open to the public is used. This dataset has 700+ images with real-world effects like shadows, moving vehicles, and different lighting. The pictures in the dataset come from online sources, which means that they are noisy and of low quality. Data is cleaned to archive error-free data set. After cleaning the data set, all the images were annotated with the relevant labels.

3.2 Model Training and Testing

Training and Testing: The Machine Learning model is developed with YOLO v7 architecture, SVM machine learning algorithm, and segmentation algorithm. The Training and Testing ratio is 85:15

3.3 Pothole Detection Using Deep Learning Model

Deep convolution neural networks have shown that they can do a lot of things to find objects. Deep learning lets you train on several object recognition models, such as the region-based convolution neural network family and the YOLO family. But the R-CNN family is hard to compute, which leads to low delay. On the other hand, YOLO is being

looked at to help the R-CNN family with its speed problems. So, for this case, we focused on YOLOv7.

3.4 YOLOv7

YOLO, which stands for "you only look once," was first used by Redmonin in 2016. The YOLO architecture can find objects by using three key terms. It is important to understand these three tactics to fully understand why this model works so quickly and accurately compared to other object identification algorithms. The YOLO approach starts with the implementation of the remaining blocks. In the first step of the architectural plan, grids were made in the specific picture using the remaining 7 × 7 blocks. these grids act as center points, and a different prediction is made for each grid based on what it shows. In a second way, the bounding boxes are made by taking each of a forecast's central points into account. Although the classification jobs are successful for each grid, it is more difficult to separate the bounding boxes for each forecast. The intersection of union (IOU) is the third and final approach. It is used to find the best bounding boxes for a given object identification job.

3.5 Pothole Detection using SVM

Support Vector Machine (SVM) comes under in supervised machine learning method which can be used for both classification and regression problems. In this method, each piece of data is represented by a point in n-dimensional space, where n is the number of features and each feature's value is a coordinate. Then, classifying is done by finding the hyperplane that best separates the twoclasses.

3.6 Segmentation

Segmentation is used to highlight the specific part of any image in this we used to highlight the pothole area for better understanding. we used threshold segmentation in this Project first we have to convert the images into greyscale images for better observation we used the sigmoid and Relu activation in this model there are a total of 119 layers we used the Relu used in the background and the sigmoid is used for the front end for flatten the output.

4. RESULT AND DISCUSSION

1. **Edge Detection**

In this method, Figure 2 demonstrates the application of the Canny edge detection algorithm to highlight the road's edges for enhanced image analysis. Initially, the input image is converted into a grayscale representation. Subsequently, the Canny edge detection method is applied to the grayscale image, effectively detecting and emphasizing the edges present in the road. The resulting

output image showcases the prominent edges, providing a clearer visual understanding for further analysis.
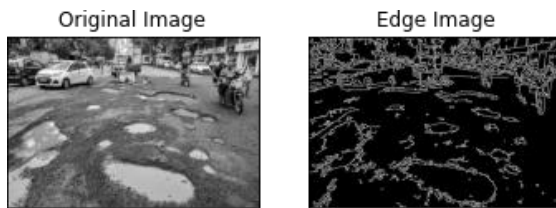

Fig2: Canny Edge Detection

2. Segmentation Output

In this method, as shown in Figure 3, the threshold segmentation technique is employed to improve the visualization of the data and facilitate better analysis. The segmentation process is applied to the input images, resulting in a segmented output that highlights specific regions of interest.

In addition to segmentation, the method utilizes multiple layers, including convolutional layers, and employs activation functions such as Relu as a backend and sigmoid as a frontend. The output of these layers is then flattened to simplify the representation of the extracted features.

Figure 4 visually represents the flattened output, showcasing the transformed data ready for further analysis or utilization in subsequent stages of the method. By applying threshold segmentation, utilizing various layers, and employing specific activation functions, this method enhances the visualization and analysis of the data.
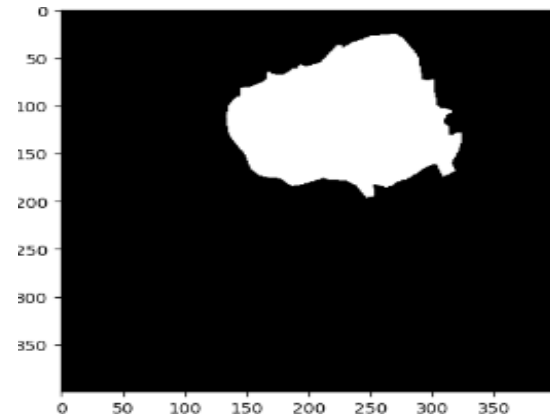

Fig3: Original Image

Fig4: Highlighted the Pothole Area

3. YoloV7

Fig5: Created the Bounding Box using Yolov7

When applied to an image of a pothole, the YOLO (You Only Look Once) algorithm, as depicted in Figure 5, generates a bounding box that precisely indicates the location of the pothole within the image. This bounding box acts as a visual representation of the pothole's extent and position, enabling subsequent analysis and potential actions based on its coordinates.

4. Support Vector Machine

The SVM graph is specifically designed to classify potholes with great accuracy. Following 5 epochs of training, the model achieves an impressive training accuracy of 0.975, indicating that it correctly identifies potholes in the training data 97.5% of the time. During the binary test, which assesses the model's performance on new data, the SVM graph demonstrates a test accuracy of 0.875, implying that it accurately classifies potholes in unseen images 87.5% of the time.

In terms of loss, the model exhibits a training loss of 3, which represents the average difference between the predicted and actual pothole labels during the training
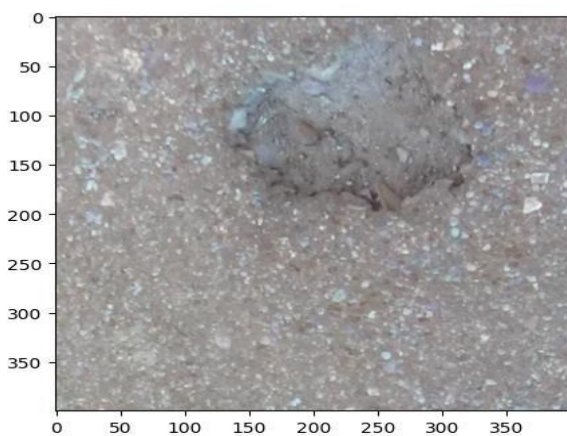
process. A lower training loss suggests that the model is fitting the training data well. Furthermore, the test loss is recorded as 0.3, indicating the average discrepancy between the predicted and actual pothole labels on the test data. A lower test loss signifies that the model generalizes effectively to unseen images by displaying only a small deviation from the ground truth labels.
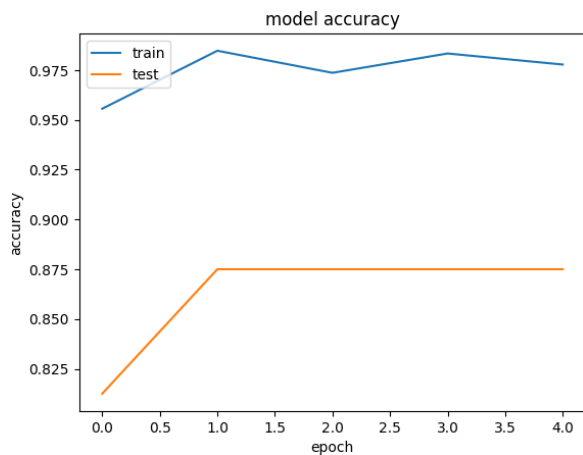

Fig6: Model Accuracy

Fig7: Model Loss

5. Web-App

Figure 8 displays a screenshot of a web application developed using Streamlit, a popular Python framework for building interactive data applications. The purpose of this web app is to detect and address potholes on roads. The user interface is designed to be user-friendly and intuitive, allowing users to easily interact with the application.

The web app built with Streamlit provides a platform for users to upload images or videos of roads containing potential potholes. It incorporates a backend algorithm,

utilizing the YOLOv8 (You Only Look Once version 7) model for object detection. YOLOv8 is a state-of-the-art deep learning model known for its high accuracy and real-time object detection capabilities.
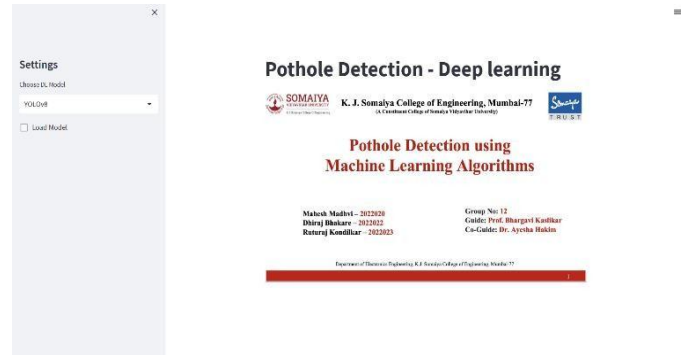

Fig8: Web-App

In Figure 9, we see the predicted results produced by the YOLOv8 model. The image shows the output of the object detection algorithm, highlighting the detected potholes in the uploaded image or video. Each detected pothole is marked with a bounding box, clearly indicating its location within the road. By combining the user-friendly interface of the Streamlit web app and the powerful object detection capabilities of YOLOv8, this application aims to streamline the process of identifying and addressing potholes, ultimately contributing to safer and well-maintained roads.

Fig9: Prediction using YOLO

5. CONCLUSION

An approach is presented for analyzing the images with potholes and performing operations on them and labeling them as pothole or non-pothole images as well as creating the bounding boxes for better visualization. This system is efficiently designed to fulfill two main criteria:

1. Detecting potholes on the road.

2. Implement Web Based Application for detection purpose.

This Project will help many peoples to detect Potholes in the Future this Software can be implemented in the Car as an in-build so the speed of detection will increase.

6. REFERENCES

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