DETECTION OF TIRE DEFECTS USING DEEP LEARNING

A MINI PROJECT-I REPORT

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LIST OF ABBREVIATION

ABBREVIATION	EXPANSION
AI	Artificial Intelligence
YOLOv8	You Only Look Once version 8
TFlite	TensorFlow Lite

ABSTRACT

Tire defects, such as cuts, bulges, and punctures, pose significant safety risks to vehicles and passengers. Early detection of these defects is crucial for maintaining road safety and preventing accidents. However, manual inspection of tires for defects is time-consuming, labor-intensive, and prone to human error. Therefore, there is a need for an automated tire defect detection system that can accurately and efficiently identify various types of defects in real-time. The YOLOv8 algorithm, an evolution of the popular You Only Look Once (YOLO) object detection family, is particularly well-suited for real-time tire defect detection in images. Its key strength lies in its ability to detect multiple objects within an image simultaneously with high accuracy and speed. This is achieved through a single neural network that divides the image into regions and predicts bounding boxes and probabilities for each region. In the context of tire defect detection, YOLOv8 can be trained to recognize various types of defects such as cuts, bulges, and punctures. By utilizing its efficient architecture and real-time processing capabilities, YOLOv8 can help improve road safety by enabling automated and rapid detection of tire defects, allowing for timely maintenance and replacement of damaged tires.

CHAPTER 1

INTRODUCTION

1.1 TYRE DEFECTS DETECTION

Tire defects are a significant concern for vehicle safety, as they can lead to accidents, breakdowns, and increased maintenance costs. Common tire defects include cuts, punctures, bulges, and uneven wear, which can compromise the structural integrity of the tire and increase the risk of blowouts. Traditional methods of detecting tire defects rely on manual inspection, which is time-consuming, labor-intensive, and prone to human error.As a result, there is a growing interest in developing automated systems for tire defect detection. Automated tire defect detection systems use image processing techniques to analyze digital images of tires and identify defects. In which the systems can provide moreaccurate and consistent results compared to manual inspection methods, leading to improved safety and reduced maintenance costs. This project focuses on the development of an automated tire defect detection system using image processing techniques. The system aims to detect common tire defects such as cuts, punctures, and bulges, as well as more complex defects such as uneven wear patterns. By automating the detection process, the system can provide faster and more reliable results, helping to ensure the safety of vehicles on the road.

1.2 DIFFERENT APPROCACHES FOR TYRE DEFECT DETECTION

1.2.1 Visual Inspection:

This is the most basic method, where trained inspectors visually examine tires for defects such as cuts, punctures, bulges, and uneven wear. While simple, this method is subjective and can be prone to human error.

1.2.2 Ultrasound Testing:

Ultrasound waves are used to detect defects within the tire structure. This methodcan detect internal defects such as delamination and air leaks, but it requires specialized equipment and training.

1.2.3 X-ray Inspection:

X-ray imaging can be used to inspect the internal structure of tires for defects. This method is effective for detecting internal defects but requires expensive equipment and specialized training.

1.2.4 Automated Optical Inspection (AOI):

AOI systems use cameras and image processing algorithms to inspect tires for defects. These systems can detect a wide range of defects, including cuts, punctures, and bulges, and can operate at high speeds. However, they can be expensive to implement and require regular maintenance.

1.2.5 Infrared Thermography:

This method uses infrared cameras to detect heat variations on the tire surface, which can indicate defects such as delamination or air leaks. It is non-contact and can be used for real-time monitoring.

1.2.6 Acoustic Emission Testing:

This method detects defects by analyzing the acoustic signals emitted by the tire when under stress. It can detect defects such as cracks and delamination, but it requires specialized equipment and expertise.

1.2.7 Pressure Testing:

By inflating the tire to a specified pressure and monitoring pressure changes over time, defects such as punctures and leaks can be detected. This method is simple and cost-effective but may not detect all types of defects.

CHAPTER 2

LITERATURE SURVEY

2.1 Research on Tire Crack Detection using Image Deep Learning method (2023)-SHIN-LIN-LIN

This paper proposes a high-precision tire defect detection system. Through the trained and improved deep learning ShuffleNet model, the tire images are detected for defects. Through the tire database experiment, it can be proved that the algorithm in this paper can accurately detect tire crack defects. In the research results, the classification accuracy of GoogLeNet is 82.7%, the traditional ShuffleNet is 85.3%, VGGNet is 87.3%, ResNet is 90%, and the improved ShuffleNet is 94.7%. This research method can be used not only for driving but also for tire factories.

2.2 Tire Defect Detection Using Fully Convolutional Network (2019)-Ren Wang, Qiang Guo, Shanmei Lu, Caiming Zhang

This paper explores the solution for the tire defect detection using FCN, which has outstanding performance in solving segmentation problems. With the feature extraction ability, VGG16 is constructed as the basic architecture to represent tire images. We fine-tune the parameters and structure of FCN to obtain coarse detection results, and refine results by a fusion strategy. Experiments show that the proposed method is applicable to more types of defects compared with traditional methods. Unlike the existing learning based method in the tire industry, this algorithm can directly segment defects, and is valid for both the sidewall and tread images.

2.3 Analysis of the Possibilities of Tire-Defect Inspection Based on Unsupervised Learning and Deep Learning (2021)-Ivan Kuric, Jaromir Klarak, Milan Sága, Miroslav Císar

In this paper, - described the design of a hybrid tire inspection system utilizing both 3D and 2D data. The applied algorithm combines both supervised and unsupervised learning methods. In terms of supervised learning, it uses pattern recognition and polynomial regression, while, in terms of unsupervised learning, the DBSCAN algorithm is used for the clustering task. Polynomial regression was used to automate the process compensating for the inaccuracies. Further work should involve managing and modifying the tire inspection stand and design background in order to identify and possibly automatically separate areas of the tire sidewall from the background.

2.4 Kandera, M. Design of Methodology for Testing and Defect Detection Using Artificial Intelligence Methods. 2020.

In this paper, we described the design of a hybrid tire inspection system utilizing both 3D and 2D data. The applied algorithm combines both supervised and unsupervised learning methods. In terms of supervised learning, it uses pattern recognition and polynomial regression, while, in terms of unsupervised learning, the DBSCAN algorithm is used for the clustering task. Polynomial regression was used to automate the process compensating for the inaccuracies described. Thus, replacing the conventional methods described. Further work should involve managing and modifying the tire inspection stand and design background in order to identify and possibly automatically separate areas of the tire sidewall from the background.

2.5 Tire Defect Detection Using Fully Convolutional Network (2015), M. Win, A. Bushroa, M. Hassan, N. M. Hilman, and A. Ide-Ektessab

This paper explores the solution for the tire defect detection using FCN, which has outstanding performance in solving segmentation problems. With the feature extraction ability,VGG16 is constructed as the basic architecture to represent tire images. We fine-tune the parameters and structure of FCN to obtain coarse detection results, and refine results by a fusion strategy. Experiments show that the proposed method is applicable to more types of defects compared with traditional methods. Unlike the existing learning based method in the tire industry, our algorithm can directly segment defects, and is valid for both the sidewall and tread images.

2.6 Defect Detection in Tire X-Ray Images Using Weighted Texture Dissimilarity (2018) F. Tajeripour, E. Kabir, and A. Sheikhi

Automatic quality inspection is strongly desired by tire industry to take the place of the manual inspection. This paper presents an efficient detection method for automatic quality inspection, which takes advantages of feature similarity of tire images and captures the texture distortion of each pixel by weighted averaging of the dissimilarity between this pixel and its neighbors. Different from the existing tire defect detection algorithms that fail to work for tire tread images, the proposed detection algorithm works well not only for sidewall images but also for tread images. Experimental results performed on real tire inspected images validate that the proposed detection method outperforms the current defect detection methods.

CHAPTER 3

PROJECT DESCRIPTION

3.1 INTRODUCTION

Tire defects pose a serious safety risk for vehicles, necessitating efficient detection methods. Manual inspection is time-consuming and prone to errors. This project proposes a tire defect detection system using the YOLOv8 algorithm, known for its speed and accuracy in object detection. Integrating this algorithm with Visual Studio will streamline development and deployment processes, enhancing the system's overall efficiency and effectiveness.

The primary goal of this project is to develop a computer vision system that can automatically detect and classify tire defects, including cuts, bulges, and wear patterns, in real time. By leveraging YOLOv8's capabilities and integrating it into Visual Studio, the system aims to improve the speed and accuracy of defect detection, thereby enhancing vehicle safety and reducing the risk of accidents caused by tire defects.

The implementation will involve training the YOLOv8 model on a dataset of annotated tire images to recognize various defect types. Visual Studio will be used to integrate the trained model into a user-friendly application that can process images from a camera installed in a production line or inspection area. The system's effectiveness will be evaluated based on its ability to accurately detect and classify tire defects under various conditions, such as different lighting and tire wear levels.

3.2 PROBLEM STATEMENT

The desire for tire defect detection arises from the critical role tires play in vehicle safety and the challenges associated with manually inspecting them. Automated tire defect detection systems aim to enhance safety by identifying defects such as bubbles, peeling, impurities, bulging, and cracks early, preventing potential hazards on the road. The systems also increase driver awareness, encourage regular tire checks, and promote adherence to proper tire change times, reducing the risk of sudden tire failures orpunctures.

3.3 BLOCK DIAGRAM

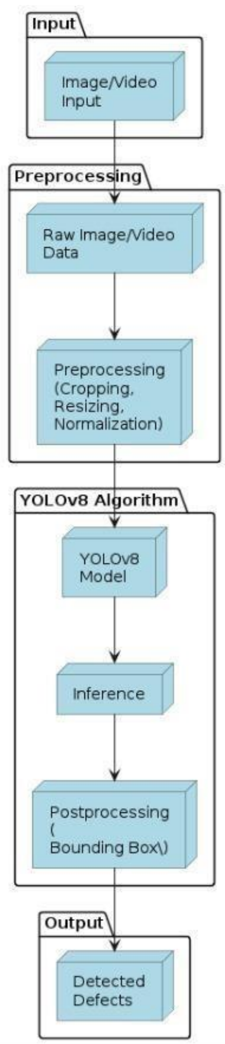


Figure 3.3.1: Block diagram for Tire Defect Detection.

3.4 MODULES

3.3.1 TRAINING DATASET:

Extracting the dataset along with the images and annotated labels and pre-training it in Roboflow. The pre-trained dataset is uploaded in the drive for training the model.

3.3.2 TRAINING YOLOv8 MODEL:

By using the predetermined package ‘Ultralytics’ to train the yolo models for object detection. Here, the light weight yolov8n.pt model is used and trained in google colab.

3.3.3 CONVERTING YOLO TO TENSOR FLOW LITE:

The trained yolo model is then converted to TFLite model for integrating it in the web/apps.

3.3.4 INTEGRATING THE TRAINED MODEL:

To integrate the trained model in, there is an ASP.NET in Visual Studio for integrating the Tensorflow model.

3.4 MERITS AND DEMERITS

3.4.1 MERITS:

1. **Improved Accuracy:** Research on tire defect detection using machine vision, deep learning, and transfer learning methods has shown significant improvements in accuracy compared to traditional manual inspection methods.

2. **Efficiency and Automation:** Implementing machine vision and deep learning technologies for tire defect detection allows for automatic and reliable inspection, reducing labor costs, and improving tire quality by eliminating the need for manual inspection, which can be subjective and time-consuming.

3. **Safety Enhancement:** Detecting tire defects accurately is crucial for ensuring driving safety, as even minor defects on tires can lead to major accidents. Advanced detection methods help in identifying defects that may not be easily visible to the human eye, thereby enhancing safety on the roads.

4. **Cost-Effectiveness:** By utilizing machine vision and deep learning technologies, tire manufacturers can reduce the number of returned tires due to defects, leading to cost savings and increased efficiency in the production process.

5. **Diverse Defect Detection:** Advanced methods can detect various types of tire defects, including cracks, bubbles, impurities, and bulges, providing a comprehensive solution for ensuring tire quality and safety

3.4.2 DEMERITS:

1. **Limitations in Detecting Diverse Defects:** While advanced technologies like deep learning show high accuracy in detecting specific tire defects like cracks, they may have limitations in identifying a wide range of defects such as air bubbles, foreign objects, and other complex issues.

2. **Dependency on Specific Data:** Tire defect detection systems based on deep learning often require extensive training datasets to ensure accurate detection. In industrial scenarios where certain defect types are rare, the effectiveness of these systems can be compromised due to insufficient training samples.
3. **Challenges in Anomaly Detection**: Anomaly detection methods, although useful for identifying outliers in defect-free samples, may face challenges in efficiently mining information from a large number of defect-free images and training models to accurately detect anomalies in tire defects.
4. **Complexity and Cost:** Implementing advanced tire defect detection systems, especially those based on deep learning and machine vision, can involve significant complexity in terms of setup, maintenance, and cost, which may pose challenges for some tire manufacturers or inspection facilities.

3.5 APPLICATIONS:

1. Automotive Industry: Tire defect detection systems are crucial in the automotive industry for ensuring the quality and safety of tires used in vehicles. By accurately identifying defects like cracks, bubbles, impurities, and bulges, these systems contribute to enhancing driving safety and reducing the risk of accidents.

2. Tire Manufacturing: In tire factories, tire defect detection technologies play a vital role in quality control processes. By automating the inspection of tire surfaces for defects, these systems improve efficiency, reduce labor costs, and enhance the overall quality of tires produced.

3. Driver Awareness: Implementing visual tire inspection systems can increase driver awareness about the importance of monitoring tire conditions regularly. By alerting drivers to potential defects like aging, oxidation, and cracking, these systems promote adherence to proper tire maintenance practices, ultimately reducing the risk of tire-related accidents.

4. Industrial Applications: Machine vision detection technology, including tire defect detection systems, is widely used in various industrial applications due to its non-contact nature, wide visual range, high reliability, and cost-effectiveness. These systems are instrumental in automating defect detection processes and improving overall product quality in industrial settings.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 PRECISION

The precision metrics in the provided plots evaluate the accuracy of object localization in a computer vision model trained for object detection using YOLOv8. They indicate how well the model identifies and delineates objects within images. The increasing trend observed in precision (B) and mAP metrics over training epochs suggests improved performance in object detection as training progresses, but further analysis considering factors like dataset quality and model architecture is necessary for a comprehensive assessment.

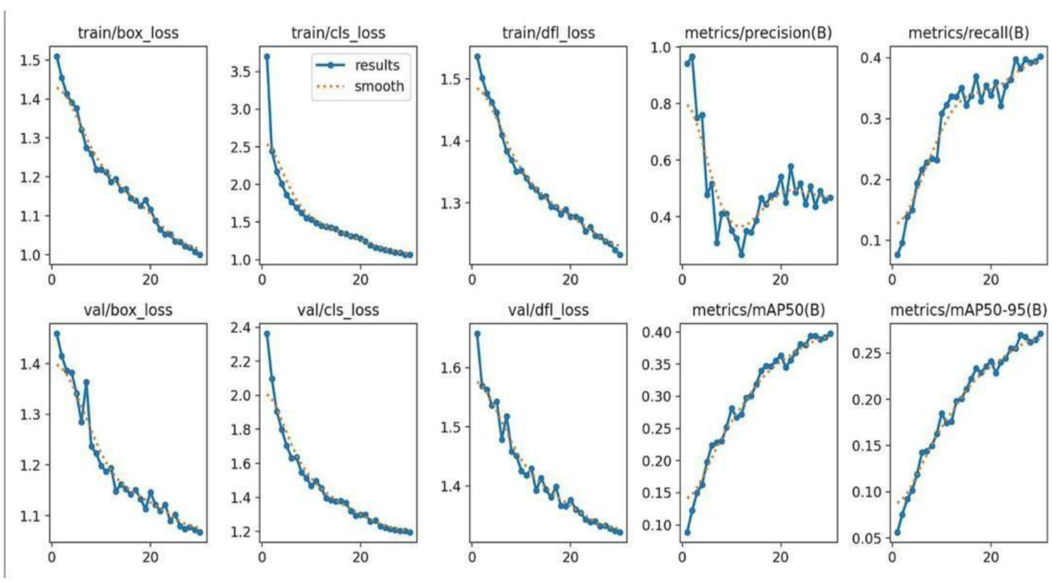


Figure 4.1.1: Precision graph of YOLOv8 model.

4.2 CONFUSION MATRIX:

The confusion matrix provides an overview of the classification model's performance in predicting various classes. Darker squares along the diagonal indicate accurate predictions, while lighter squares off the diagonal represent misclassifications. Analyzing the matrix helps identify which classes the model predicts well and where it struggles, guiding improvements in its performance.

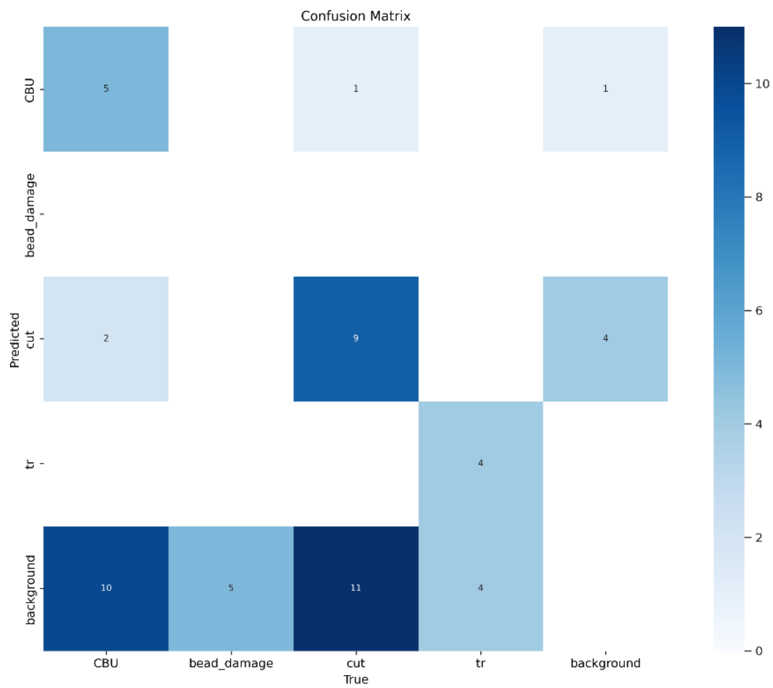


Figure 4.2.1 Confusion Matrix of YOLOv8 model.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION:

In conclusion, tire defect detection using the YOLOv8 algorithm offers a powerful solution for enhancing vehicle safety. YOLOv8 provides real-time detection with high accuracy and efficiency, making it ideal for quickly identifying various tire defects such as cuts, bulges, and wear patterns. Its versatility and ease of integration make it a practical choice for integration into existing systems or standalone applications. Overall, YOLOv8's capabilities make it a valuable tool for improving vehicle safety and preventing accidents caused by tire defects.

5.2 FUTURE SCOPES:

1. **Enhanced Sensor Technology:** Integration of advanced sensor technologies, such as 3D imaging and hyperspectral imaging, could provide more detailed information about tire conditions, leading to better defect detection.
2. **IoT and Connectivity:** Integration of tire defect detection systems with IoT devices and cloud computing could enable real-time monitoring of tire conditions and predictive maintenance, enhancing vehicle safety and efficiency.
3. **Autonomous Vehicles:** Tire defect detection will be crucial for the safe operation of autonomous vehicles, driving the need for more robust and reliable detection systems.
4. **Data-driven Insights:** Utilizing data analytics and artificial intelligence to analyze tire defect data could provide valuable insights for improving tire design,manufacturing processes, and overall vehicle safety.
5. **Augmented Reality (AR) and Virtual Reality (VR):** Integration of AR/VR technologies could enhance the visualization of tire defects, aiding in training and improving the efficiency of inspection processes.

APPENDICES

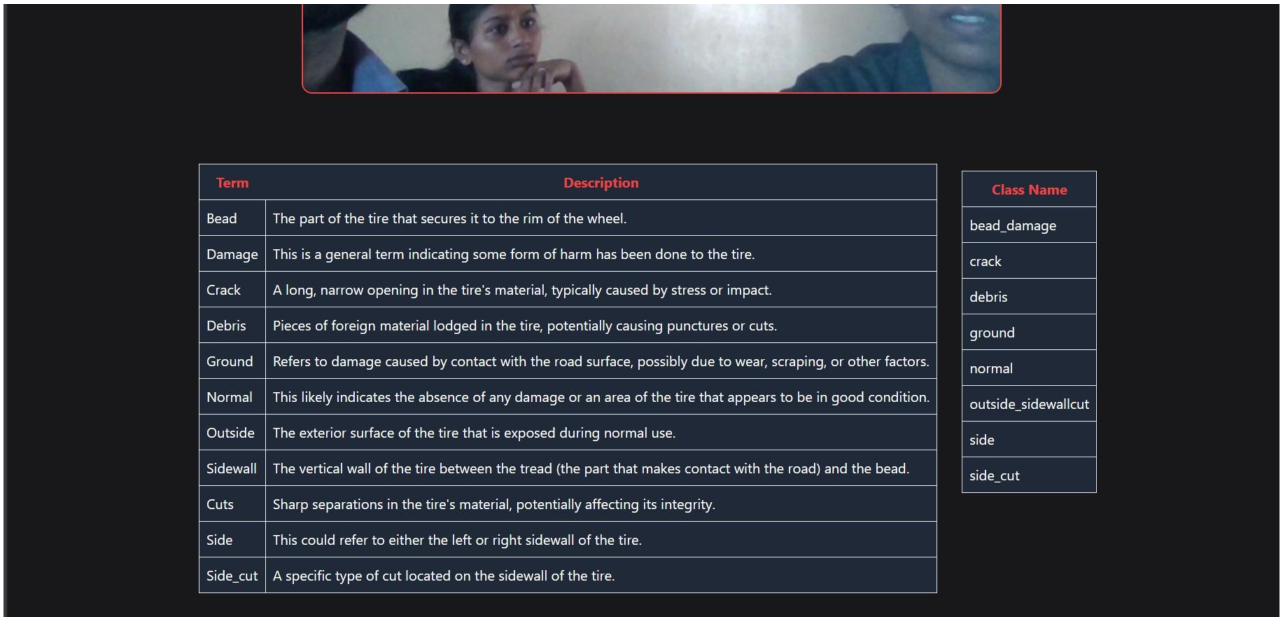
APPENDIX 1

SOFTWARE TOOLS

1. **Visual Studio:** This is the main software were this project is fully implemented. The Visual Studio which is an open-source software for developing web, applications. here, the web , user integration and model integration are done in Visual Studio.
2. **OpenAI API:** This API is free provided by OpenAI, were the chatbot is created and integrated in the Android Studio.
3. **YOLOv8:** The YOLOv8 (You Only Look at Once version 8) provided by Ultralytics which is used for detecting the ingredients and providing the bounding boxes while detection.
4. **Python:** The python which is a versatile programming language which is commonly used for machine learning and data science. Here the python programming language is used to train the YOLO model and used to convert it into TensorFlow model.
5. **Image Processing Libraries:** The image processing libraries for accessing the camera in the application by using the OpenCV libraries.

APPENDIX 2

OUTPUT



Term	Description
Bead	The part of the tire that secures it to the rim of the wheel.
Damage	This is a general term indicating some form of harm has been done to the tire.
Crack	A long, narrow opening in the tire's material, typically caused by stress or impact.
Debris	Pieces of foreign material lodged in the tire, potentially causing punctures or cuts.
Ground	Refers to damage caused by contact with the road surface, possibly due to wear, scraping, or other factors.
Normal	This likely indicates the absence of any damage or an area of the tire that appears to be in good condition.
Outside	The exterior surface of the tire that is exposed during normal use.
Sidewall	The vertical wall of the tire between the tread (the part that makes contact with the road) and the bead.
Cuts	Sharp separations in the tire's material, potentially affecting its integrity.
Side	This could refer to either the left or right sidewall of the tire.
Side_cut	A specific type of cut located on the sidewall of the tire.

Class Name
bead_damage
crack
debris
ground
normal
outside_sidewallcut
side
side_cut

Fig no:5.1 webcam shows the list of classes

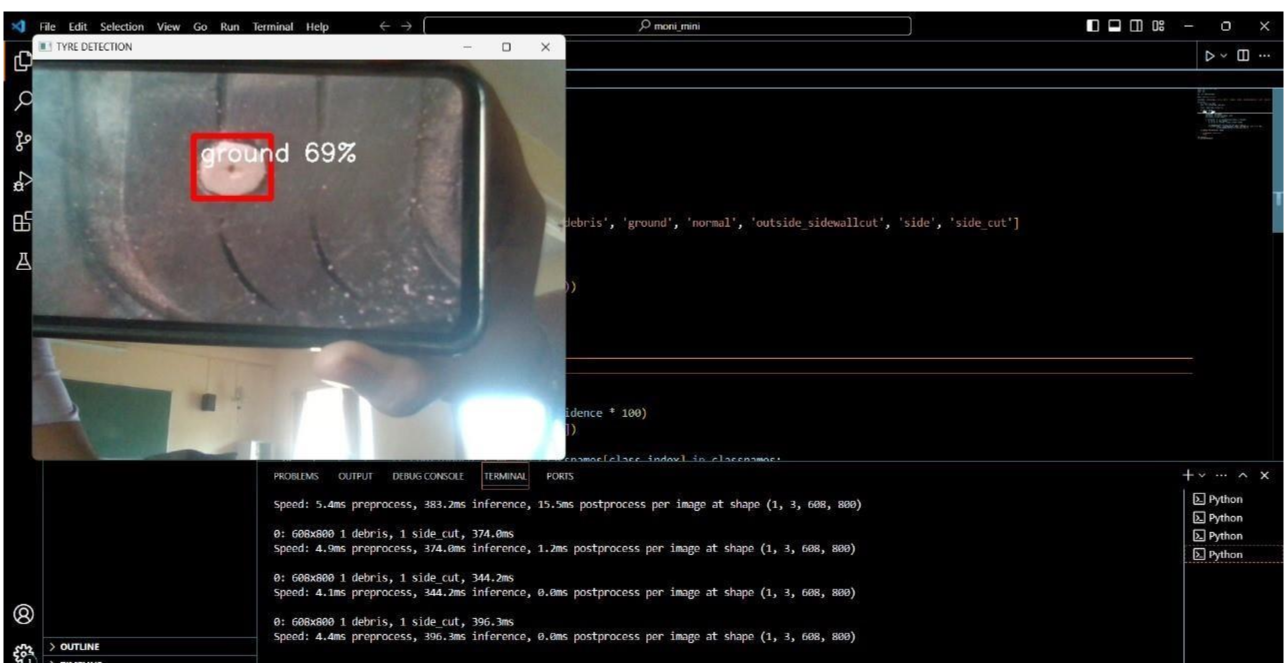


Fig no 2: Defect 1: Ground

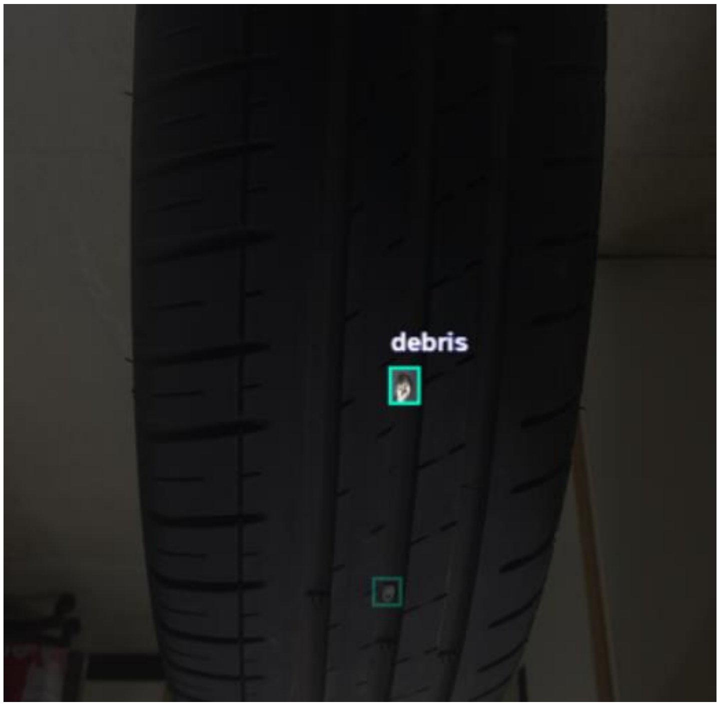


Fig no 3: Defect 2: Debris

Fig no 4: Defect 3: side cut

CHAPTER 6

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