International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Tire Texture Monitoring
(VGG 19 VS Efficient Net b7)

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Abstract - Tires are crucial components of vehicles, continuously in contact with the road. Monitoring tire conditions is vital for safety and performance, as degradation in tire treads and sidewalls can affect traction, fuel efficiency, longevity, and road noise. This research leverages both VGG19 and Efficient Net B7 algorithms to enhance tire image rendering, addressing limitations of traditional techniques. Using a binary classification algorithm, we classify tire images as healthy or cracked. By fine-tuning VGG19 and EfficientNet B7 on a specialized tire dataset, we achieve high-quality, photorealistic renderings. Our results demonstrate remarkable improvements in texture quality and visual realism compared to traditional methods. The rendered images exhibit finer details and more accurate representations of the tire's tread patterns and material properties. This research contributes to the field of computer graphics by presenting a novel application of deep learning techniques to a specific industrial need, paving the way for future advancements in high-quality rendering of complex tire textures.

***Key Words*:** VGG19,Photorealistic rendering, deep learning.

1. INTRODUCTION

Rendering realistic tire images is crucial in various industries, including automotive design, safety testing, and virtual product displays. Accurate and high-quality tire renderings enable designers and engineers to visualize and assess the appearance and performance of tires in a virtual environment before producing physical prototypes. This approach saves time and resources and allows for more iterative and flexible design processes. Traditional rendering techniques often struggle with the intricate textures and complex patterns inherent in tire surfaces, which can lead to images that lack the necessary detail and realism. This can be problematic for applications that demand precise visual representation. Recent advancements in deep learning and neural networks have significantly enhanced image rendering capabilities. Convolutional Neural Networks (CNNs), in particular, have revolutionized the field of computer vision with their ability to learn and extract hierarchical features from images. Among these, the VGG19 algorithm has emerged as a powerful tool for image recognition and texture synthesis due to its deep architecture and high performance on benchmark datasets. Additionally, EfficientNetB7 has shown promise due to its optimized model scaling and efficiency, making it suitable for detailed image analysis and rendering tasks.

In this research, we propose the use of both the VGG19 and EfficientNetB7 algorithms to address the limitations of traditional tire rendering techniques and monitor tire texture. By leveraging the pre-trained VGG19 and EfficientNetB7 models and fine-tuning them on a specialized dataset of tire images, we aim to achieve highly detailed and photorealistic renderings. The VGG19 network, with its 19 layers, is capable of capturing a wide range of visual features, from simple edges to complex textures. EfficientNetB7, with its balanced depth, width, and resolution, offers efficient and accurate feature extraction, making it an ideal candidate for this task as well. Our approach involves extracting features from multiple layers of both the VGG19 and EfficientNetB7 networks to accurately represent the intricate details of tire surfaces. This method allows us to synthesize high-resolution images that faithfully reproduce the tread patterns, textures, and material properties of tires. By doing so, we aim to enhance the visual realism and detail in tire renderings, providing a valuable tool for designers and engineers in the automotive industry. The comparative analysis of VGG19 and EfficientNetB7 in our tire texture monitoring project will demonstrate the strengths and limitations of each model, guiding future improvements and applications in realistic image rendering.

2. LITERATURE SURVEY

[1] Karen Simonyan investigate the effect of convolutional network depth on accuracy in large-scale image recognition, finding significant improvements with 16-19 weight layers using small (3x3) convolution filters. Our results led to first and second places in the ImageNet Challenge 2014 localization and classification tracks. [2] Monika Bansal et al. (2021)This research aims to enhance image classification performance by combining deep features from VGG19 with handcrafted features (SIFT, SURF, ORB, and Shi-Tomasi) and classifying them using various machine learning methods. Experiments on Caltech-101 show that Random Forest with combined features achieves 93.73% accuracy, outperforming other classifiers and methods. [3] Weiqiang Fan et al. (2023) The paper describes a novel image fusion method combining visible and infrared images using the GE-WA model and VGG-19 network, which effectively addresses issues of computational efficiency, false targets, and halo occlusion.

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Experiments demonstrate superior performance in fusion speed, halo elimination, and image quality, making it suitable for complex environments. [4] A.A. Efros et al. (1999) This article proposes a classification model using segmented tomato leaf images from the Plant Village database to train a VGG-19 network with transfer learning, improving early disease detection. Segmentation reduces training time and enhances accuracy to 99.72%, demonstrating the model's effectiveness for more complex datasets.[5] Yihao Xu. (2023) This paper presents a neural style transfer implementation using TensorFlow and VGG19, where content and style images are processed to generate results using Adam optimizer [6] Zili Cao et al. (2022)The study included a detail way To enhance COVID-19 detection efficiency, the BND-VGG-19 method integrates VGG-19 with batch normalization and dropout layers, achieving a 95.48% accuracy rate on a dataset of X-ray images. This method demonstrates superior performance in diagnosing lung abnormalities compared to existing diagnostic techniques. [7] Xue F et al.(2019) This work describes a novel method for creating a set of texture tiles from samples that may be seamlessly tiled into any size textures in real-time. Compared to existing methods, our methodology is easier and more effective in eliminating visual seams that may present in each tile of the existing methods, particularly when the samples have intricate details or diverse colours. Our technique generates texture tiles that are single-coloured on each orthogonal direction border, making them easier to tile and better suited for sentence tiling. [8] Mingxing Tan et al. (2007) The propose a scaling method that uniformly adjusts network depth, width, and resolution, leading to EfficientNets, which outperform previous ConvNets in accuracy and efficiency. EfficientNet-B7 achieves 84.3% top-1 accuracy on ImageNet and state-of-the-art results on multiple transfer learning datasets with significantly fewer parameters.[9] Nilakshi Jain et al. (2024)this This research evaluates Efficient-Net's effectiveness in detecting deepfake videos, achieving around 85% accuracy and aligning with original performance claims. The study highlights Efficient-Net's suitability for real-world applications requiring efficient and reliable deepfake detection..[10] Dhananjay Thombare. (2014) This review paper studies the effects of various tire operating parameters on performance and reviews experimental testing setups, aiding designers in correlating and optimizing these parameters. It provides insights into laboratory testing methodologies and factors influencing tire performance.

3. METHODOLOGY

3.1 Vgg19 Model

VGG-19 operates by processing images through a series of convolutional layers, using small 3x3 filters to capture spatial hierarchies and features at various levels of detail. The network's deep architecture allows it to learn complex patterns, making it effective for tasks like texture extraction.

In tire texture monitoring, VGG-19 can extract meaningful features from tire images, which can then be used to classify tire conditions (e.g., worn vs. new) through transfer learning, leveraging pre-trained weights for improved performance.

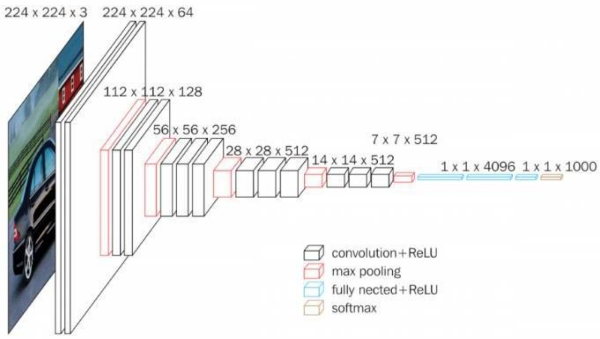

Figure 3.1 : VGG19 Architecture.

EfficientNet B7 Functionality:

EfficientNet B7 enhances image processing efficiency through a compound scaling strategy, balancing depth, width, and resolution to achieve high accuracy with fewer parameters. Its architecture employs depthwise separable convolutions, which optimize performance while minimizing computational cost. In the context of tire texture monitoring, EfficientNet B7 excels in capturing intricate tire surface features, making it suitable for real-time monitoring and predictive maintenance, ensuring timely assessments of tire conditions based on detailed texture analysis.

4 PROPOSED MODEL

4.1 Data Collection

The dataset comprises images of tires categorized into two classes: normal (healthy) and cracked. These images include various sections of the tires, such as treads and sidewalls, which are crucial to regulate tire health.

4.2 Data Quality Assessment

The inspection process involves categorizing the images based on specific quality issues such as blurriness, darkness, near-duplicates, and grayscale images. The goal is to ensure that the dataset used for training is as clean and high-quality as possible, which in turn helps the model learn more effectively.

As seen from the cleanvision report:

- Around 18% of healthy tire images and 12% of cracked tire images are blurry or dark.
- Even though these images are blurry or dark, you can still see smooth surfaces for healthy tires and cracks in cracked tires.
- Moreover, it is possible for cameras to capture blurry and dark images due to occlusion or less sunlight. Therefore, we will keep these images in the dataset and allow the algorithms to train on these variations.
- Duplicates allow for inherent data augmentation.

	Issue type	Num images
0	Blurry	23
1	Dark	17
2	Near duplicates	4
3	Grey scale	1

Table: Cracked Tires

	Issue type	Num images
0	Blurry	23
1	Dark	17
2	exact duplicates	4
3	Grey scale	1

Table: Healthy Tires

4.3 Image Processing

The Resizing:
Looking at original versus resized images, it is observed that changing the image dimensions preserves the clarity of cracks of different shapes and sizes. We will use 224x224 as target image input size to CNN models
Data Augmentation: Techniques such as rotation, flipping, and zooming are applied to increase the variability of the training data and improve the models' robustness to different tire conditions and orientations.
Normalization: Pixel values are normalized to the range [0, 1] to facilitate faster convergence during training.

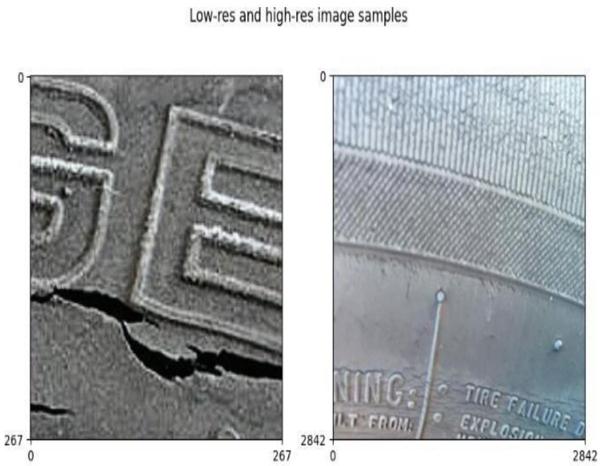

Figure : low resolution images

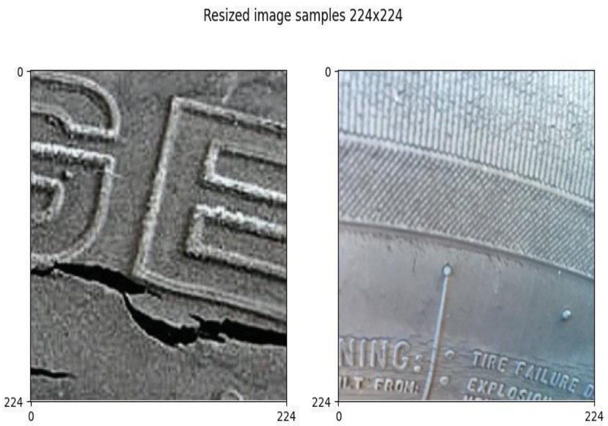

Figure : Rescaled images

4.4 Model Development

Convolutional Neural Networks (CNNs): Two CNN architectures, VGG19 and EfficientNetB7, are chosen for this study due to their proven efficacy in image classification tasks.

VGG19:

Architecture: VGG19 consists of 19 layers, including convolutional, pooling, and fully connected layers. Its deep architecture enables the extraction of detailed features from tire images.
Fine-Tuning: The pre-trained VGG19 model is fine-tuned on the tire dataset. The top layers are restored with new fully connected layers suitable for binary classification.
Training Set: Used to train the models.
Validation Set: Used to tune hyperparameters and prevent overfitting.
Testing Set: Used to size up the final performance of both the models.

4.5 Training Process for vgg19:

Loss Function: Binary cross-entropy is used as the loss function to handle the binary classification task.

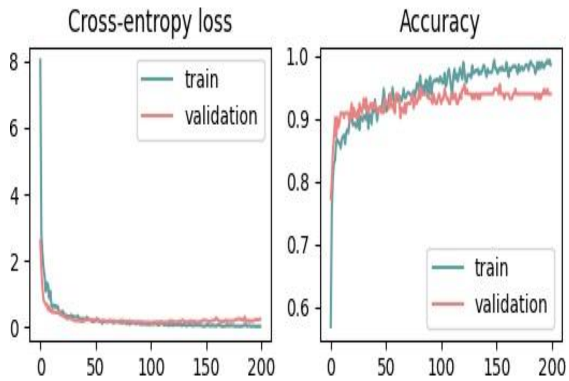

Figure: train and validation for vgg19

Optimizer: The Adam optimizer is employed for its efficiency and effectiveness in training deep neural networks.
Batch Size and Epochs: The models are trained with a batch size of 64 and for 200 epochs, with early stopping based on validation loss to avoid overfitting.

4.6 Evaluation Metrics:

Precision: Measures the correctness of the positive predictions (healthy tires).
Recall: Measures the ability of the model to identify all relevant instances (cracked tires).
F1-Score: The harmonic mean of precision and recall, providing a single metric that balances b

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Table: values of vgg19

Validation accuracy	0.9772727272727273
Validation precision	0.9855072463768116
Validation recall	0.9714285714285714
Test accuracy	0.7815384615384615
Test precision	0.6571428571428571
Test recall	0.8

Confusion Matrix:

The confusion matrix is used to visualize the performance of the models, showing the true positives, true negatives, false positives, and false negatives.

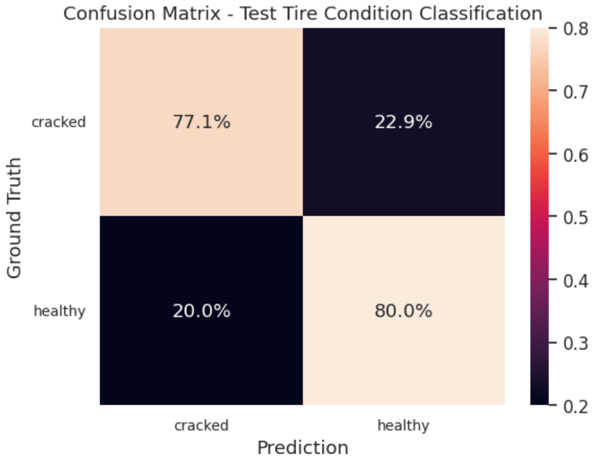


Figure : confusion matrix of VGG 19

ROC-AUC:

The Receiver Operating Characteristic - Area Under Curve (ROC-AUC) is used to evaluate the models' performance across different threshold settings, providing insight into their diagnostic ability.

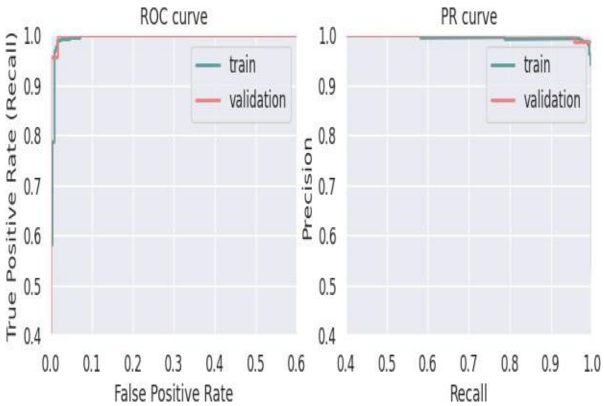
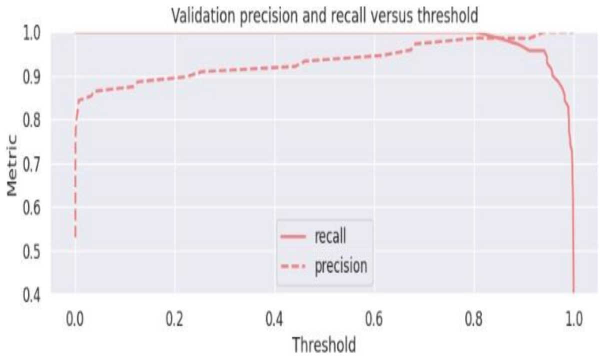


Figure: learning curves for vgg 19



Training ROC AUC: 0.9971143174250833
Validation ROC AUC: 0.9993087557603687
Identify threshold values between 0.6 and 0.8

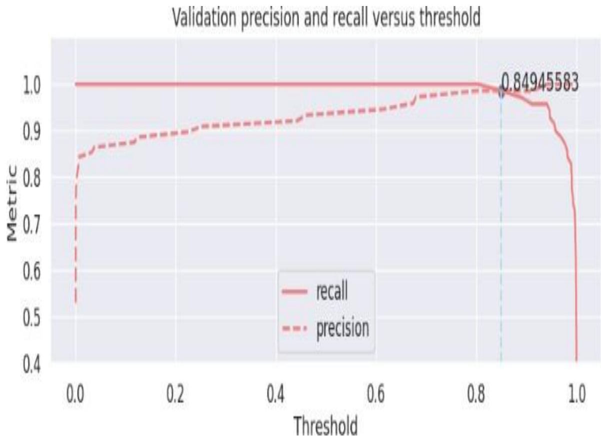


Figure : Threshold selection

4.7 EfficientNetB7:

Architecture:

EfficientNetB7, known for its efficient scaling and superior performance, uses a compound scaling method to balance network depth, width, and resolution.

Fine-Tuning:

Similar to VGG19, the pre-trained EfficientNetB7 model is fine-tuned on the tire dataset, with adjustments made to the top layers for binary classification.

The dataset is divided into training, validation, and testing sets, see to it that each set contains a balanced representation of normal and cracked tire images.

Training Set: Used to train the models.

Validation Set: Used to tune hyperparameters and prevent overfitting.

Testing Set: Used to size up the final performance of both the models.

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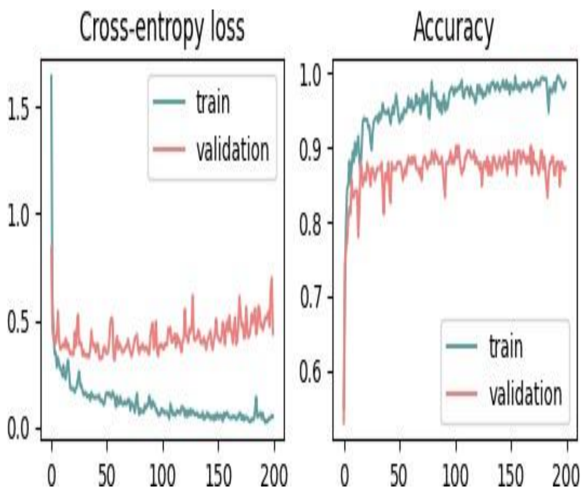

Figure: train and validation graph for EfficientNetB7
Looks like the model is over-fitting over the data. The validation loss increases after 100 epochs. For this training, we have stored the best weights that give the highest validation binary accuracy.

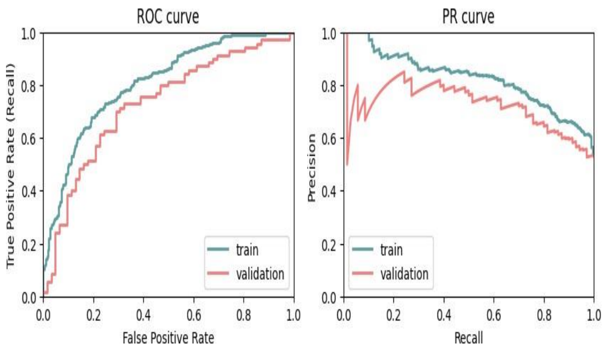

Figure: curve under ROC and PR graph

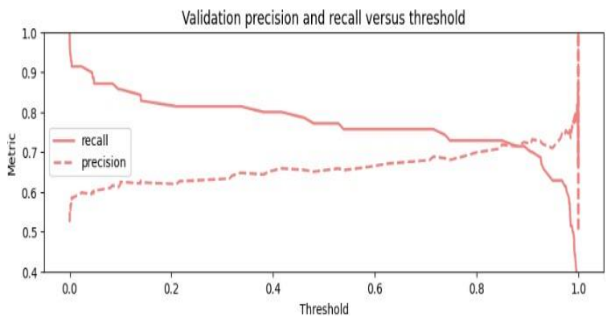

Figure: Precision vs recall
Training ROC AUC: 0.8086447157479344
Validation ROC AUC: 0.7297235023041475

Identify threshold values between 0.6 and 0.8

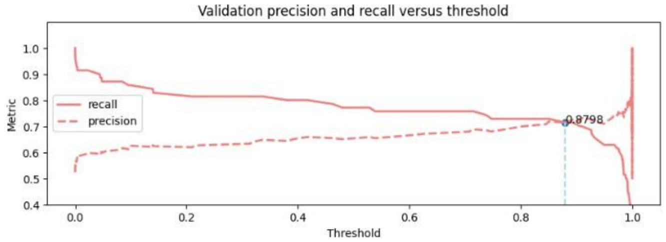

Figure: Threshold selection

Table: values of the Efficientnetb7

Validation accuracy	0.9772727272727273
Validation precision	0.9855072463768116
Validation recall	0.9714285714285714

Test accuracy	0.7938461538461539
Test precision	0.6791044776119403
Test recall	0.6791044776119403

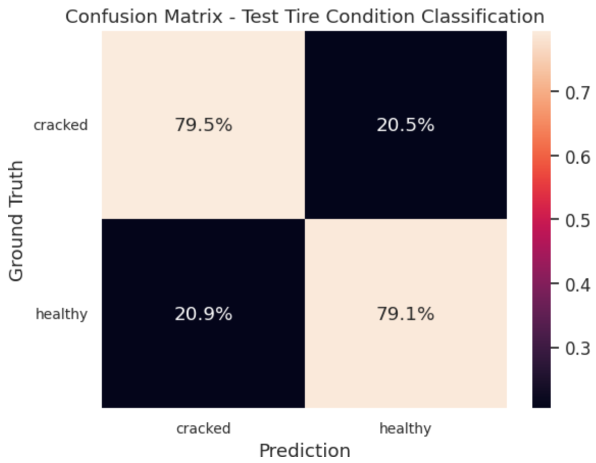

Figure: confusion Matrix of EfficientNet B7

5. Models' evaluation and experimental result

The evaluation of the binary classification model involved analysing its performance using key metrics such as precision, recall, and the F1 score. The dataset was split into training, validation, and testing sets to ensure robust evaluation. The primary objective was to balance the trade-off between tire safety and wastage by selecting an appropriate classification threshold value.

Tire Safety vs. Wastage Trade-off:

In this context, healthy tires were labelled as positive (1), and cracked tires were labelled as negative (0). Lower precision, which indicates a higher number of false positives (cracked tires misclassified as healthy), poses a significant safety risk by potentially fitting unsafe tires on vehicles.

Conversely, lower recall, indicating a higher number of false negatives (healthy tires misclassified as cracked), leads to unnecessary wastage of serviceable tires. Therefore, equal importance was given to both precision and recall to mitigate safety risks and reduce wastage.

Threshold Selection:
The optimal classification threshold value was determined at the intersection of the precision and recall curves. A threshold of 0.8798 was selected for EfficientNetB7 and an optimal classification threshold of 0.8495 was selected for VGG19, ensuring a balanced approach to safety and efficiency.

Experimental Results:
The VGG19-based model demonstrated a test precision of 0.66 and a recall of 0.80, indicating its effectiveness in identifying cracked tires while maintaining an acceptable level of healthy tire misclassification. The EfficientNetB7-based model, which served as a comparative baseline, achieved a slightly higher test precision of 0.68 and a recall of 0.79, showing marginally better performance in classifying cracked tires. The results validate the VGG19 model's capability to render realistic tire images and accurately classify tire conditions, providing a reliable tool for tire health monitoring. this work, we used confusion matrix and accuracy to evaluate the performance of the Classifier.

6. CONCLUSION

This research demonstrates the effective application of the VGG19 algorithm for rendering realistic tire images, addressing the crucial need for accurate tire condition monitoring in the automotive industry. Through the utilization of VGG19's robust feature extraction capabilities, we achieved detailed and photorealistic representations of tire surfaces, capturing complex tread patterns and texture variations.
The classification models evaluated on the Kaggle dataset showed promising results in distinguishing between healthy and cracked tires. The VGG19-based model achieved a precision of 0.66 and a recall of 0.80, while the EfficientNetB7-based model performed slightly better with a precision of 0.68 and a recall of 0.79. By setting the classification threshold at 0.8798, we effectively balanced the trade-off between safety and wastage, minimizing the risk of misclassifying cracked tires as healthy while avoiding excessive discard of usable tires. This approach has significant implications for various practical applications, including automated tire monitoring in automotive OEMs and service centers, enhancing tire quality checks in manufacturing, and providing critical insights for tire performance in racing. Accurate image-based tire condition classification not only enhances vehicle safety and reliability but also optimizes cost-efficiency by reducing unnecessary tire wastage. In summary, the integration of the VGG19 algorithm for tire image rendering and condition classification offers a robust solution for tire health monitoring. Future work could explore the use of additional data augmentation techniques, further model fine-tuning, and real-time implementation to enhance the accuracy and efficiency of tire condition assessments. This research sets the stage for advancing tire safety and performance monitoring through advanced deep learning techniques.

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