iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68862

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Wild Fire Detection Using Deep Learning

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Abstract: ***Forest fires are a caused by many factors like dry rainfall conditions, climate change, high temperatures, lightning strikes. Forest Wildfire are major problem that causes harm to people, the environment, and the economy. To reduce the damage, its essential to detect wildfires early. Traditional methods like CNN and SVM have been used, but they have limitations such as low accuracy and requiring large amounts of data. To overcome these challenges, this project proposes using a deep learning approach called Reduced VGGNet for Wildfire Classification, which can automatically extract features from images and improve detection accuracy. The project aims to design a system that can detect wildfires and wildfire regions efficiently and effectively. The Vibe algorithm is used and bounding boxes are generated to detect the Wildfire region. Our proposed solution aims to provide a more efficient, scalable and cost-effective approach to addressing the problem. Our goal is to provide a reliable and efficient solution that can make a meaningful impact in addressing the problem and we're confident that our proposed framework can achieve this.***

Keywords: Forest fires, classification, detection, VGGNet, Reduced VGGNet, Vibe Algorithm, Environmental Management, Disaster Management, Image Processing.

I. INTRODUCTION

Wildfires are the big problem around the world. They hurt the environment, the economy and people's lives. To stop wildfires from getting worse, we need to find them early and know exactly where they are. There are some old ways to find wildfires using pictures like looking for edges or colors. But these ways aren't very good. They can't find wildfires very accurately, and they get confused by complicated scenes. They also send out false alarm and are slow. We have new technology called deep learning that can help us find wildfires better.

Deep learning is a way for computers to learn from pictures and get better at finding what they're looking for. We want to use deep learning to make a system that can find wildfires quickly and accurately. Our goal is to create a that can look at pictures says "Yes, that's a wildfire" or "No, that's not a wildfire". We want this system to be fast, accurate and reliable. So, it can help people prevent wildfires from spreading and keep everyone safe. By using deep learning, we can make a big difference and help solve this important problem.

The main objective of this project is to develop an automated wildfire detection system using deep learning techniques. It aims to accurately identify fire incidents in real-time while minimizing false alarms caused by similar visual patterns. The system is designed to improve response time, enabling authorities to take action and prevent large-scale disasters. By reducing reliance on manual surveillance it enhances detection efficiency, especially in remote forest areas where traditional methods are less effective.

The project focuses on optimizing computational performance for faster processing, making it suitable for real-time applications. Utilizing Reduced VGG16 model, it ensures better feature extraction and classification of wildfire images. The proposed solution will assist emergency services in wildfire monitoring and prevention, helping to safeguard lives, property and natural ecosystems. Through early fire detection, this project haves contributes to environmental conservation and disaster management efforts.

The main contributions about this paper can be summarized as follows:

(1) We propose a wildfire image classification algorithm based on Reduce-VGG16, which can reduce the training parameters of VGG16 and achieve 98.42% in accuracy.

(2) We propose a wildfire region detection using Vibe algorithm and detecting regions using bounding boxes, calculating fire percentage and send SMS Alert.

The experimental results on FLAME VISION dataset show the effectiveness of our method.

The rest of our paper is structured as follows. In Section II, we provided the literature review. The implementation methodology is presented in Section III. The results are presented in Section IV. Finally, the conclusion is provided in Section V.

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II. LITERATURE REVIEW

[1] "Forest fire prediction using ML and AI," explores the application of Machine Learning and Artificial Intelligence techniques to predict forest fires based on environmental data. They utilize a structured data like temperature, humidity, wind speed, historical fire records for prediction of forest fire.They used ML algorithms such as Logistic Regression, Decision Trees, Support Vector Machine, Random Forests, KNN.

[2] The Paper titled "Deep Learning Approaches for Early Detection of Forest Fires," used CNN based models such as VGGNet, ResNet, MobileNet for fire classification and detection, The U-Net and DeepLab models are used for pixel level fire detection.They utilized the videos dataset for the classification and detection of the wildfire.

[3] The paper titled "A Deep Learning-Based Experiment on Forest Wildfire Detection in Machine Vision" Course suggests that the paper explores the application of deep learning techniques for detecting forest wildfires using machine vision method. Recent advancements in deep learning have significantly improved the accuracy and efficiency of forest wildfire detection using machine vision techniques. Traditional methods of wildfire detection relied on satellite imaging and sensor networks, which, while effective, often suffered from delays and environmental constraints. Furthermore, research highlights the importance of training models on diverse datasets to improve their robustness against environmental variations, such as smoke, lighting conditions, and weather changes. Despite these advancements, challenges remain, including false alarms, computational costs, and the need for extensive labeled datasets. Continued research in this domain focuses on optimizing deep learning architectures and integrating multi-sensor data fusion to enhance the accuracy and reliability of wildfire detection systems.

III. IMPLEMENTATION METHODOLOGY

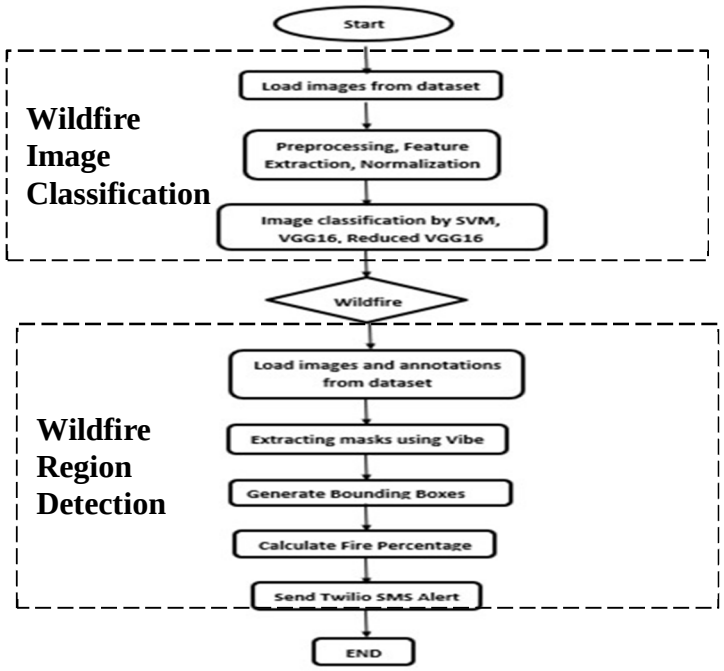


Fig. 1: Flowchart of Forest Wildfire Detection

A. Wildfire Image Classification

1) Dataset Collection: The 'Flame Vision' Dataset is collected from Mendeley Website. There were 2350 images total. The collected dataset has classification module where each has Train, Valid and Test sets and Detection module has Fire images and its Annotations.

2) Data Pre-processing: The images that are collected might be different dimensions and has to be preprocessed to get the required dimensions of 224 by 224 by 3. Thereafter we extract the shape, texture and color features of the images and normalizes them

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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Then we input those images to SVM, Full-VGGNet and Reduced-VGGNet and compare there performances.

a) SVM (Support Vector Machine)

SVM is mainly designed to classify data by using best hyperplane between them to separate different classes. The data points closest to this hyperplane (also known as support vectors) plays main role in defining the boundary. For linearly separable data, SVM uses a straight line, whereas non-linearly separable, it uses kernel trick (such as RBF, sigmoid kernels) to transform data into high dimensional space where it becomes linearly separable. The figure 2 shows the SVM architecture.

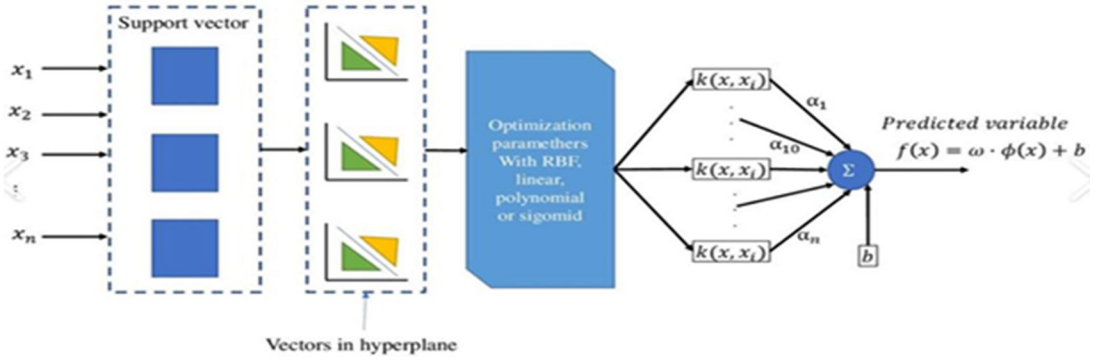


Fig. 2 SVM Architecture

b) Full VGG16(Visual Geometry Group)

VGG16 is used for classification of the data. The model takes 224×224 RGB images as input. The pixels values are normalized by rescaling. The pre-trained VGG16 model (with ImageNet Weights) is loaded by removing the fully connected layers are removed, and a custom classifier is added. It consists of small 3×3 convolution filters, increasing depth from 64 to 512 filters, followed by ReLU activations and max pooling. The final output is flattened and passed through fully connected layers. The figure 2 shows the Full VGG16 architecture.

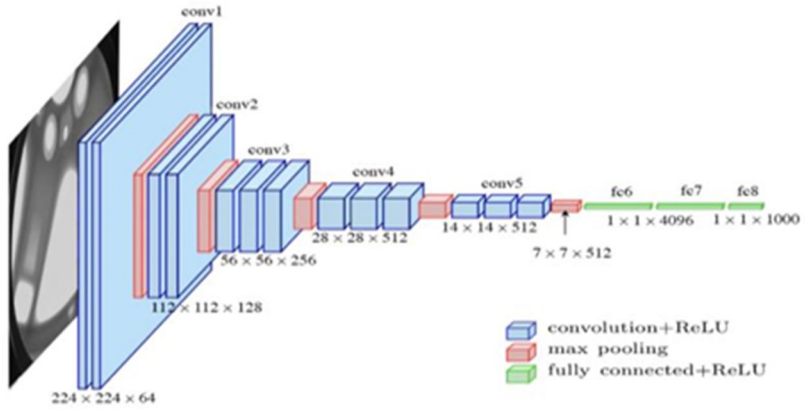


Fig. 3 Full VGG16 Architecture

c) Reduced VGG16

Reduced VGG16 model is a binary Classification model based VGG16 with transfer learning It utilizes VGG16 as a feature extractor, where first 10 layers are frozen to retain pre-trained ImageNet weights. This model replaces with 2 dense layers (256 and 128 neurons) with L2 regularization and dropout, followed by a single neuron with sigmoid activation function for binary Classification. The model is trained for 5 epochs with a batch size of 16 to classify images into fire and no-fire categories. The figure 4 shows the Reduced VGG16 architecture.

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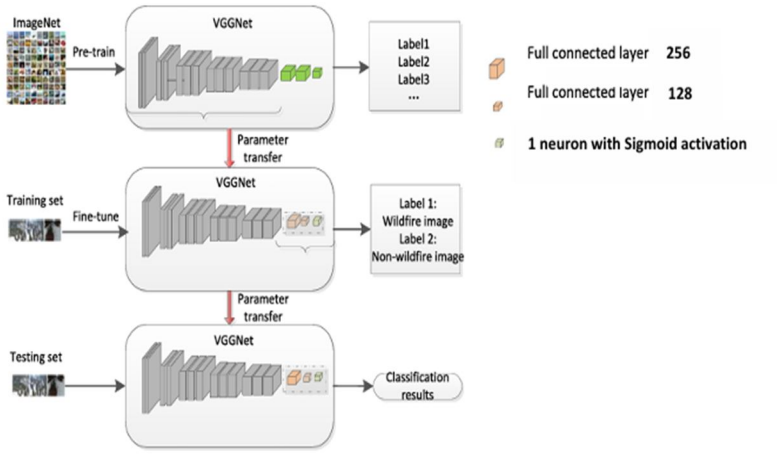


Fig. 4 Reduced VGG16 Architecture

B. Wildfire Region Detection

Finally, the wildfire region detection module requires further annotating the fire regions on the wildfire images, uses vibe algorithm to extract masks from the image and draws bounding boxes around the fire region indicating fire. Thereafter the fire percentage is calculated and then the SMS alert is sent with the image link and the fire percentage. The model's main goal is to classify the Wildfire images and Non-Wildfire images, then detecting the region of wildfire and transmit a message indicating that wildfire is detected.

IV. RESULTS

On the collected dataset, for the Classification module, the models were trained, the validated and tested. For the Detection Module, the masks were generated, bounding boxes are drawn annotations, fire region coordinates are extracted and SMS Alert is sent through Twilio API.

A. Results of Wildfire Classification

Classification of Wildfire and Non-Wildfire Images:

The model is trained to perform the necessary classification of Wildfire and Non-Wildfire. The model is trained using the collected dataset. The dataset contains both Wildfire and Non-Wildfires. The dataset itself consists of 6400 images and its pre-split into a training ser, validating set and a testing set. The collected dataset was split in the ratio 3:1:1. In the dataset collected, the forest images that are labelled as wildfire has the fire in it. Whereas the forest images that are labelled as non-wildfire doesn't have the fire feature. For testing the model that is trained, the different images of both classes are given to the model after completing training. The model is accurate and classified the images correctly. The figure 5 is a real forest image and is also classified as Wildfire by the model. It has been classified as Wildfire because there is a fire on the image.



Fig. 5 Wildfire Images

Similarly, the figure 6 is a real forest image and is also classified as non-wildfire by the model. It has been classified as non-wildfire because there is no fire on the image.

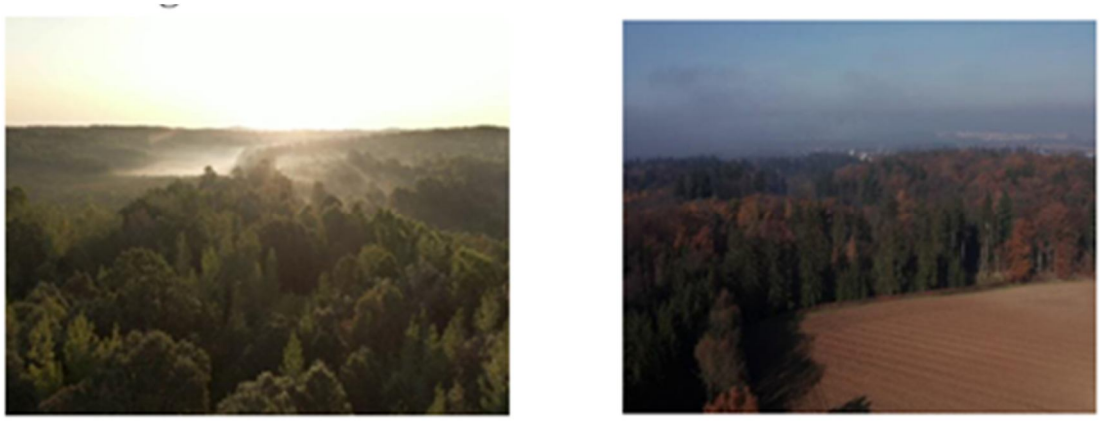


Fig. 6 Non-Wildfire Image

1) Results of SVM

The accuracy rate for SVM for classification of wildfire images is 65.3%. The precision is 60.2%, Recall is 1.00% and the F1-Score is 75.1%. The figure 7 shows Precision-Recall Curve and Confusion Matrix of SVM.

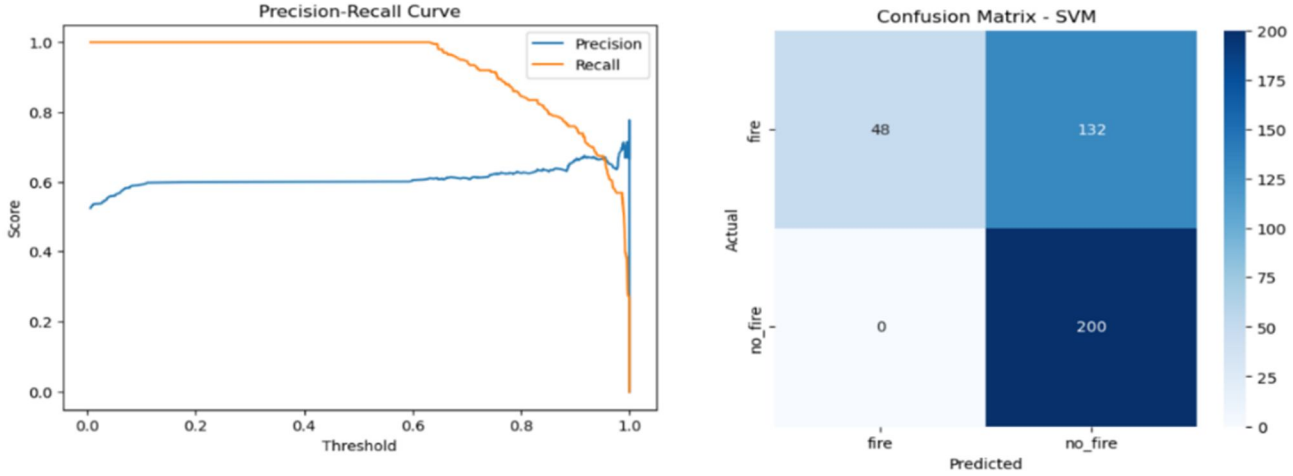
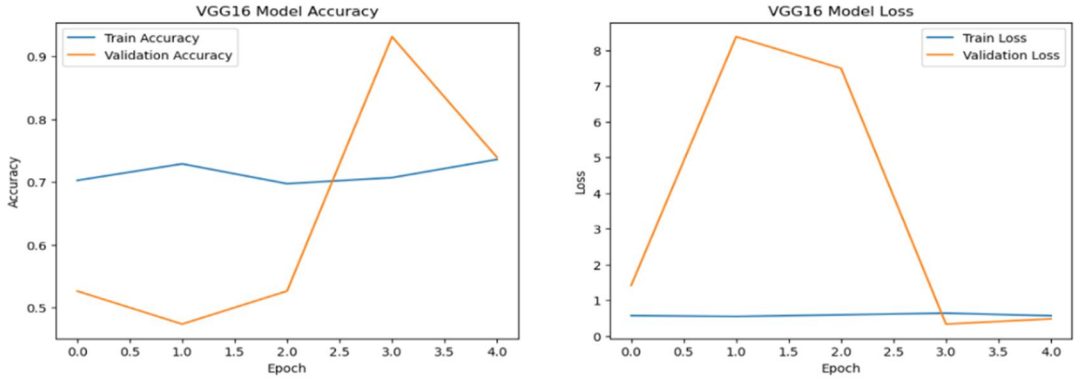


Fig. 7: Precision-Recall Curve and Confusion Matrix of SVM

2) Results of Full VGG16

The accuracy rate for Full-VGG16 for classification of wildfire images is 74.4%%. The precision is 75.5%, Recall is 92.5% and the F1-Score is 83.1%. The Figure 8 shows Training and validation Accuracy and Loss curves and Confusion Matrix of Full VGG16.



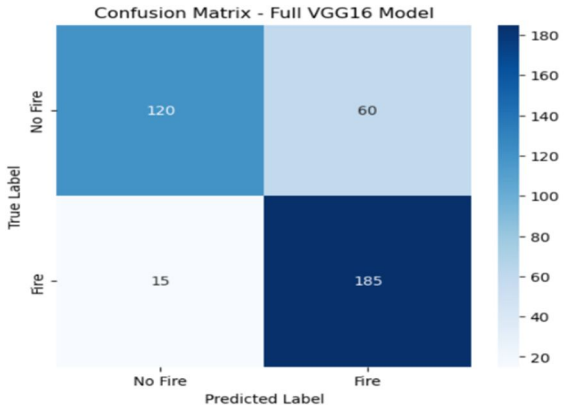


Fig. 8 Training and validation Accuracy and Loss curves and Confusion Matrix of Full VGG16

3) Results of Reduced-VGG16

The accuracy rates for reduced-VGG16 for classification of wildfire images is 98.42%. The precision is 96.66, Recall is 1.00% and the F1-Score is 98.2%.

Figure9 shows the experimental results of Reduce-VGG16. The epochs are set to 5 and batch size is 16, the test set reaches 98.42%. It can be seen that the experimental result of this method is superior to that of SVM algorithm and Full VGG16 model. Figure 10 shows the confusion matrix of the reduced-VGG16.

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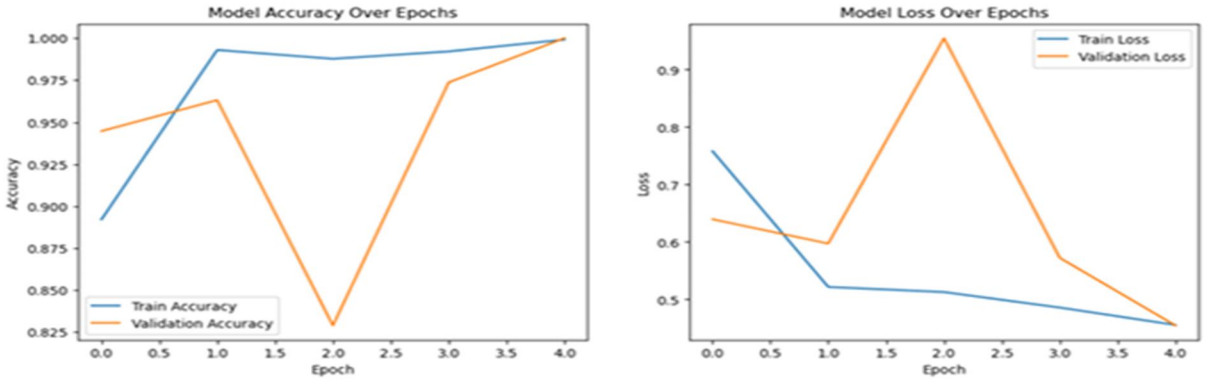


Fig. 9 The Training, Validation- Accuracy and Loss Curve of Reduced-VGG16

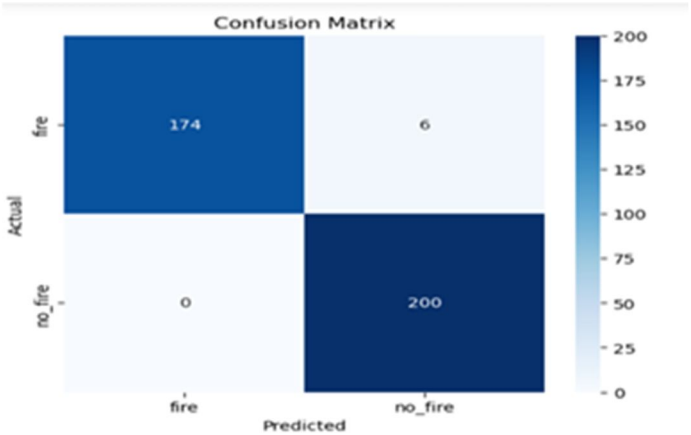


Fig. 10 The Confusion Matrix of Reduced-VGG16

4) Calculation of Metrics

The Wildfire Classification is evaluated using the metrics like Accuracy, Precision, Recall and F1-Score.

Accuracy: Percentage of correct predictions out of total predictions.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN}$$

Precision: When the model predicts positive, how often is it correct?

$$\text{Precision} = \frac{TP}{TP+FP}$$

Recall: Out of all actual positives, how many did the model catch?

$$\text{Recall} = \frac{TP}{TP+FN}$$

F1-Score: A balance between Precision and Recall.

$$\text{F1-Score} = \frac{2.*Precision*rRecall}{Precision+Recall}$$

Where, TP = True Positives, TN = True Negatives, FP = False Positive, FN = False Negatives.

We compare the performances of three models(Support Vector Machine, Full Visual Geometry Group, Reduced Visual Geometry Group) using these metrics.

The table 1 shows the comparative analysis of Accuracy, Precision, Recall, F1-Score using different models SVM, Full-VGG16, Reduced VGG16 for wildfire classification.

Model	Accuracy	Precision	Recall	F1-Score
SVM	65.3%	60.2%	100%	75.1%
Full VGG16	74.4%	75.5%	92.5%	83.1%
Reduced-VGG16	98.4%	96.6%	100%	98.2%

TABLE. 1 Comparative Analysis Of Wildfire Classification

B. Wildfire Region Detection

1) Mask Extraction

The masks are generated using Vibe algorithm. The output of Vibe is a binary fire mask, where white pixels represent fire regions and black pixels represent non-fire regions. This fire mask can then be used for further processing, such as drawing bounding boxes around fire regions or sending. The Figure 11shows Wildfire Image and Mask extracted using Vibe Algorithm.



Fig. 11 Wildfire Image and Mask extracted using Vibe Algorithm

2) .Generating Bounding Boxes

Later, region is extracted from the Annotations collected from dataset and the wildfire region detection is displayed by drawing bounding boxes with the help of annotations. The Figure 12 shows Region detected by drawing bounding with the help of annotations.



Fig. 12 Region detected by drawing bounding with the help of annotations

3) Fire Percentage Calculation

The total number of pixels in the image and nonzero(fire) pixels in the mask are calculated. By dividing fire pixels by total pixels, the fire percentage is determined, which helps assess the severity of fire in image. The Figure 13 shows the Wildfire image with bounding boxes, total pixels, fire pixels and fire percentages.

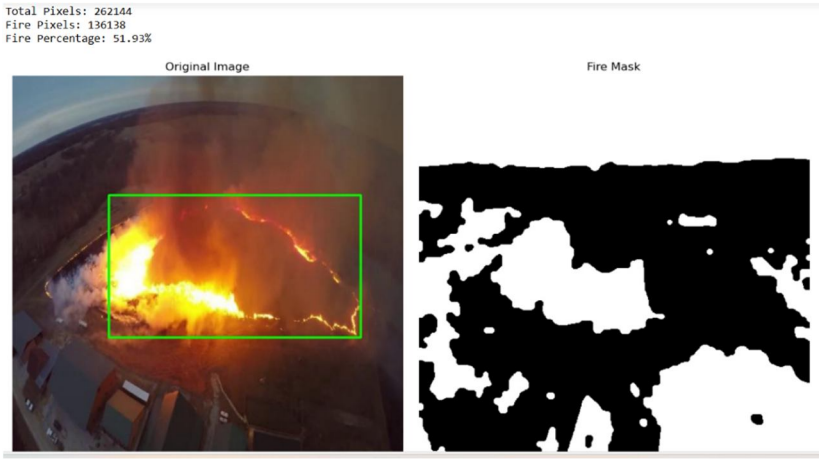


Fig.13 The Wildfire image with bounding boxes, total pixels, fire pixels and fire percentages

Calculations:

$$Total\ Pixels = Width \times Height$$

$$Total\ Pixels = 512 \times 512 = 262{,}144 \text{ pixels}$$

Total Pixels = 262,144

Fire Pixels = 136138

Fire Percentage= (262144/1848) × 100 = 51.93%

4) SMS Alert

The wildfire region coordinates are extracted from the annotations and bounding boxes. When the wildfire region is detected, an SMS Alert is sent through Twilio API, message displaying “Wildfire detected! Fire covers 51.93% of the image. Immediate action required! Check the fire location in the image.” With the image link. The figure 14 shows the SMS alert.

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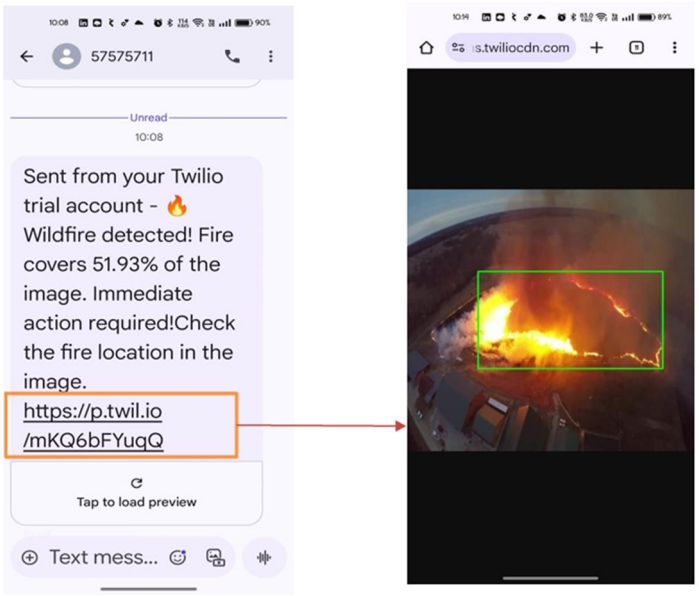


Fig. 14 SMS Alert

V. CONCLUSION

The wildfire detection system developed in this study successfully classifies wildfire and non-wildfire images and detects fire regions using advanced machine learning and computer vision techniques. The classification module, trained using a dataset of 1900 images, demonstrated high accuracy, with the Reduced-VGG16 model achieving 98.42% accuracy, significantly outperforming SVM and

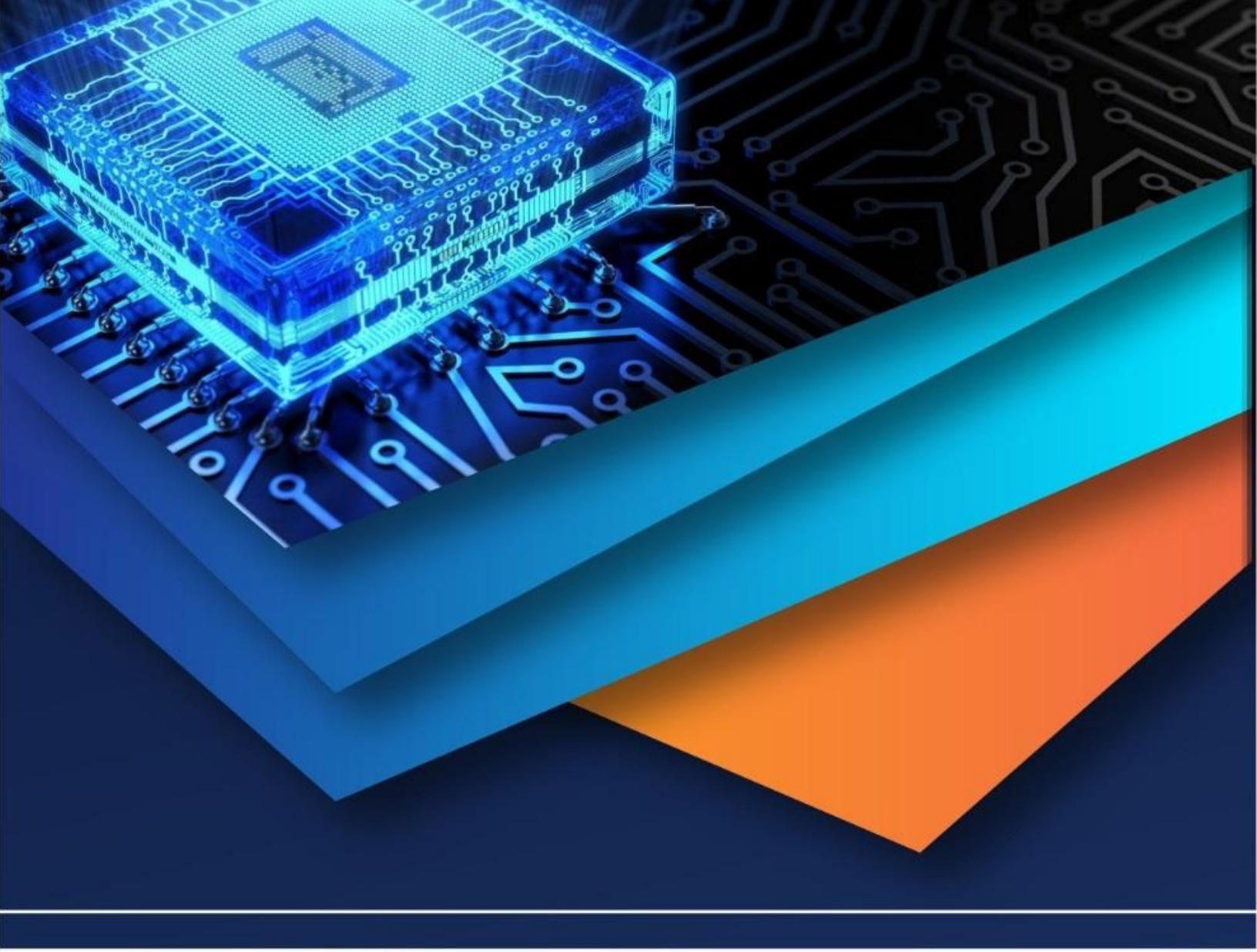
Full-VGG16 models. The wildfire region detection module employed the Vibe algorithm to extract fire masks and detect fire regions, further validated using annotations. The

system efficiently draws bounding boxes, extracts fire coordinates, and integrates Twilio API for real-time alerts.

The comparative analysis of different models highlighted that deep learning-based approaches, particularly the Reduced-VGG16 model, provide significantly better classification accuracy, precision, and recall compared to traditional machine learning models like SVM. The integration of fire percentage calculation allows for fire severity assessment, making the system more informative and useful for real-world applications. Overall, the proposed approach provides an accurate, efficient, and real-time wildfire detection system, capable of sending timely alerts for wildfire management and mitigation.

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