International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 8 Issue 4 April - 2024, Pages: 59-65

Forest Fire Detection using Deep Leaning

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Abstract: *Forests are areas with a high density of trees, and they play a vital role in the health of the planet. They provide a habitat for a wide variety of plant and animal species, and they help to regulate the climate by absorbing carbon dioxide from the atmosphere. While in 2010, the world had 3.92Gha of forest cover, covering 30% of its land area, in 2019, there was a loss of forest cover of 24.2Mha according to the Global Forest Watch institute. Discovery and classification depend on human experience and effort, so the error in the results of this process can lead to forest fires and disasters. Therefore, deep learning algorithms from artificial intelligence and machine learning sciences have been applied to help specialists avoid false or inaccurate diagnoses when detecting Forest fires in images using a pre-trained convolutional neural network called VGG16. The model was customized to fit the Forest fires classification and then applied to a dataset consisting of (14,000) of the Forests collected from the Kaggle depository. We trained, validated, and tested the modified VGG16 model. The proposed VGG16 model obtained Precision (99.96%), Recall (99.96%), and F1-Score (99.96%).*

Keywords: Forest fire, deep learning,

1. INTRODUCTION

Forests are areas with a high density of trees, and they play a vital role in the health of the planet. They provide habitat for a wide variety of plant and animal species, and they help to regulate the climate by absorbing carbon dioxide from the atmosphere. Forests also provide valuable resources, such as timber, medicine, and food.

However, forests are under threat from various sources, including deforestation, urbanization, and climate change. One of the biggest dangers to forests is forest fires, which can be caused by lightning, human activity, or other factors. Forest fires are a major natural disaster that can have devastating consequences for both the environment and human communities. Early detection of fires is crucial for mitigating their impacts, as it allows for timely intervention and prevents the spread of the fire.

In recent years, the use of remote sensing technologies, such as satellite imagery, has become increasingly popular for detecting and monitoring fires. However, manual analysis of these images can be time-consuming and prone to errors, leading to a need for more efficient and accurate methods.

Deep learning techniques have shown great potential for improving the accuracy and efficiency of fire detection and classification. through feature extraction and classification by modeling contain multiple layers to data processing, then training on the dataset and testing, the greatest success in this is due to the convolutional neural network (CNN) [1]-[10], which was proposed in the late 1990s, which achieved great popularity, especially in classifying images and extracting features from them with high accuracy and other two-dimensional data compared to other models.

In this paper, to examine the efficiency of the convolutional neural network in diagnosing and classifying bone deformities in radiographs, the VGG16 model was chosen to apply to a dataset consisting of (14,000) samples for an images of the forest fires from Kaggle composed of 2 types of two types of photos, photos of fire, and photos of smoke, VGG16 Configured for retraining, after reprocessing the dataset using the Python programming language, the Keras library and the Tensor Flow platform in the Google Collab environment with GPU to get the results of the classification of the forest dataset in terms of fire and smoke.

VGG16 was chosen because it is a convolutional neural network that is pre-trained on a massive dataset of 1,000 classes, and was awarded the highest award in 2015, containing 16 convolutional layers and weights that can detect and extract features from an image with an accuracy of 97%[11]-[12]. Through the results, it is possible to predict in the future the possibility of suggesting a better model or not, so in this paper, we review the methodology and its application and record its results to compare it in the future with the performance of other models.

2. PROBLEM STATEMENT

The problem addressed in this project is the detection and classification of forest fires using the VGG16 algorithm, a deep learning algorithm [13]-[15]. Forest fires can have serious consequences, including loss of life, damage to property, and destruction of critical habitats for plants and animals. They can also release large amounts of carbon dioxide into the atmosphere, contributing to global warming. Therefore, it is important to be able to detect and classify forest fires in a timely and accurate manner in order to minimize their impact. The VGG16 algorithm, a deep learning algorithm [16], may be able to help with this task by analyzing images or video footage of forests and identifying areas that show signs of a fire [17]. The goal of this paper is to develop a system using the VGG16 algorithm that is able to detect and classify forest fires with a high degree of accuracy.

3. OBJECTIVES

3.1 Main objective

Detect and classify forest fires using the VGG16 algorithm, a type of deep learning algorithm.

3.2. Specific objectives:

- Rapid diagnosis and detection of forest fires.
- Increase proficiency using deep learning to detect forest fires.
- To evaluate the performance of the VGG16-based model in terms of its accuracy, precision, and recall in detecting and classifying forest fires.
- To provide recommendations for the use of the VGG16-based model in operational systems for detecting and classifying forest fires.

4. LIMITATION

The dataset collected from the Kaggle depository for a forest fire is limited to the following: smoke and fire. The total number of labels in the dataset is two. Each type of image in the dataset is either smoke or fire.

5. REVIEW OF LITERATURE

There are many studies for detecting fire forest in the past 5 years. They use different datasets, different deep learning models with f1-score ranging from 81.97% to 99.57%. Table 1 summarizes the previous studies in terms of year published, Deep Learning model used, dataset used, and best model with best F1-scoe[18]-[20].

Our study is different from the previous studies in terms of the deep learning model and dataset. We will use VGG16 deep learning model and the dataset is collected from Kaggle depository.

Table 1. Summary of previous studies

Reference	Year	Deep Learning Model	Dataset	Best Results
[21]	2021	FU-NetCast (U-Net)	Private	F1-score = 92.73%
[22]	2021	R-CNN	ConFoBi	F1-score = 92.4%
[23]	2020	DenseNet, CycleGAN	CycleGAN	F1-Score = 98,16%
[24]	2020	CNN RNBFE	WHU-RS, UCM	F1-score (UCM)= 97.84%
[25]	2018	FireNet(DCNN)	AInML	F1-score = 98.00%
[26]	2017	Bi-CNN	YUPENN and BUAA	F1-score = 93.00%
[27]	2021	MobileNetv3	MSCOCO	F1-score = 99.57%
[28]	2021	CNN, UNet	FLAME	F1-score = 87.75%
[29]	2020	MobileNetv2, CNN, FireNe, AlexNet	Private dataset	F1-score = 99.30%
[30]	2021	MobileNetv2, Resnet152, DenseNet121	COCO	MobileNet : F1-score = 87.50%
[31]	2021	DenseNet121, Resnet152, MobileNetv2	UAV	DenseNet121 : F1-score = 93.1%
[32]	2020	UNet++ UNet	Andong	F1-scoer = 83.11%
[33]	2021	New model	Drone	F1-score = 81.97%

6. METHODOLOGY

The methodology that we used in this study has the following steps: dataset collection, data preprocessing, data splitting, proposed deep learning model, model training, and testing as in Figure 1.

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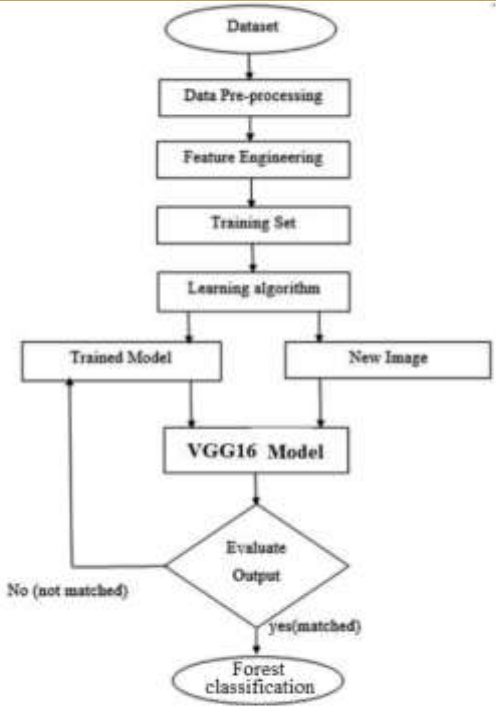

Fig. 1. Methodology used in this paper

6.1 Data Collection

We have collected the forest fire Images from the Kaggle depository. The data set has 2 classes: smoke, and fire.

6.2 Data Splitting

We have split the dataset into two datasets: Training and testing datasets. The ratio of splitting is 80%, and 20%, respectively. Furthermore, the Training dataset was split into train and valid datasets with 60% for train and 20% for valid datasets. The new total number of images is (14,000). Table 2 shows the number of images in each class of the 2 classes in training, validation and testing datasets. Samples of the 2 classes are shown in Figure 2.

Table 2. The number of images in each class in each dataset

Dataset	Number of images in Fires class	Number of images in Fires class	Total Images
Training	4536	4536	9072
Validation	1232	1232	2464
Testing	1232	1232	2464

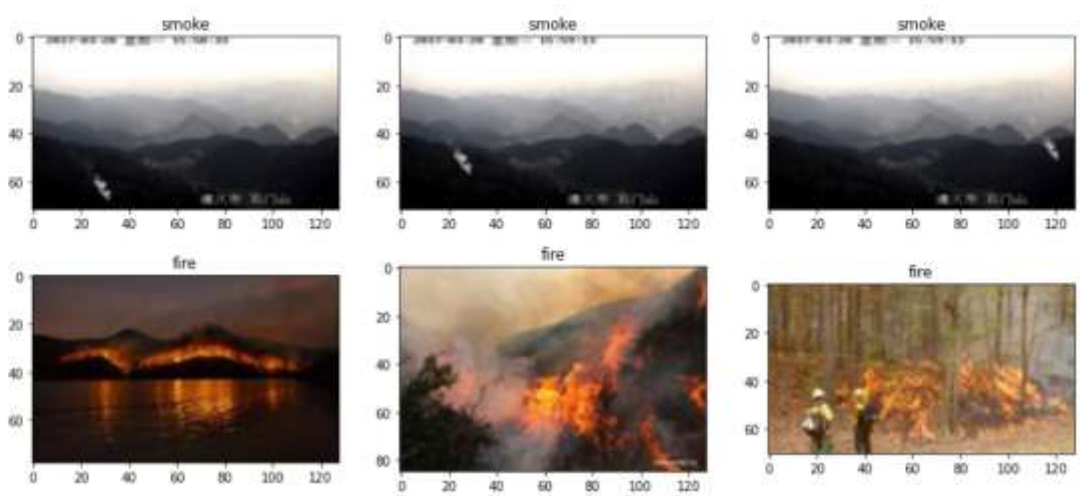

Figure 2. Samples of the forest fire dataset

6.3 Performance measures

We used the most common criterion for measuring the performance of the proposed VGG16 model:

- Precision is defined by True Positive divided by the summation of True Positive and False Positive as in equation 1.

- Recall is defined by True Positive divided by the summation of True Positive and False Negatives as in equation 2.
- F1-score is defined by 2 times Precision times Recall divided by the summation of Precision and Recall as in equation 3.
- Accuracy is defined by the summation of True Negative and True Positive divided by the summation of True Negative, True Positive, False Positive and False Negatives as in equation 4.

$$\text{Precision} = \frac{\text{TP}}{\text{TP + FP}} \quad (1)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP + FN}} \quad (2)$$

$$F1 - score = 2 * \frac{\text{Precision x Recall}}{\text{Precision + Recall}} \quad (3)$$

$$\text{Accuracy} = \frac{\text{TN + TP}}{\text{TN+FP+ TP + FN}} \quad (4)$$

Where: FP = False Positive; FN = False Negative; TP = True Positive; TN = True Negative

6.4 Proposed model

In the current study, we proposed to utilize the VGG16 model for the classification of 2 classes of fire or smoke images. The original architecture of the VGG16 before modification is shown in Figure 3. The original VGG16 model was used to classify 1000 classes of different things. The original VGG16 mode cannot be used directly to classify the 2 classes of a forest fires. Therefore, we need to modify it by replacing the top layer (classifier) with our own classifier. The modified VGG16 mode is represented in Figure 4.

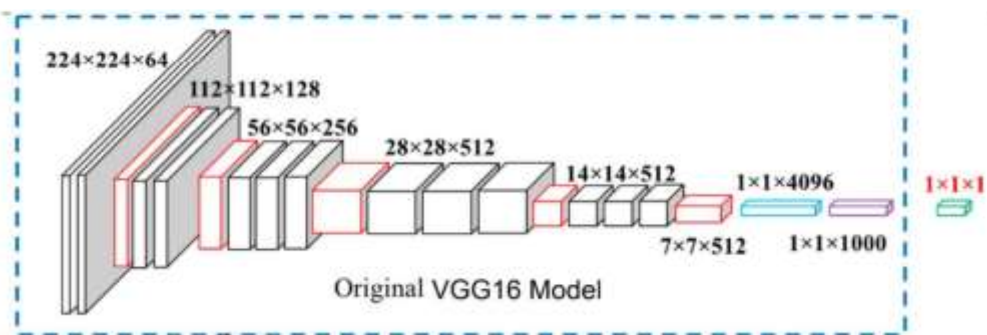

Figure 3. Original VGG16 Model

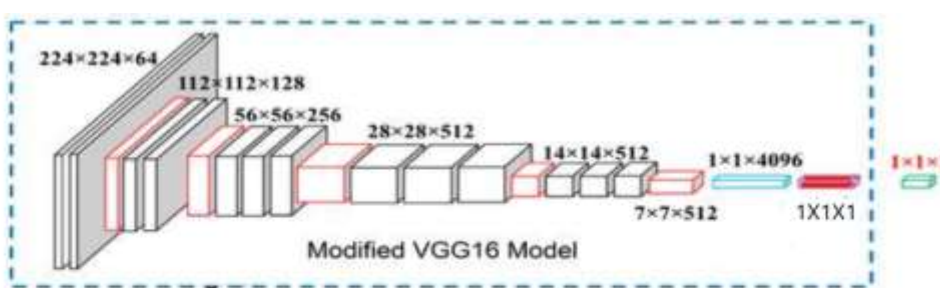

Figure 4. Modified VGG16 Model

6.5 Model Training and Validating and Testing

The proposed VGG16 model was trained using the train dataset and validated using the valid dataset. The training was done through 20 epochs with learning rate (0.0001), batch size (128) and sigmoid function and Adam as Optimizer. Furthermore, to overcome the training problems that can occur during the training, augmentation was utilized. Figure 5 and Figure 6 shows the loss and accuracy of the training and validation of the proposed VGG16 model. After finishing the training of the VGG16 proposed model, we tested it using the testing dataset.

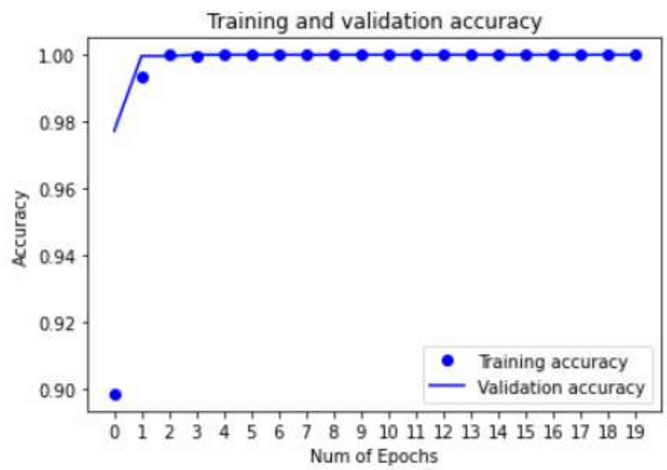

Figure 5. Training and validation accuracy of the proposed model

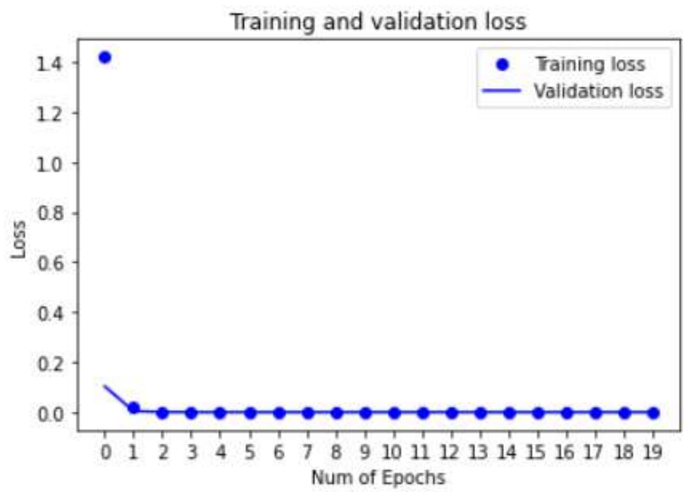

Figure 6. Training and validation loss of the proposed model

7. RESULTS AND DISCUSSION

The proposed VGG16 model attained Training Accuracy (100%), Validating Accuracy (100%), and Testing Accuracy (99.96%). In terms of loss, in the customized model the training Loss is (0.0000), Validating Loss is (0.0000), and Testing Loss is (0.0014). In terms of the time required for training and testing, the VGG16 proposed model required 288 seconds for training and 3.25 seconds for testing.

Table 2 shows the precision, Recall, and F1-Score of each class in the dataset in terms of the 2 classes that the proposed VGG16 model used for the classification of a forest fire: smoke, and fire. The proposed VGG16 model attained average Precision (99.96 %), Recall (99.96%), and F1-Score (99.96%). Furthermore, the ROC Curve measure for each class in the dataset reached 100%.

Even though, the results we obtained is much better than the previous studies results, the deep learning model and dataset we used are different from the one used in the previous studies.

Table 2. VGG16 Precision, Recall, and F1-Score of Each Class in the Dataset

Class	Precision	Recall	F1-score	Number of images used
fire	0.9992	1.0000	0.9996	1232
smoke	1.0000	0.9992	0.9996	1232
Accuracy			0.9996	2464
macro avg	0.9996	0.9996	0.9996	2464

weighted avg	0.9996	0.9996	0.9996	2464

8. CONCLUSION

A forest is an ecosystem characterized by the presence of trees and other woody vegetation. Forests can be found all over the world and are home to a diverse array of plant and animal life. Forests play a critical role in maintaining the balance of the planet's natural systems, and they provide a variety of ecological, social, and economic benefits. Forests are also an important source of timber, paper, and other products. But sometimes, due to various accidents, a forest is exposed to some fires, which lead to disasters and loss of ecological balance.

The main aim of the study is to propose a deep-learning model for the classification of the 2 classes of images for the forest.

We proposed a newly customized deep learning model for diagnosing Forest fires called VGG16 to do the job. We modify the VGG16 model to suit the 2 classes we have of images for a forest.

The Dataset was collected from Kaggle and boosted using data augmentation. We split the dataset into three datasets: training, validation and testing. We trained, validated, and tested the modified VGG16 model. The proposed VGG16 model obtained Precision (99.96 %), Recall (99.96%), and F1-Score (99.96%).

ACKNOWLEDGEMENT

We would like to thank Google for letting us use their laboratories in general and Google Colab in particular.

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