Early Wildfire Detection Leveraging Convolutional Neural Networks

Dr. Deepa B.G Assosiate Professor
School of CSA REVA University

Prateeksha S.G Assistant Professor
School of CSA REVA University

Hari Prasad E Msc Data Science School of CSA Reva University Bengaluru,

Abstract— **Wildfire, which is also known as forest fire, which is very difficult to control, especially occurs in grasslands, forests, wildlife santuries.it is very significant to take action towards forest fire detection or else it leads to the destruction on forests and as well damage to environment as well. We celebrate world environment day on June 5 every year in order to celebrate the happiness of environment, hence detection of wildfire plays a significant role. Deep learning is an excellent field which contributes for detection and classification. We have many convincing algorithms found in dl, whereas one such algorithm used in this paper is CNN, which has activation functions, pooling layers, convolutional layers which makes detection or classification much easier. Dataset used in this paper is Wildfire Detection image data which leverages for both ml and for evaluating ml models., which consists of two labels with fire and no fire. The usability for this dataset mentioned is above 5, which has quite good usability. Wildfire Detection Image Data can be found in Kaggle website. After evaluation of the work, CNN model provided results around 96.4% ad been obtained.**

Keywords—deep learning, machine learning, Specificity, Sensitivity, Recall, F1 Score,

1. INTRODUCTION

Wildfire are caused due to global warming as well due to afforestation, which results in damage of crops and tress, and also destroying this wildfire leads to the air pollution which is again an imbalance that is observed in an ecosystem. Every year about 200,000 are happening over 2 decades. Which has been a significant loss in life as well as in property [1]. The main component to keep the environment safe is forest since it's a giant region which includes lots of crops, trees, birds, animals etc. hence outbreak of fire in forest is quite hazardous and dangerous [2]. Unfortunately, forest fires can be seen once after the spread in huge region, which also releases carbon dioxide due to this uncertain fire in forests [3]. wildfires are uncertain, they can begin anywhere and occur at any point of time which results in lightning [4]. High temperatures and dry lands catches fire which in turn impacts on human life [5]. In recent years innovation on CNN benefits forest fire detection because of its convolutional layers, and automatic feature extraction, where CNN is one of the traditional ml and dl technique.[6]. CNN network which is used in both detecting and differentiating the forest fire images.[7]. various types of forest fire as follows: Ground, Surface, and crown which is shown in fig1.

Fig1.Types of Forest Fire

II. MOTIVATION

Our work mainly concentrates on, the betterment for forests and to save environment, one need to take precautionary measures in order to protect property and human lives. Early detection of forest fire helps in preventing small fires spreading to larger regions becoming catastrophic. wildfires also result in release of large amount of carbon dioxide which makes the quality of air low and toxic. Furthermore, wildfires also result in damaging property, devastate communities and displace people from one place to another place. Our research aims to develop a robust deep learning classifier used for forest fire detection, which has complex patterns within wildfire detection image data. We try to address the issue in early detection of forest catching fire due to various factors such as might be high temperatures or dry lands. Technically, our research mainly contributes on interdisciplinary research using ml technique specifically by using CNN algorithm. This research significantly also opens an opportunity on skill development and also to try the modern technologies like cloud and edge computing. By using the CNN technique to our model, we aim to detect early wildfire which might results in damaging properties and releases hazardous air pollutants, also results in destructive of people from one place to another place. CNN helps to enhance image classification, and as well in image detection. Our main contribution of this research as follows:

2.1 Designing and implementing an CNN-based wildfire detection model

2.2 The proposed model is evaluated against various classifier models and we try to intrepret efficiency and scalibility.

2.3 Providing a robust and reliable tool for early detection of wildfire, ultimately saving lives and properties.

III LITERATURE SURVEY

SayalMadkar, dr. dipti.Y. Sakhare, Komal. A. Phutane, Anagha.P. Haral, Kirti. nikam and S. tarunyaha [8] worked on project work. They had worked on detection of fie and smoke using two models namely yolo and CNN. Their approach involved CNN and yolo to enhance wildfire forest Main motto of the research is to monitor and detect fire in forest.The model concentrates on to improve accuracy which results hazardous in real world. This study also acknowledges the study of future experimentation, in this paper they have worked on yolo v5. In future by using v6 and v7 versions they can enhance and increase the accuracy by using these versions of yolo model

Mohammad Safeer khan, Rajvardhan Patil, Sayed Ali Haider [9] worked on a paper which has titled as "Application for Convolutional Neural Network Fir Wildfire Detection" which has got larger wilfire image database. The study used a CNN model to detect fire images.it has achieved 97.9 accuracy but they haven't mentioned this results in this paper. They had mentioned that it is observed 97.9% of accuracy by using CNN layer of one,64 number of classification nodes, and 2 fully connected layers will provide the better results. In limitation they have informed that the accuracy of this work will be submitted in next paper as a future scope

Yutong li[10], had worked on a paper, using efficient Net model which is one of the dl model, which works best for image detection and image classification, due to its 3 components called as depth, width and resolution, also it works great because of its compound scaling. They had got quite prominent results which is around 85.3% of accuracy. However, limitations include the need of changing the whole model into product.

Byron Arteaga, Mauricio Diaz, Mario Jojoa [11], had worked on a paper. Usually, detection of forest fire ad captured from ground and in air using helicopter, data samples are collected from these methods as mentioned above. Models used in this experiment was Resnet and Vgg models. from Vgg model the results obtained are 99.3% and by suing Resnet model from this model the results obtained were 99.50%.

Divya B, Kavitha S, Muthu Pandeeswari, Sreenidhi R, Po Vaishnavi MR, Loshine S [12], had worked on paper which had titled " Fire and Smoke Detection Using Deep Learning", wildfire used to cause lots of destruction to property as well as caused harm for animal life, hence the researchers had divided the problem into two parts, whereas one was focused on the wildfire and the other was focused on the commercial fire. They have used Grad-cam method to identify smoke in the image. They have used CNN model and obtained results around 96.8%.

Muhammad Iqbal, Casi Setianingsih, Budhi Irawan [13] had worked on a paper. Sensors and cameras were used to detect indoor fire detection uses a models called CNN and backpropagation. these methods Rae used to detect the fire systems where results it was obtained using back propagation method is 95% and by using CNN model the results obtained was 97%.

Gowtham V s Sandeep Ganti, Sunny Nalluri, Lakshmi Jyothi Maram [14] had worked on a paper and it uses satellites photos to detect fire detection in forests. Researchers have used CNN model using u net model and obtained results around 95.91%. these people also used several methods to identify fire detection few of them are, Image sacking, Gaussian Filtering, grayscale conversion to improve the input data. Which has been a useful technology to detect forest fire in forests.

IV. METHODOLOGY

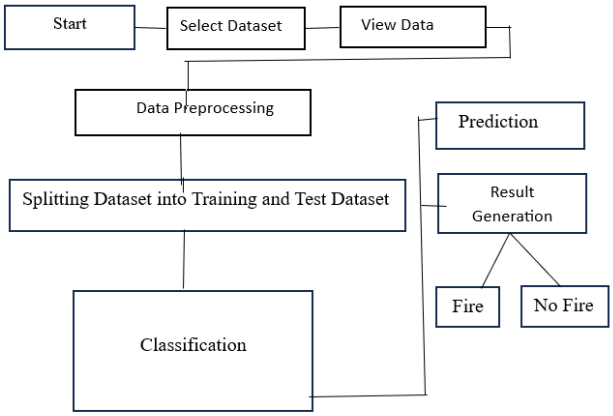

Fig: The representation of the proposed model

4.1 Dataset:

Wildfire detection Image data is a dataset which is obtained or found in Kaggle website, where Kaggle is a website where it consists of lots of datasets related to all fields where it is used for data science and ml projects. It is useful for an interdisciplinary work too. This dataset contains useability above 5.and also where Kaggle is one of the data science competition platforms and online community of data scientists and ML practioners. This dataset contains 2 labels, which is named as fire and no fire.

Fire No Fire

Fig 4.1.1: Collection Of Wildfire Detection Images

4.2 Data Preprocessing:

Data Pree-Processing for wildfire detection consists of several crucial steps, whereas collection of data from wildfire detection image data from Kaggle involves typically raw data is collected and then labels are annotated and then image resize is done, where noise data and irrelevant data is removed CNN model is used to detect wildfire in forests. The preprocessing is significant to improve picture quality to interpret data which intern very much necessary for feature extraction.

Data preprocessing is an important and crucial step for further operations to perform and also to interpret results. Before data preprocessing data will be in a raw format, where handling with those kind of data results in misinterpretation. And we do not contain accurate results.

4.3 Dataset Splitting:

Dataset is huge and therefore, it had been divided into 3 categories which is training phase, test phase and validation phase, training data is used to train the model with certain images, and validation data is used to finetune the hyperparameters to improve the accuracy whereas test data is used to perform well on unseen data.

Model Selection:

The best model must be selected for wildfire detection can be done by considering some key points. The model has to comprehend with data, should have better transfer learning methods, should provide good evaluation metrics results, it should refine the model in a better way, all these parameters will help to have an efficient and enhanced results. In order to work on this project, the model which suits better and most likely to choose is CNN model.

4.4.1. CNN:

The abbreviation for CNN stands for convolutional neural network. Usually, all the models work on two phases which is, training and testing phase. Here the model CNN used photographs of forest fires to train the model. CNN model consists of more than one layer of neural network, it's one of the techniques under deep learning. stands for Convolutional Neural Network.it consists of one of the building blocks in order to process the images, it's very significant in feature extraction from images, also consists of many types of filters in order to study the spatial patterns within the data. The fundamental building block for many images processing tasks, using filters to extract features from images. It's a fundamental architecture in deep learning, particularly effective for extracting features from images. It uses filters to learn spatial patterns within the data. CNN model is used for object detection and image classification can also customize the parameters in order to obtain efficient results.

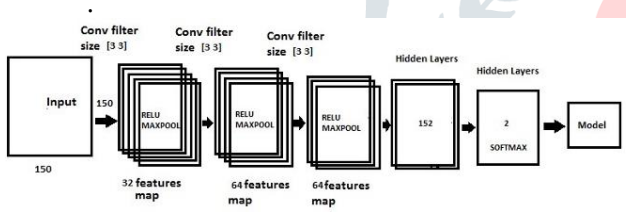

Fig 4.4.1 CNN Architecture

The CNN layer uses a convolutional kernel which is used to fit into image since it has got a specific size in it, and hence obtain unknown information or new information. pooling layers are also present in this architecture which intern reduces dimensions in the matrix and also computational power will be increased. Therefore, CNN model has kernels, filters and strides, two types of pooling layers can be observed here, namely maximum pooling and average pooling.

CONVOLUTION LAYER:

Convolution layer in a CNN model. This convolutional layer consists of two grids, where one of the grids contain the attributes which as to be learnt and other grid contains the input of specific or constrained area. And therefore, this layer is a dot product of above-mentioned grids. (consists of all attributes which it must be learned) and other grid which has the constrained area of the input.

POOLING LAYER:

The surrounding outputs has been calculated by calculating the aggregate stats and substitution of networks output is also performed by pooling layer. Therefore, the spatial size is also lowered therefore computation power and weights are also decreased.

FULLY CONNECTED LAYER:

This layer consists of output layer and has a pooling kernel which is obtained from pooling layer. And therefore, it is called as fully connected layer.

V RESULTS AND DISCUSSION

This specific section discusses about finding the models' experiments and experimental results are mentioned here.also the consistent results can be increased by increasing number of tests. Therefore, the overall results obtained from the CNN model is evaluated and the results are mentioned below.

Table 5.1: Obtained results Using CNN Model

MODEL	Train-test split ratio	Accuracy
CNN	80:20	99.95%

CNN model was evaluated based on its training accuracy, test accuracy, precision, recall, and F1-score. All these words have been clearly explained below

•Training Accuracy: It can be defined as the accuracy of a model on examples it was constructed on and makes the correct predictions out of it.

• Testing Accuracy: It can be defined as the accuracy of a model on example it has not seen.

•Precision: Precision refers to number of true positives divided by total number of positive predictions.

• Recall: It can be defined as how often a model correctly predicts true positives to the actual positives in the model.

•F1-score: It defines the model's accuracy on a dataset which is used to evaluate the binary classification system.

All these evaluation metrics are significant to achieve results in a more efficient form and for enhanced results.it is also used to provide few insights to know the effectiveness of the models and guide for the development of model and makes decisions easy based on the model's performance. These are also known as the tools in Machine Learning

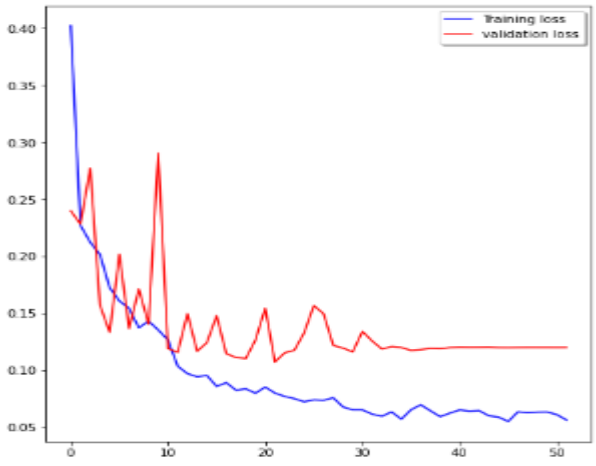

Fig5: model loss graph

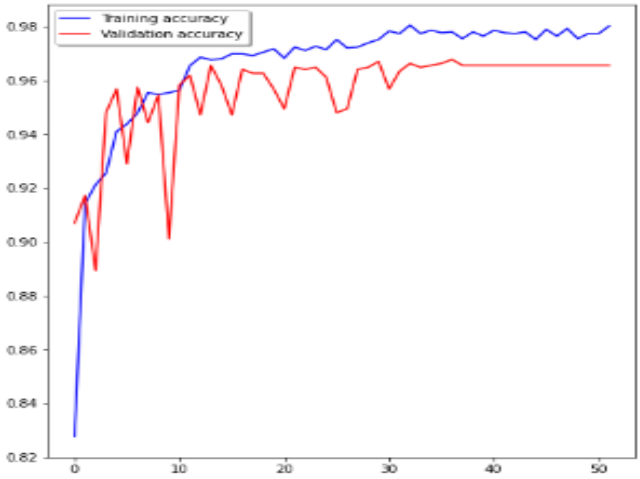

Fig5.1: model accuracy graph

Fig.5 indicates model loss graph This model shows ow the loss function varies accordingly to training over each epoch. Lower loss value always indicates better performance. Two curves can be seen in the graph i.e. validation loss and training loss. Overall if the training loss choses to decrease when the validation loss choses to increase and stops to decrease then the model would suffer from overfitting. which mean models perform best on training data but not on test data or unseen data. And Fig.5.1 shows or describes accurate predictions made to the total prediction in the model given. Like model accuracy graph even this has 2 curves, if both curves increase and stabilize at high value, indicates that model generalizes well to the data. one for training accuracy and another for validation accuracy.

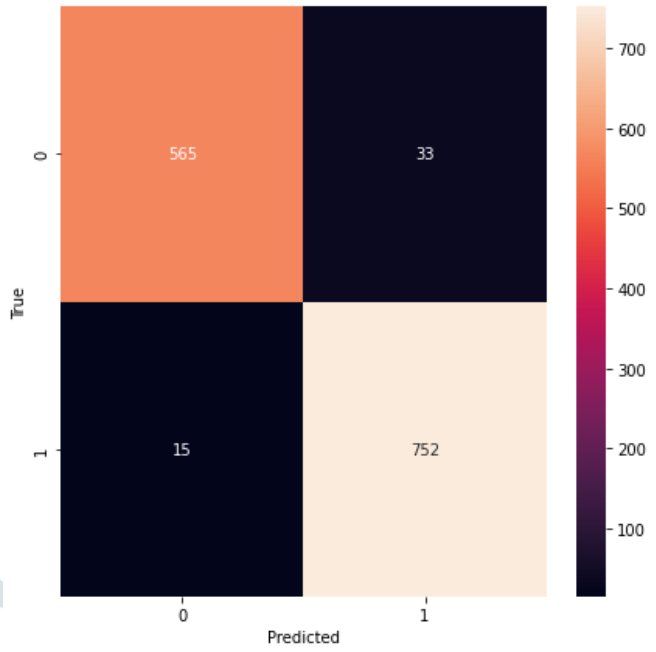

Fig 5.2: Representation Of Confusion Matrix for CNN Model

Fig 5.2 Indicates confusion matrix where it indicates or reveal critical insights on both true positive and true negative values indicates that model accurately identifies both fire and no fire images. Which help for robust detection capabilities. Therefore, confusion matrix I a representative of the dataset were results in providing a clear picture for enhanced results. confusion matrix consists of true positive, true negative values and false positive, and false negative vale. More values in false positive or false negative indicates that to change few hyperparameters or to finetune few parameters to generalize well on data and a well as on model.

Table 5.3 Comparative Analysis

No	Authors	models	Accuracy
1	Sarang Batlapalli, P. Krishna Prasad, Ramesh Ponnala (2023)	CNN, MobileNet, ResNet	97.8%
2	Dr Rachana P, Dr B Rajalakshmi, Tushar Bhat, Sukhmanjeet Kaur, Stuti Bimali (2022)	CNN	98.6%
3	Wenzheng Li, Zongyang Yu (*2021*)	CNN (Yolo edge)	63.66%
4	Jefri Zulkarmain, Mohammad Rezza Pahlevi, Yustikamasy Astica, Widi Pangestuti, Kusrini (2022)	CNN	99.72%
5	*E Hari prasad, Dr. Deepa B G,*	CNN	96.4%

VI. Conclusion

In our work, CNN model has shown few promising remarks to detect wildfire which occurs more often in forests, which would destroy the environment and results in loss of human lives and property. CNN architecture comes under deep learning where the images are taken from “wildfire detection image data” dataset. 2 labels are given in the dataset where it

defines forest as one label and no forest as another label. Our model has provided around 96.4% of accuracy. The model is evaluated based on the evaluation metrics and the results are obtained. Adam optimizer and learning rate of 0.0001 provided better results. CNN architecture had been one of the best models in object detection and image classification and hence this architecture is more suitable for our research.

References

[1] Singh, Jagmohan, M. Shilpa Aarthi, and Austin Shibu Idikkula. "Convolutional Neural Networks for Early Detection of Forest Fires." In 2023 2nd International Conference on Automation, Computing and Renewable Systems (ICACRS), pp. 777-780. IEEE, 2023.

[2] Ranjani, D., M. Haripriyabala, J. Indhu, V. Janani, and A. Jothi. "Forest Fire Detection using Convolutional Neural Networks (CNN)." In 2023 7th International Conference on Trends in Electronics and Informatics (ICOEI), pp. 852-857. IEEE, 2023.

[3] Meena, Utkarsh, Geetika Munjal, Sanya Sachdeva, Pranjul Garg, Daksh Dagar, and Anushka Gangal. "RCNN Architecture for Forest Fire Detection." In 2023 13th International Conference on Cloud Computing, Data Science & Engineering (Confluence), pp. 699-704. IEEE, 2023.

[4] Gayathri, K., J. V. D. Prasad, T. Divya Kiran, and V. Mythili. "Forest Fire Detection Using Convolution Neural Networks." In 2022 IEEE 2nd International Conference on Mobile Networks and Wireless Communications (ICMNWC), pp. 1-5. IEEE, 2022.

[5] Dawar, Ishaan, Soumyo Deep Gupta, Rashika Singh, Yash Kothari, and Shirshendu Layek. "Forest Fire Detection using Deep Learning Techniques." In 2023 2nd International Conference on Vision Towards Emerging Trends in Communication and Networking Technologies (ViTECoN), pp. 1-6. IEEE, 2023.

[6] Khirani, Siham, Abdelkerim Souahlia, and Abdelhalim Rabehi. "Forest Fire Detection Using a Low Complex Convolutional Neural Network." In 2023 2nd International Conference on Electronics, Energy and Measurement (IC2EM), vol. 1, pp. 1-6. IEEE, 2023.

[7] Indumathi, R., G. Selvakumari, V. Selvi, R. Swathi, and N. Palanivel. "Forest Fire and Smoke Detection using Convolution Neural Networks." In 2023 International Conference on System, Computation, Automation and Networking (ICSCAN), pp. 1-5. IEEE, 2023.

[8] Madkar, Sayali, Dipti Y. Sakhare, Komal A. Phutane, Anagha P. Haral, Kirti B. Nikam, and S. Tharunyha. "Video based forest fire and smoke detection using YoLo and CNN." In 2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), pp. 1-5. IEEE, 2022.

[9] Ranjani, D., M. Haripriyabala, J. Indhu, V. Janani, and A. Jothi. "Forest Fire Detection using Convolutional Neural Networks (CNN)." In 2023 7th International Conference on Trends in Electronics and Informatics (ICOEI), pp. 852-857. IEEE, 2023.

[10] Li, Yutong. "Forest fire smoke recognition and detection based on EfficientNet." In 2022 IEEE Conference on Telecommunications, Optics and Computer Science (TOCS), pp. 712-719. IEEE, 2022.

[11] Arteaga, Byron, Mauricio Diaz, and Mario Jojoa. "Deep learning applied to forest fire detection." In 2020 IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), pp. 1-6. IEEE, 2020.

[12] Divya, B., S. Kavitha, R. Sreenidhi, Ponvaishnavi Mr, and S. Loshine. "Fire and Smoke Detection Using Deep Learning." In 2024 2nd International Conference on Networking and Communications (ICNWC), pp. 1-6. IEEE, 2024.

[13] Iqbal, Muhammad, Casi Setianingsih, and Budhi Irawan. "Deep learning algorithm for fire detection." In 2020 10th Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS), pp. 237-242. IEEE, 2020.

[14] Ganti, Gowtham VVS Sandeep, Sunny Nalluri, and Lakshmi Jyothi Maram. "Detection of Forest Fire using CNN U-Net model." In 2023 OITS International Conference on Information Technology (OCIT), pp. 138-143. IEEE, 2023.

[15] Bathalapalli, Sarang, P. Krishna Prasad, and Ramesh Ponnala. "A Deep Learning Approach to Forest Fire Detection and Monitoring." In 2023 International Conference on Advances in Computation, Communication and Information Technology (ICAICCIT), pp. 263-268. IEEE, 2023.

[16] Rachana, P., B. Rajalakshmi, Tushar Bhat, Sukhmanjeet Kaur, and Stuti Bimali. "Comparative study of different methods for fire detection using convolutional neural network (CNN)." In 2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT), pp. 1759-1765. IEEE, 2022.

[17] Li, Wenzheng, and Zongyang Yu. "A lightweight convolutional neural network flame detection algorithm." In 2021 IEEE 11th International Conference on Electronics Information and Emergency Communication (ICEIEC) 2021 IEEE 11th International Conference on Electronics Information and Emergency Communication (ICEIEC), pp. 83-86. IEEE, 2021.

[18] Zulkarnain, Jefri, Mohammad Rezza Pahlevi, Yustikamasy Astica, Widi Pangestuti, and Kusrini Kusrini. "Fire Detection based on Smoke Image using Convolutional Neural Network (CNN)." In 2022 4th International Conference on Cybernetics and Intelligent System (ICORIS), pp. 1-5. IEEE, 2022.