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Forest Fire Susceptibility Using Neural Network

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Abstract: Forest fires have impacted negatively on ecosystems, cultures, and economies all across the world. Modeling and anticipating the incidence of wild fires are essential to minimize these damages and reducing forest fires because they can help with forest fire prevention strategies. The convolutional neural network (CNN) has emerged as a key state-of-the-art deep learning method in recent years, and its application has enriched a wide range of fields. As a result, we proposed a CNN-based spatial prediction model for forest fire susceptibility. The concept is that this model is used to identify a fire or the beginning of a fire in a forest using (aerial) surveillance data. In the event of a fire, the model might be applied in real time to low-framerate surveillance video or picture and provide a warning. The network will be trained on a dataset that includes images in three categories: 'fire,' 'no fire,' and 'start fire.' The majority of the photographs will be of forests or forest-like situations. Photos labelled 'fire' have visible flames, while images labelled 'start fire' have smoke sensing the beginnings of a fire. Finally, photographs with the title 'no fire' were taken in forests. We will leverage the data augmentation function offered by Keras (Python Deep Learning API) to conduct a series of random transformations on photos before feeding them to the network in order to train a network that generalizes well to new images. Finally, our goal is to create a legible project which handles every aspect of CNN creation and training. Early detection of fire in the forest is very helpful and our biodiversity can be saved.

Keywords: Forest Fire Susceptibility, Convolutional Neural Network Techniques, Machine Learning.

I.INTRODUCTION

A forest fire is a phenomenon that can be defined as an accidental fire in a flammable vegetation region. They have the potential to cause plenty of environmental disasters, as well as significant economic and ecological damages. Forest fire surveillance and tracking have become an important method for preventing this, attracting increasing interest throughout the world. Massive forest fires occurred in a number of locations across India's Karnataka state's Bandipur National Park in February 2019. The Indian Space Research Organization's (ISRO) National Remote Sensing Centre conducted an estimate of the total area damaged by the fire. On February 25, 2019, was projected that the burned area had grown to around 10,920 acres in the five days since February 21, 2019. Because regional forest fire susceptibility is typically influenced by a variety of factors and has typical nonlinear and complex properties, developing accurate forest fire prediction models remains a challenge. For predicting forest fire susceptibility, a variety of methodologies have been proposed, ranging from physics-based methodologies to statistical and machine learning (ML) techniques. ML algorithms have demonstrated the capacity to deliver superior results for the geographical forecast of wildfires when compared to standard qualitative and statistical analytic methodologies. Artificial neural networks, random forests (RF), support vector machine (SVM), multilayer perceptron neural network (MLP), kernel logistic regression (KLR), naive Bayes, and gradient descent trees are just a few of the machine learning algorithms that have already been successfully developed and commonly used to create wildfire susceptibility visualizations.

Deep learning (DL) techniques have lately gotten a lot of attention and have had a lot of success. Deep learning techniques are widely used in domains such as object identification and detection, audio recognition, and natural language processing because they aim to uncover numerous representation levels. In recent studies in areas such as disaster damage detection, remotely sensed image classification, and landslide susceptibility mapping, the convolutional neural network (CNN) has been recognized as one of the most effective and commonly used DL algorithms, which has generated major improvements.

The CNN can fully utilize contextual information and identify several layers of representations from input data, making it better suited to the evolution of fire event spatial features. The DL method shows deep characteristics and may differentiate between geographical entities. As a result, examining the use of the CNN algorithm in forest fire susceptibility assessments has some practical value. The likelihood assessment of fire occurrence in a region is characterized as forest fire susceptibility in this article. The major goal of this research is to use contextual-based CNNs with deep architectures to forecast regional forest fire susceptibility spatially. The forest fire susceptibility model is built using a CNN, and the model's hyperparameters were tuned to increase predictive accuracy.

The remaining part of the paper is laid out as follows: Section II is Literature Survey, Section III describes the proposed methodology, Section IV includes conclusion and future enhancement.

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II.LITERATURE SURVEY

Several articles were explored in order to develop our method for this project. Chief among those is:
[1] "Convolutional Neural Networks Based Fire Detection in Surveillance Videos" Published in "IEEE Access" in the year 2018 by Khan Muhammad[1], Jamil Ahmad[2], Irfan Mehmood[3], Seungmin Rho[4], and Sung Wook Baik[5]. The approach is based on the input of surveillance video. The video was passed through the Convolutional neural network where it was passed through different layers like convolution layers, polling layer, filter SoftMax and output maps. Then output maps is compared through the training data and output as "Fire" or "No Fire". They were able to get the accuracy of 90.02%.

[2] "Forest Fire Detection Using a Rule-Based Image Processing Algorithm and Temporal Variation" Published in "Hindawi Mathematical Problems in Engineering" in the year 2018 by Mubarak A.I. Mahmoud[1] and Honge Ren[2]. In this study the following steps has been suggested to make up a forest fire detection algorithm. To begin, the background subtraction is used to discover movement contained regions. Second, the segmented moving areas were converted from RGB to YCbCr color space, and five fire sensing criteria were used to separate potential fire pixels. After that, temporal variation is used to distinguish between fire and fire-color objects. The suggested approach is evaluated using a data set of six videos gathered from the internet. The final findings suggest that the proposed technique can obtain accurate sensing rates of up to 96.63 %.

[3] "Early fire detection using convolutional neural networks during surveillance for effective disaster management" Published in "ELSEVIER Journal" in the year 2018 by Kahn Muhammad[1], Jamil Ahmad[2] and Sung Wook Baik[3]. In this study they offer an early fire detection framework for CCTV surveillance cameras that uses fine-tuned convolutional neural networks and can detect fire in a variety of indoor and outdoor scenarios. They offer an adaptive prioritizing technique for cameras in the surveillance system to enable autonomous response. Finally, they offer a cognitive radio network-based dynamic channel selection method for cameras, providing accurate data transmission. Experiments shows the accuracy of 94.03%.

[4] "Forest fire image recognition based on convolutional neural network" Published in "Journal of Algorithm & Computational Technology" in the year 2019 by Wang Yuanbin[1], Dang Langfei[2] and Ren Jieying[3]. This study proposed a convolutional neural network-based forest fire image identification system for automatically detecting fire. They divided Fire identification algorithms into two categories. The first is based on classic image processing, while the second is based on convolutional neural networks. According to them the network's learnt properties aren't exact enough, and the recognition rate may suffer as a result. In order to address this issues, traditional image processing approaches are merged with convolutional neural networks, and an adaptive pooling strategy is proposed. This algorithm divides the flame region and learn the features of the flame. Experiments reveal that the convolutional neural network approach based on adaptive pooling has a greater recognition rate and better performance.

[5] "Image fire detection algorithms based on convolutional neural networks" Published in "ELSEVIER Journal" in the year 2020 by Pu Li[1] and Wangda Zhao[2]. This study proposes innovative picture fire detection methods based on the advanced object detection CNN models of Faster-RCNN, R–FCN, SSD, and YOLO v3. The accuracy of fire detection algorithms based on object detection CNNs is greater than other algorithms, according to a comparison of proposed and present techniques. The method based on YOLO v3 has an average precision of 83.7 percent, which is greater than the other offered algorithms. Furthermore, the YOLO v3 has improved detection performance robustness, and its detection speed reaches 28 FPS, meeting real-time detection needs.

[6] "Survey on different fire and smoke detection techniques using image processing" Published in "International Journal of Engineering Research - Online" in the year 2016 by Amit D. Purohit[1] and Prof. P.H. Pawar[2]. This study provides a comparison of various models for smoke and fire detection using image processing. This document discusses several fire and smoke detection systems, as well as their benefits and drawbacks. It is included because smoke is an excellent predictor of fire. They have used two phases to fire detection technology. The initial phase uses the pixels 'color and intensity fluctuation information to select the candidate for the fire region. To acquire the ultimate fire area, the second phase refines the results of the first step. A system that can detect fire by analyzing real-time video footage would function in an open environment and would not require a large budget.

[7] "Fire Detection Using convolutional neural network (CNN) Approach" Published in "International Journal of Scientific & Technology" in the year 2020 by N Prabhu Ram[1], R Gokul Kannan[2], V Gowdham[3] and R Arul Vignesh[4]. This paper suggested a fire detection technique based on Convolutional Neural Networks for high-accuracy fire picture identification that is consistent with training employing datasets. Convolution, activation functions, and the max pooling

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technique are used to train the model. The model is trained by varying batch sizes and epoch settings. The model's accuracy is 94%.

[8] “Fire Detection Using Digital Image Processing” Published in “IRE Journals” in the year 2020 by B. Triveni[1], K. Siva Mounika[2], and B. Jeen Rahelu[3]. This paper offers a fire detection approach based on a color model. Color characteristics are used to verify each pixel for the presence or absence of fire, and periodic activity in fire zones is also examined. The borders of the fire Region of Interest are also detected via a dynamic boundary check (ROI). The chromatic and dynamic measures are used to identify potential fire zones. The Open CV module is used to complete this project.

[9] “Weakly-supervised fire segmentation by visualizing intermediate CNN layers” Published in “Research gate” in the year 2021 by Milad Niknejad[1] and Alexandre Bernardino[2]. This paper look into poorly supervised segmentation of fire in photos in this research, where the network is trained purely on image labels. They show that the mean value of features in a mid-layer of classification CNN may outperform the classic Class Activation Mapping (CAM) technique, in the instance of fire segmentation, which is a binary segmentation issue. We also recommend adding a rotation equivariant regularization loss to the features of the final convolutional layer to boost segmentation accuracy even further.

[10] “Flame Detection Using Appearance-Based Pre-Processing and Convolutional Neural Network” Published in “Applied Science Journal” in the year 2021 by Jinkyu Ryu[1] and Dongkurl Kwak[2]. This study is to limit the number of false detections, HSV color conversion and Harris Corner Detection were utilised in the picture pre-processing stage in this investigation. Furthermore, the area of the corner point facing the higher direction was extracted as a region of interest (ROI) among the identified corners, and the fire was estimated using a convolutional neural network (CNN). These approaches were created to identify the appearance of flames using top pointing features, which led in greater accuracy and precision than when traditional object identification algorithms employed input photos. This significantly lowered the rate of erroneous fire detection, allowing for high-precision fire detection.

III.METHODOLOGY

The convolutional neural network (CNN) is one of the most well-known deep learning (DL) algorithms, with good results in feature learning for image categorization and identification. It's a feed-forward neural network whose parameters are learned using the backpropagation technique and the traditional stochastic gradient descent algorithm.
The CNN is made up of numerous layers, including convolutional, pooling, and fully linked layers. The many types of processing layers have varied functions. The feature maps are produced by the convolutional layers, which conduct linear convolution operations between the input tensor and a collection of filters.
A nonlinear activation function is usually used after each feature map. The most widely employed activation function is the rectified linear unit (ReLU), which conducts a nonlinear modification of the feature map created by the convolution layer and adds nonlinearity into the system.
The convolution technique is used to extract distinct characteristics from the input layer and accomplish weight sharing. Each stage's input and output are feature maps, which are collections of arrays. If the input is a 2-dimensional image x, for example, the input is first decomposed into a sequential array x= {x1, x2,..., xN}. Equation of convolution layers is given as:

$$y_j = f\left(b_j + \sum_i k_{ij} * x_i\right)$$

Where y_j is the j^{th} output of the convolution layer and input feature maps is x_i. k_{ij} is convolutional kernel with i^{th} input map x_i. * is discrete convolution operator, b_j stand for trainable bias and f is nonlinear activation.

To minimize the size of the feature maps, the pooling layers execute a subsampling process. The pooling layer may be separated into max-pooling and average-pooling layers based on the maximum and average functions. High-level abstraction features are provided by the fully connected layers, which are flat feedforward neural network layers. They are frequently utilized at the conclusion of the network design to construct the final nonlinear feature combinations needed by the network to make predictions. The activation function for the final fully linked layer must be chosen carefully based on the tasks at hand. The posterior probability for each grid cell may be computed using the SoftMax or sigmoid function.

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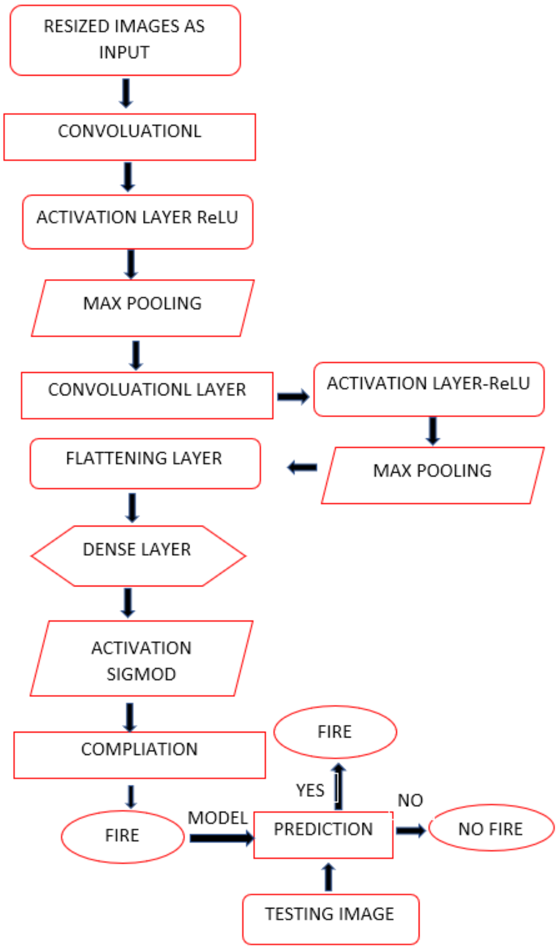

Fig.1 Flowchart of CNN training model.

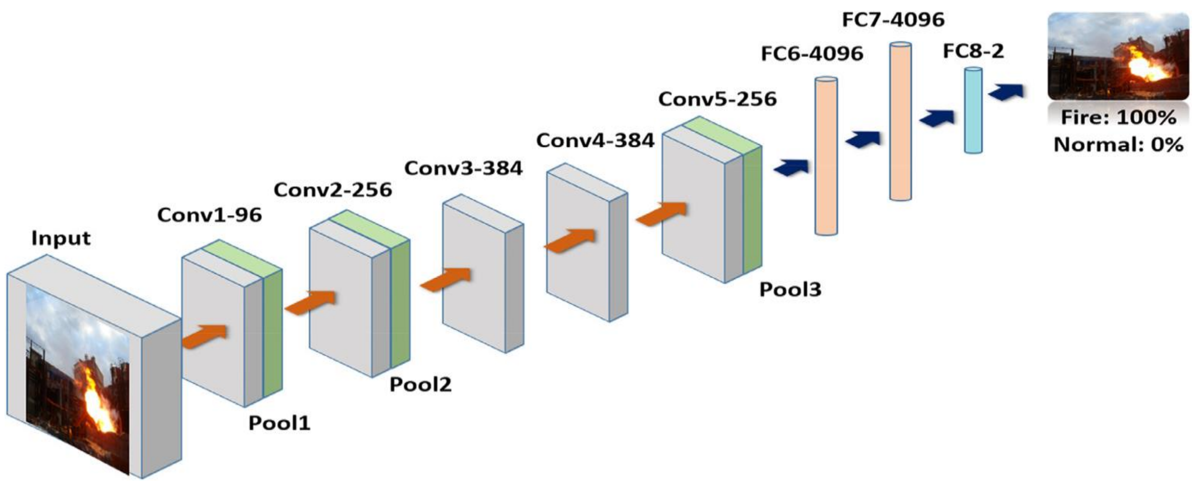

Fig.2 Architecture of proposed CNN.

We employed a model with a similar architecture to the AlexNet model, with some alterations to fit our problem of interest. As illustrated in Fig. 2, it contained five convolution layers, three pooling layers, and three fully linked layers. Color photos with a size of 224 x 224 x 3 are fed into the model as input. To produce 96 feature maps, the first convolution layer applies 96 kernels of size 1111 with a stride of 4 to the input picture. The first pooling layer chooses the highest activations from these feature maps in tiny regions of 3 x 3 pixels with a stride of 2 pixels. As a result, the feature maps'

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size is decreased by a factor of two. The second convolution layer is made up of 256 5 x 5 kernels, followed by a max pooling layer that is comparable to the first. It is followed by a stack of three convolution layers, each with 384, 384, and 256 kernels with uniform kernel sizes of 3 x 3. The third and final pooling layer works in a similar way to the first two. Finally, there are three fully linked layers with 4096, 4096, and 2 neurons apiece (corresponding to the number of classes). The SoftMax classifier uses the output of the final layer to determine probabilities for the two classes.
Following the training and fine-tuning procedure, a target model is created that may be used to anticipate fires in their early phases. Unlike traditional fire detection approaches, which need a significant amount of time and effort for pre-processing and feature engineering, our proposed CNN-based solution does not necessitate any pre-processing. Furthermore, it avoids the time-consuming and difficult process of extracting hand-crafted features by learning extremely powerful features automatically from the raw data. Furthermore, the suggested CNN-based model learns tiny scale information, allowing it to identify fire even at a small scale, i.e., in its early stages. The query image is run through the proposed model for testing, yielding probability for both fire and normal classes. The image is assigned to the relevant class based on the greater likelihood. Fig.3 shows an example of query photos together with their probability.

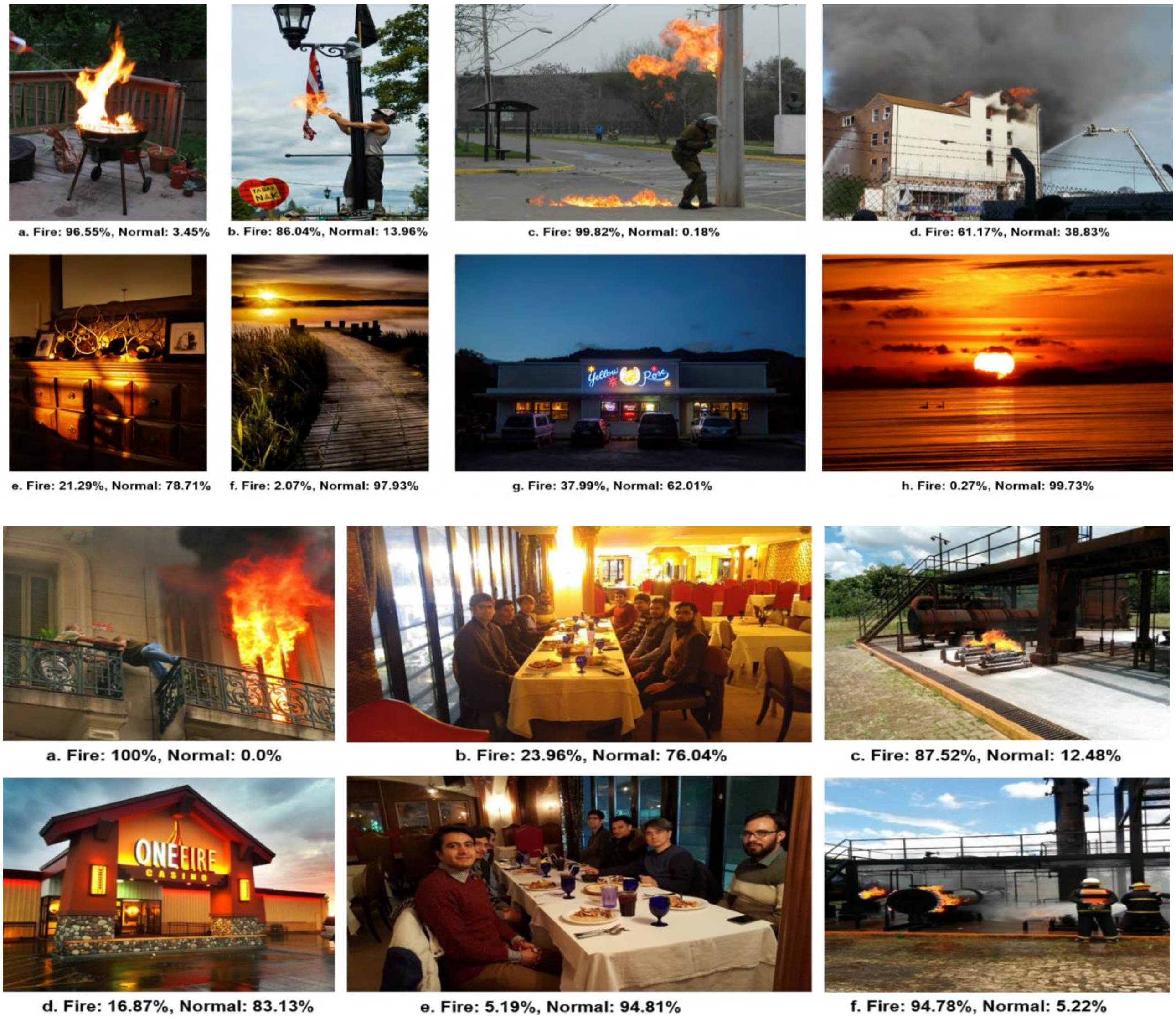

Fig. 3 For CNN-based fire detection, here are some sample query pictures and associated probabilities.

IV.CONCLUSION AND FUTURE ENHANCEMENT

CCTV cameras can now do several forms of processing, such as object and motion recognition and tracking, thanks to recent advancements. With these processing skills, it is feasible to identify fire at an early stage during monitoring, which can aid disaster management systems by preventing massive ecological and economic losses and saving a large number

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of human lives. We suggested an early fire detection approach based on fine-tuned CNNs during CCTV monitoring with this objective in mind. We demonstrated that by including deep characteristics into our framework, fire may be detected at an earlier stage with greater accuracy in a variety of indoor and outdoor contexts while reducing false fire alarms. The CNN architecture is created for forest fire susceptibility prediction in the research region, and hyperparameters were adjusted to increase prediction accuracy. The CNN model uses many typical strategies to avoid overfitting, including additional training data, regularization, batch normalization, and reduced architectural complexity. The test dataset was then loaded into the trained model, and the CNN model created a prediction map of Fire probability. Future research might concentrate on putting the model on a Raspberry Pi and employing the appropriate support packages to identify real-time fires by creating demanding and particular scene understanding datasets for fire detection techniques and extensive trials.

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