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FOREST FIRE DETECTION USING CONVOLUTIONAL NEURAL NETWORKS

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Abstract
Forest fires pose a significant threat to ecosystems, biodiversity, and human settlements, wild life habitat. One of the primary causes of environmental damage is forest fires. To preserve forests from fires, early detection and preventive measures are required. To bring down these problems, we are implementing a model which uses Convolutional Neural Networks (CNN).With the use of convolutional neural network our model aims to verify whether a forest fire is noticeable in a picture. Our network is trained using a dataset that includes images divided into three categories: "fire", "no fire", Images labelled "fire" have fire, and images labelled with "no fire" have no fire. Employing these techniques decrease false alarms and provides accurate fire detection results. The proposed system involves preprocessing of aerial images to enhance features relevant to fire detection. These images are then fed into CNN architecture trained to distinguish between normal forest scenes and those containing fire. Transfer learning techniques are employed to leverage pre-trained CNN models, optimizing performance even with limited training data. The trained model is capable of real-time detection and localization of fires with large forested areas.

Keywords: Neural Networks, Convolutional, Fire Detection, Internet Of Things, CNN, Real time Detection, Localization

1.Introduction
An uncontrolled fire that originates in a wilderness area like a forest, meadow, is known as a wildfire. Wildfires can begin anywhere and occur at any time. Forests are one of the main factors in balancing the ecology.[1-10] The emission of large amount of carbon dioxide (CO_2) from the forest fire damages the environment. The damage and the cost for apart fire because of forest fire can be reduced when the fire detected early as possible. So, the fire detection is important in this aspect.[11-17] The major one is burning the dry areas or like in Canada, they are using flying water tanks for fire reduction[18-26].Convolutional Neural Networks (CNNs),using various algorithms, have shown remarkable success in various image recognition tasks. Their ability to automatically learn and extract features from basic depiction data makes them particularly suitable for forest fire detection. [27-30]By practicum CNNs on large data sets, it is possible to develop models that can accurately identify fire outbreaks and discern them from other phenomena such as clouds, smoke, and sun glare. The main benefit of using this system is high temporal resolution and spatial resolution[31-32]. The development of an efficient model for forest fire detection using CNNs addresses the need for scalable solutions capable of operating in real time and resource-constrained environments. Such a model can be deployed on different platforms, including unmanned aerial vehicles (UAVs), surveillance cameras, and satellite systems, providing continuous monitoring and surveillance of forested areas.[33-35] One of the major challenges in forest fire detection using CNNs is the optimization of model performance and computational efficiency, particularly for deployment on edge devices with limited processing power and also limited bandwidth. Environment can be destroyed by the forest fire, and it could be makinga huge amount of loss. Recently, the amazon forest has had a fire and it remained for over 15 days[36-40]. This resulted a huge loss and it affected negatively to the diversity and global conditions. The wireless sensor networks help in detecting the forest fire. It can give a

warning as soon as if there unusual event occurs. [41-45]Sometimes, these networks can be making false alarms according to the wrong detection. Fire can be detected by using the amount of smoke. The smoke sensors are used to measure the amount of smoke from the fire, and it could be compared with a threshold value and if it is beyond that value, it is considered as a fire scenario. Using image processing, fire can be detected as soon as possible. Fixing the CCTV camera everywhere and the images from these cameras can be processed to monitor the fire. If any changes occur, it is easy to detect and extinguish the fire quickly. This system has a water extinguisher for extinguish the fire when the alarm turns on.[46-49] The CCTV camera is used for recording the video of a particular spot and it is connected to a minicomputer called Raspberry-pi. So that it could get the constant video recording of a particular area. The captured video pictures are processed frame by frame and once the fire detected, the alarm would be turn on. This paper proposes that forest fires can be detected by vision-based fire detection systems which can be mounted to an unmanned aerial vehicle (UAVs) for strategically scanning acreage of fire prone areas.

2.Literature Survey

[1] Abhay Chopde et al 2022 in this article used image processing and region proposals to identify fire related features. And also introduced advanced model in computer vision that segments an image into regions and classifies each region to detect objects. This provides High accuracy and early detection also Scalability is applied to various types of CNN. Limitations are it requires significant computational resources, Data Dependency and highly reliant on quality, it is complex.

[2] Zheng et al. 2024 in this article they used modified Convolutional Neural Network (CNN) and it has accuracy for detection. Modified Deep CNN is taken into this article for fire detection also thereis feature fusion Algorithm. High accuracy of 95.8% which indicates high reliability in detectingfires, Adaptability is more, low false alarm rate. Complexity is more also data dependency heavily relies on the quality and diversity of dataset.

[3] Kumari et al. 2024 had Mostly used deep convolutional neural networks, transfer learning are the techniques used. This involves using deep CNNs to process and analyse images for detecting forest fires. Efficient training and robustness, data augmentation helps in making models more robust. It hasthe limitation of CNNs require significant computational power and memory, which might be a limitation for deployment in resource-constrained environments.

[4] Megdad et al. 2024 Using a deep learning approach centered around a pre-trained (CNN) model, specifically VGG16. The techniques involved customizing VGG16 to classify forest fire images.The study aimed to leverage the robust feature extraction capabilities of the VGG16 model for forest fire detection. This approach helps in efficiently training the model.. Utilizing a pre-trained model like VGG16 reduces the need for extensive datasets, high efficiency and accuracy. Limitations of thisresearch is Despite the use of a pre-trained model, there is still a risk of overfitting, especially if the training dataset is not sufficiently large or diverse.

[5] Kalaivani et al. 2022 The core of this method is a custom CNN designed specifically for satellite image analysis to detect forest fires. The CNN architecture is tailored to process and analyse satellite images, focusing on features indicative of forest fires such as smoke and flames. The use of ALO helps in better parameter tuning, leading to more efficient training and potentially faster convergence. The inclusion of ALO adds to the computational complexity of the model, which mightrequire significant computational resources for training and deployment.

[6] Reis, H. C., et al. 2023 They used ResNet-50 architecture, which is adapted and fine-tuned to enhance its performance on forest fire detection tasks using a custom dataset. CNNs are designed for high accuracy in image recognition tasks. ResNet-50, known for its deep layers and, is used to avoid vanishing gradients and enhance learning efficiency. ResNet-50’s deep layers and skip connections enable effective feature extraction, crucial for accurate fire detection in diverse environments. The architecture of ResNet-50 can be complex to implement and fine-tune, requiring expertise in deep learning techniques.

[7] Paidipati Kiran Kumar ,et al.2024 This study has developed a new FFD Net technique for FFD in WSN by the use of CV and DL models. The major intention of the FFDNet technique is to identify the occurrence of forest wire using sensors in WSN and DL models. Primarily, the sensor nodes transmit the images to the BS where the actual classification process takes place. The range of wireless communication in WSNs is limited, which can be a challenge for large-scale deployments orin environments with obstacles that obstruct radio signals.

[8] Xu, R, el at.2021 This article chooses dataset techniques and yolo5 , Yolo is a state-of-the-art, real-time object detector, and Yolov5 is based on Yolov1- Yolov4. In this paper, a novel method basedon ensemble learning for forest fire detection is proposed. . Our ensemble model has good performance on ground fires, trunk fires, and canopy fires ,and small-scale, medium-scale, and big-scale fires at night.lack of diversity in the ensemble when models are trained independently or sequentially without considering their interactions.

[9] Almasoud, A. S, et al.(2023) Int this article a new IWFFDA-DL ,ACNN-BLSTM are the techniques used .Author described the response time of emergency corps dramatically affects the losses and consequences by them ,Hence the improvement of FFD and prevention schemes could be considered as a primary objective to conserve the environment . Advantage of using this technique is to identify forest fires at earlier stages through integrated sensors .

Datasets:

https://www.kaggle.com/datasets/brsdincer/wildfire-detection-image-data

Fig:1 Data Set1

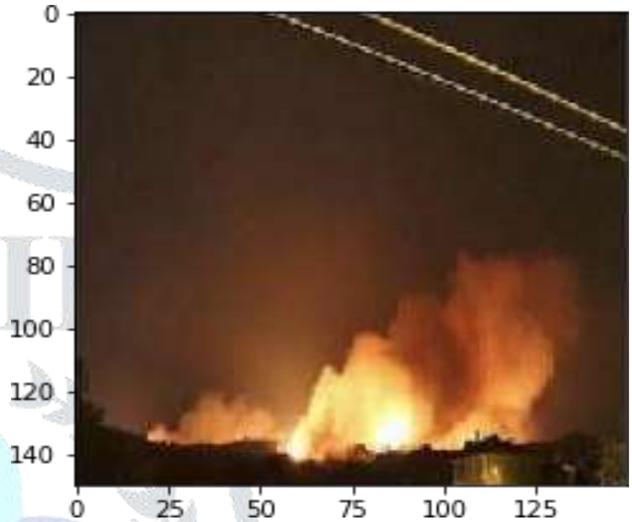

Fig:2DataSet 2

3.Existing System

The existing system for detecting fire are smoke alarms and heat alarms. The main disadvantage of the smoke sensor alarm and heat sensor alarms are that just one module is not enough to monitor all the potential fire prone places. The only way to prevent a fire is to be cautious at the time. Even if they are installed in every nook and corner, it just is not sufficient for an efficient output consistently. As the number of smoke sensor requirement increase the cost will also increase to its multiple. The proposed system can produce consistent and highly accurate alerts within seconds of accident of the fire. It reduces cost because only one software is enough to power the entire network of surveillance. Research is active on this field by data scientists and Deep Learning researchers. The real challengeis to minimize the error in detection of fire and sending alerts at the right time.

4.Proposed Framework

The proposed framework utilizes the advantages of a convolutional neural network. The CNN receives input, it is preprocessed and pools them using region of proposals. Then the region-based object detection algorithm in CNN classifies those proposals into fire and non-fire in the region of interest (ROI) with the help of convolutional layers.

4.1 Convolutional Neural Networks (CNN):

Convolutional neural networks are special kind of artificial neural network that can mimic the human brain activity to analyze data with supervised learning. CNN is modified multilayer perceptron, which means fully connected network. It consists of several layers namely, input layer, output layer and many hidden layers to make it happen. These hidden layers are convolutional hence the name convolutional neural networks. It offers beyond the limit abilities to perform object detection. These convolutional layers use several mathematical models to critically evaluate and analyze data. Now the image is in an abstract form, then the layers convertthis abstract image into a feature map. This is repeated layer after layer which simulates the working of brain neurons. Since it is fully connected network all the output gets filtered and combined as a single output in the output layer. The number of filters directly proportional to the feature map size.

4.2 Architecture:

The architecture of a Convolutional neural network comprises of convolutional layers. CNN is different from other object detection algorithms because of the ability to generate region of interest in the original image using image transform filters called as convolutional kernels. While other algorithms take the weighted sums and connection weights to build the model. The number of feature maps generated will be equal to the number of kernels. The pixel color in the feature maps represents activation points. White pixels in the feature map are points in the original image with strong activation points. Grey pixels represent weak activation points, Black pixels represents strong negative activation points. The fire region in the original image is reddish orange so the convolutional kernel changes the pixels to white. Each neuron in the convolution neural network receives an input from a restricted part of the previous layer.

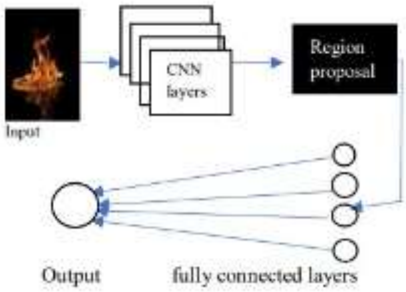

Fig :3 Architecture of CNN

The above Fig:3 represents the basic architecture of Convolutional neural networks, the data is given as input, images of fire in this case. Then the layers of the network make an abstract form of the image removing all background noises and highlight the object that needs to be detected.

4.3 METHODOLOGY

In this paper, the proposed methodology consists of different stages. The stages include

4.3.1 Acquisition Of Dataset

Data is in form of video frames which are obtained from CCTV footages, but for the ease custom made videos are to be used to perform training and test. the collection of such videos with fire is a tedious task. The frames with fire and without fire are then stored as respectively. Then we divide the dataset as training set and test set.

4.3.2 Data Preprocessing

Preprocessing is the next stage of building a quality Deep Learning model. Here, the data gets cleaned and processed or simply make the data fit for use. Data preprocessing consist of removing noises and other unwanted objects from the frame. The algorithm must require relevant data otherwise it may produce undesired results.

4.3.3 Feature Extraction

For the neural network to accurately detect fire, it needs to know the features of fire, how it looks like in computer's vision. The feature of fire is easily identifiable by human eye. Fire emits reddish color; it has a shape under different circumstances and motion depending on the fuel it uses to burn. In this paper, the shape, color and motion of fire and smoke is used for the detection. We extract the features from different frames in the training set..

4.3.4 Building The Model

The extracted features are then passed to the network to build a model. This model is a set of thresholds to help the network to accurately detect fire. The model learns from the features extracted and set a standard for analyzing new input data.

4.3.5 Validation and testing

Validation of the Deep Learning model is essential because it is clearly important to get the accuracy and see if the system is working. The validation process is executed using another set of video frame which is completely unique from the dataset provided to build the model. According, the test results the system achieved about 93 % accuracy with the validation set.

5.Algorithm

1.import matplotlib.pyplot as plt
2.import numpy as np
3.# Define specific values for epochs and model accuracies
epochs = np.arange(1, 11)
accuracy_model1 = [0.65, 0.70, 0.72, 0.75, 0.78, 0.80, 0.82, 0.83, 0.85, 0.87] accuracy_model2 = [0.60, 0.65, 0.68, 0.72, 0.74, 0.76, 0.78, 0.79, 0.80, 0.82] accuracy_model3 = [0.62, 0.67, 0.70, 0.73, 0.76, 0.77, 0.79, 0.81, 0.83, 0.84]

4.# Create the plot
plt.figure(figsize=(10, 6))

plt.plot(epochs, accuracy_model1, label='Deep Learning Model 1', color='blue', linestyle='-', linewidth=2)
plt.plot(epochs, accuracy_model2, label='Deep Learning Model 2', color='green', linestyle='--', linewidth=2)
plt.plot(epochs, accuracy_model3, label='Deep Learning Model 3', color='red', linestyle='-.', linewidth=2)

5.# Add titles and labels
plt.title('Comparison of Deep Learning Models over Epochs', fontsize=16) plt.xlabel('Epochs', fontsize=14)
plt.ylabel('Accuracy', fontsize=14)

6.# Add a legend plt.legend(fontsize=12)

7.# Customize ticks plt.xticks(fontsize=12)
plt.yticks(fontsize=12)
8.# Add a grid
plt.grid(True)
9.# Show the plot plt.show()

6.Results

The findings of the project are greatly satisfying. The system detected fire with an accuracy rate of 93 %. The result obtained show promise for implementation of Convolutional neural networks for detecting fire based on deep learning techniques compared to other neural networks. The system combines several training data intelligently for calculating and reduce false alarm rates with fully connected network. Then this data is passed to decision-making algorithm to classify whether there isa fire or not. Although it has minor detection errors in some images, the overall performance and statistics are super-efficient. The only downfall is that it is a bit slow because it needs more computational power to produce results. The score of false alarm may be reduced by cleaning thedata more and more. When implementing the rate of false alarm should be kept to minimum.

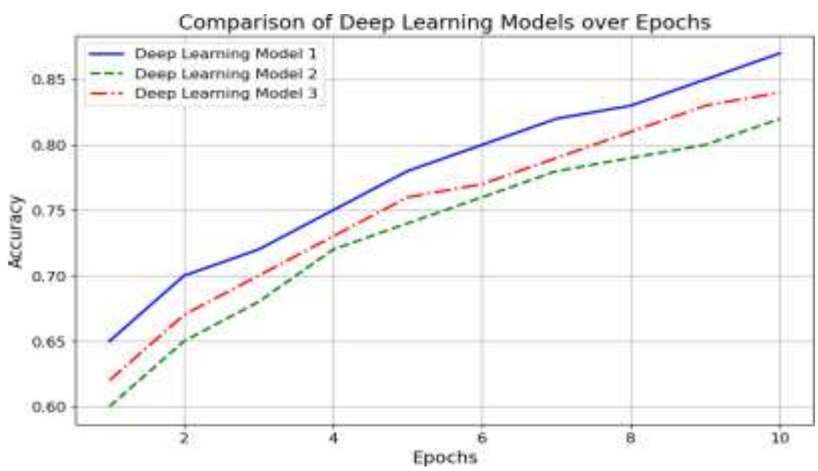

Fig:4 Comparison of DL Model

7.Conclusion

The scope of using video frames in the detection of fire using Deep learning is challenging as well asinnovative. If this system with less error rate can be implemented at a large scale like in big factories, houses, forests, it is possible to prevent damage and loss due to random fire accidents by making use of the Surveillance systems. The proposed system can be developed to more advanced system by integrating wireless sensors with CCTV for added protection and precision. The algorithm shows great promise in adapting to various environment. Detection of forest fires is an essential and challenging task. Here, due to the limitations of traditional methods, Deep Learning methods, which have recently become popular in image processing applications and pattern recognition in the automatic forest fire detection process, can effectively solve the problem. In this study, suspected flames undetected during forest fire surveillance were classified and their image features were extracted for improved recognition. Several feature extraction methods were systematically analysed and compared, with feature types being manually set. Following the construction of the CNN network model, the optimal learning rate and iteration number for precise flame detection were meticulously selected. Training was conducted with an established set of flame image samples, leading to the development of a robust training model. The model's accuracy was then evaluated against other models, with its superior performance underscoring the efficacy of the proposed approach. The model accuracy was on nearly to 0.86.

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