Emerging Methods For Early Detection Of Forest Fires

Abstract

This article surveys the literature on the detection of forest fire. Forest fires are a major environmental issue, creating economic and ecological damage while endangering human lives. There are typically about 100,000 wildfires in the United States every year. Over 9 million acres of land have been destroyed due to treacherous wildfires. It is difficult to predict and detect Forest Fire in a sparsely populated forest area. To overcome such situations, we proposed a Forest Fire Detection system using Convolution Neural Networks (CNN) which can detect fire in varying indoor and outdoor environments. To balance the efficiency and accuracy, the model is fine-tuned considering the nature of the target problem and fire data. Experimental results on benchmark fire datasets reveal the effectiveness of the proposed framework and validate its suitability for fire detection. It uses Computer Vision (CV) Technology to detect the forest fire by video frames given to the Deep learning model. If it predicts the fire detection then it will alert.

Introduction

As stated by National Institute of Disaster Management, Ministry of Home Affairs in their latest report on Forest Fire Disaster Management, forest fire is the major cause of injury and loss to forest. This loss due to fire has a major impact on forest ecosystem by indirectly affecting the nature’s ecosystem. As per one estimate of United Nations Development Program the loss due to such a fire in forest, economically will be around `9000/- per ha per annum. This means a single event of forest fire at a large scale will always cause a loss of worth crores which will turn the net asset of forest into ashes.

Therefore, greater emphasis is laid on the survey that can be used for the purpose of design and development of detection and monitoring system. Incidents which lead to regular forest fires include man-made incidents, climate changes, and other factors; there has been a constant increase in the frequency of forest fires.

In general fires that occur in the forest can be classified into three types which are:

GROUND FIRE

SURFACE FIRE

CROWN FIRE

Problem Statement

Fire detection is crucial task for the safety of people. To prevent damages caused by fire, several fire detection systems were developed. One can find different technical solutions. Most of them are based on sensors, which is also generally limited to indoors. However, those methods have a fatal flaw where they will only work on reaching a certain condition. In the worst-case scenario, the sensors are damaged or not being configured properly can cause heavy casualty in case of real fire. Those sensors detect the particles produced by smoke and fire by ionization, which requires a close proximity to the fire. Consequently, they cannot be used for covering large area. To get over such limitations video fire detection systems are used.

Project Description

Early detection of fire-accidents can save innumerable lives along with saving properties from permanent infrastructure damage and the consequent financial losses. Due to rapid developments in digital cameras and video processing techniques, there is a significant tendency to switch to traditional fire detection methods with computer vision based systems. Video-based fire detection techniques are well suited for detecting fire in large and open spaces. We aim to develop a classification model using Deep learning to recognise fires in images/video frames, thus ensuring early detection and save manual work. This model can be used to detect fires by processing the forest fire videos. Unlike existing systems, this neither requires special infrastructure for setup like hardware-based solutions, nor does it need domain knowledge and prohibitive computation for development.

Forest Fire Detection Techniques

With reference to the work carried out, development shown in the field of fire detection and monitoring, the techniques used can be under categories which use

1. Techniques which use animals as sensor or animal behaviour as sensors to detect fire.
2. Techniques which use Wireless Sensor Networks to detect fire.
3. Techniques which use image processing to detect and monitor fire.
4. Techniques which use cameras for visual interpretation to detect fire.
5. Techniques that use Unmanned Aerial Vehicles (UAVs) to detect fire.

Background Study

Forest fires break out in India from November-May every year due to various natural and anthropogenic reasons including accumulation of inflammable materials such as dry leaves, twigs, pine needles, etc.

This is 2.7 times more than the fires reported between November 2019 and June 2020. This includes large, continuous and repeated forest fires.

Odisha reported the maximum fires among all states (51,968), followed by Madhya Pradesh (47,795) and Chhattisgarh (38,106).

Uttarakhand recorded the sixth-highest fire counts in the country; incidences were up 28.3 times this forest fire season compared to last.

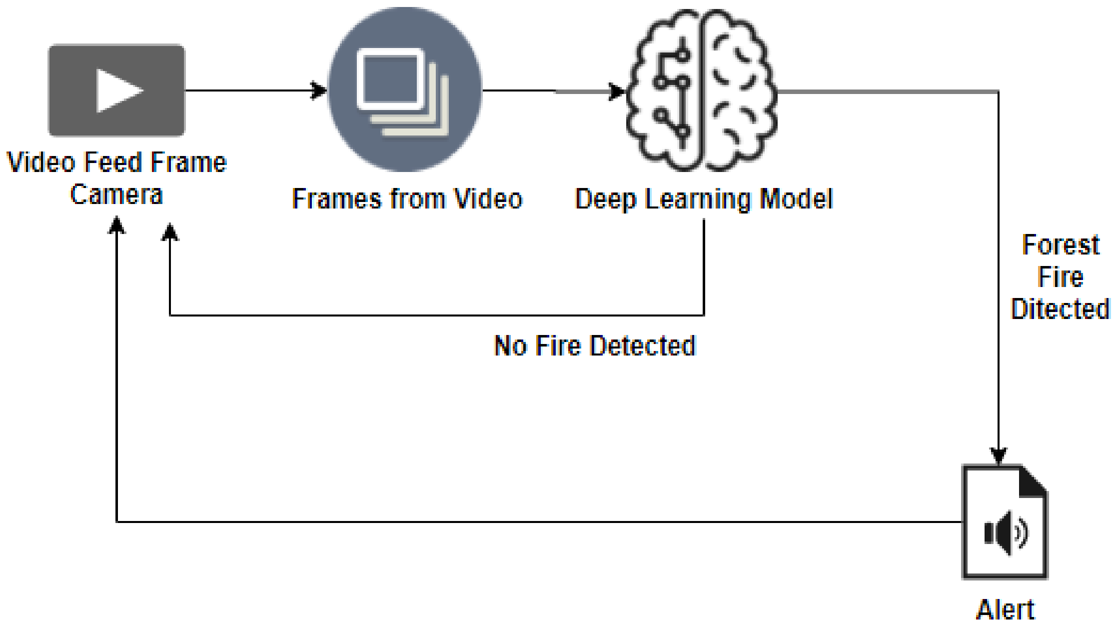
Project Objectives

Fire detection systems are designed to discover fires early in their development when time will still be available for the safe evacuation of occupants.Early detection also plays a significant role in protecting the safety of emergency response personnel.

Property loss can be reduced and downtime for the operation minimized through early detection because control efforts are started while the fire is still small.

Most alarm systems provide information to emergency responders on the location of the fire, speeding the process of fire control.

System Architecture



- First, User interacts with a web camera to read the video.
- Once the input image from the video frame is sent to the Deep learning model, if the fire is detected it is showcased on the console, and alerting sound will be generated and an alert message will be sent to the Authorities.

Here we use Convolution Neural Networks for the deep learning model and to interact with the user we use Computer vision (CV) to get input of video.

Data collection

Artificial Intelligence is a data hunger technology, it depends heavily on data, without data, it is impossible for a machine to learn. It is the most crucial aspect that makes algorithm training possible. In Convolutional Neural Networks, as it deals with images, we need training and testing data set. It is the actual data set used to train the model for performing various actions. The dataset contain with different set of class's Normal Forest and Forest with fires. To evaluate the model, we divide the dataset to 70% for training data and 30% for testing the data.

Image Preprocessing

Image Pre-processing includes the following main tasks

1. Import ImageDataGenerator Library.
2. Configure ImageDataGenerator Class.
3. Applying ImageDataGenerator functionality to the trainset and test set.

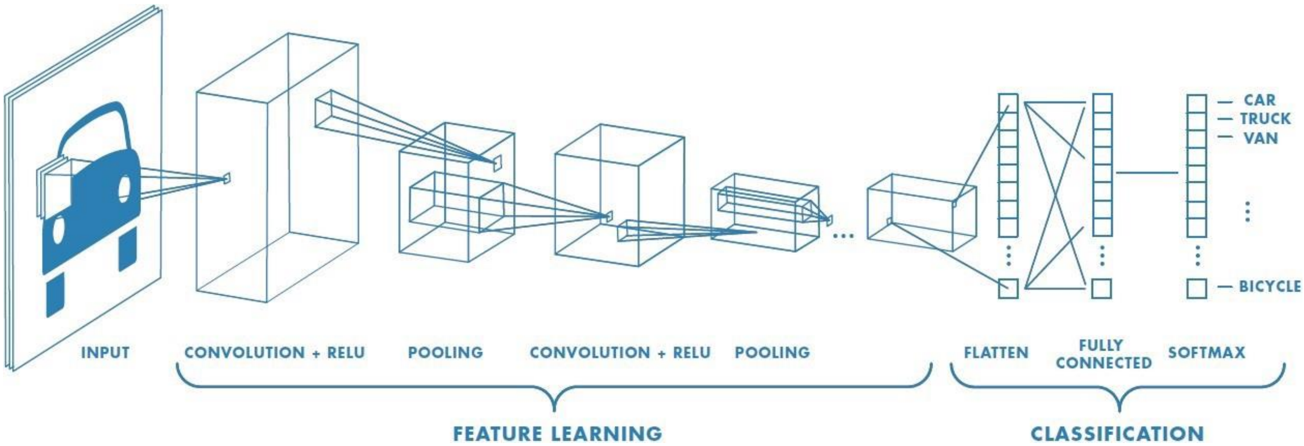
The ImageDataGenerator accepts the original data, randomly transforms it, and returns only the new, transformed data.

The dataset images are to be preprocessed before giving it to the model.

Methodology

The methodology is proposed using CNN (Convolutional Neural Networks) model. The image datasets are created from fire images captured by videos and converting it into frames. Some images in the dataset are added to dataset taken from Kaggle. Images are to be classified as fire and non-fire. Number of images in the datasets for fire and non-fire is 2316 and 541 respectively. Totally there are 2857 images. These images are resized as (300,300) and then reshaped as (-1,300,300,1) and stored as a linear array. This is given as a input to the convolutional layer

The neural network model is to be built by adding different network layers like convolution, pooling, flattening, dropout and neural layers.



we start building our model by:

1. Initializing the mode
2. Adding Convolution layers

3. Adding Pooling layers
4. Flatten layer
5. Full connection layers which include hidden layers

In these operations, several kernels of different sizes are applied on the input data to generate feature maps. The model consists of 64 convolution filters of size 3x3 each. The feature maps go through a ReLU activation function. These feature maps are subjected again to convolution layer and pooling layer which has kernel size of 3x3. Then a flatten layer which converts 2D feature maps into a vector that can be fed to fully connected layer. Among these three main operations, the convolution and fully connected layers contain neurons whose weights are learnt and adjusted for better representation of the input data during training process.

A dense layer represents a matrix vector multiplication. The values in the matrix are the trainable parameters, which are updated during back propagation. Therefore, you get an m dimensional vector as output. Finally, we have an activation function such as Softmax to classify the outputs as fire and non fire. Softmax function provides a probability distribution that maps output to a 0 to 1 range. That’s why it is used as final layer of classifying model. The model is compiled using an Adam optimizer which provides an adaptive learning rate to find individual learning rate of each parameter. Categorical cross entropy loss function is used in this classification as only one result could be correct.

At last, we compile the model with layers we added to complete the neural network structure.

CNN-based Fire Detection

After the training and fine-tuning process, a target model is achieved which can be used for prediction of fire at early stages. Unlike conventional fire detection methods, where a lot of effort is required for pre-processing as well as feature engineering, our proposed CNN-based method does not require any pre-processing. Further, it avoids the conventional time-consuming and tedious approaches of extracting hand-crafted features as it learns very powerful features automatically from the provided data in raw form. In addition to this, the proposed CNN-based model learns details at small scales, enabling it to detect fire even at small scale, i.e., in the early stages. For testing, the query image is passed through the proposed model, which results in probabilities for both classes of fire and normal. Based on the higher probability, the image is assigned to its appropriate class.

Confusion matrix

The number of correct and incorrect predictions are summarized with count values and broken down by each class. The confusion matrix shows the ways in which your classification model is confused when it makes predictions. It gives us insight not only into the errors being made by a model but more importantly the types of errors that are being made. Actual labels (Y) and Predicted labels (Z) are used to compute the confusion matrix.

	CLASS-1 PREDICTED	CLASS-2 PREDICTED
CLASS-1 ACTUAL	TP	FN
CLASS-2 ACTUAL	FP	TN

Here,

- **Class-1** : Positive (Fire)
- **Class-2 :** Negative (Non-Fire)
- **True Positive (TP) :** Actual is positive, and is predicted to be positive.
- **False Negative (FN) :** Actual is positive, but is predicted negative.
- **True Negative (TN) :** Actual is negative, and is predicted to be negative.
- **False Positive (FP) :** Actual is negative, but is predicted positive.

Accuracy is given by the relation:

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

Recall is given by the relation:

$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

Precision is given by the relation:

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives + False Positives}}$$

High recall, low precision: This means that most of the positive examples are correctly recognized (low FN) but there are a lot of false positives.

Low recall, high precision: This shows that we miss a lot of positive examples (high FN) but those we predict as positive are indeed positive (low FP).

F-measure: Since we have two measures (Precision and Recall) it helps to have a measurement that represents both of them. We calculate an F-measure, which uses Harmonic Mean in place of Arithmetic Mean as it punishes the extreme values more. F-Measure will always be nearer to the smaller value of Precision or Recall.

$$F_1 = 2 * \frac{precision * recall}{precision + recall}$$

Conclusion & Future Scope

Fire detection systems increase response times, as they are able to alert the correct people in order to extinguish the fire. This thus reduces the amount of damage to the property. Fire detection systems can be connected to sprinklers that will automatically respond when a fire is detected. The potential benefits, feature of interest for forest fire detection monitoring and providing assistance to firefighting have been highlighted in the review of the literature. Fire is the most dangerous abnormal event, as failing to control it at an early stage can result in huge disasters leading to human, ecological and economic losses. Fire accidents can be detected using the cameras.

So that, here we proposed a CNN approach for fire detection using cameras. Our approach can identify the fire under the camera surveillance. Furthermore, our proposed system balances the accuracy of fire detection and the size of the model using fine-tuning of datasets.These values shows that the model gives a better prediction. We conduct experiments using datasets collected from recording of fire and verified it to our proposed system. In view of the CNN model's reasonable accuracy for fire detection, its size, and the rate of false alarms, the system can be helpful to disaster management teams in controlling fire disasters in a short time. Thus, avoiding huge losses. This work mainly focuses on the detection of fire scenes under observation.

Future studies may focus on deploying the model into raspberry pi and using necessary support packages to detect the real time fire by making challenging and specific scene understanding datasets for fire detection methods and detailed experiments.

References

- Punam Patel and Shamik Tiwari in(2016) proposeda paper entitledFlame Detection using Image Processing Techniques in International Journal of Computer Applications Volume 58– No.18.

- Jareerat Seebamrungsat, Suphachai Praising, and Panomkhawn Riyamongkol in (2014)proposeda paper entitled Fire Detection in the Buildings Using Image Processing in Third ICT International Journal of IEEE Access in Department of Electrical and Computer Engineering.

- Khan Muhammad and Jamil Ahmad in (2018) proposed a paper entitled Efficient deep CNN based fire detection system and localization in video surveillance system at IEEE Transactions on Systems, Man, and Cybernetics Systems.

- Abdulaziz and Young Im CHO in (2018) proposed a paper entitled An Efficient Deep Learning Algorithm for Fire and Smoke Detection with Limited Data in IEEE Explore Advances in Electrical and Computer Engineering.

- Qingjie Zhang, Jiaolong Xu, Liang Xu and Haifeng Guo in ([2016) proposed a paper entitled Deep Convolutional Neural Networks for Forest Fire Detection in International Forum on Management, Education and Information Technology Application by Aviation University of Air Force, Changchun.

- Sebastien Frizzi1, Rabeb Kaabi, Moez Bouchouicha, Jean-Marc Ginoux in (2017) proposed a paper entitled Convolutional Neural Network for Video Fire and Smoke Detection in IEEE Transactions