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Forest fire detection using Advanced Technology

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Abstract-With the increase in the evolution of technology, the likelihood of occurrence of various natural and man-made calamities have also drastically risen. Forest fires have become a prominent disaster in recent times. Forest fires not only destroy animal life and vegetation but also affect the overall groundwork of a community. Global warming and climate change have resulted in a spike in the forest fire occurrences over the globe. Forest fires are gaining a lot of attention due to the large-scale destruction that they cause worldwide. Pollution is a subsequent product of forest fires and will directly contribute to the overall deteriorating climate crisis. As of now there isn't any standard fire warning system being implemented for early detection of forest fires. Hence the warning message to fire rescue authorities are often long delayed. Various methods such as sensing the fire using fire sensor, UAV (Unmanned Aerial Vehicle), WSN (Wireless Sensor Network) and satellite-based techniques have been experimented on, previously. We propose a Technique where a classification-based algorithm is used for the detection of forest fires and it is implemented in the following stages. Initially the model is trained on CNN (Convolutional Neural Network) classification algorithm. Background subtraction method is applied to the frames extracted from the video, to detect the region that contains movement. Color detection is then performed on the specific frames. The trained model is then utilized to predict the fire and non-fire probabilities.

Keywords: Convolution neural network (CNN), Background subtraction, Color Detection, Region of Interest

I. INTRODUCTION

Forest commitments to economic development are remarkably enormous and broad. Forests play a vital role in meeting rural needs, ensuring food security and having a better source of revenue; proposing promoting opportunities for mid-term green growth; and providing basic long-standing natural ecosystems such as clean water and air, protecting biodiversity and global change mitigation. For our endurance, we rely on the forests, from the air we people breathe to the wood we use. In addition, forests also provide watershed safety, reduce soil erosion and minimize climate change by creating habitats for animals and livelihoods for humans. The immense threat that forest fire poses on economic properties and community safety has resulted in increase in demand for the development of more efficient forest fire detection systems. Every year forest fires ruin hundreds and thousands of hectares, and over 2 Lakh forest fires occur all across the globe. It has resulted in destruction of an approximate area of between 3.5 and 4.5 million km. The common approach for fire detection is training humans and appointing them as inspectors, as the management of human resource was not cost effective as well as the productivity of these methodologies were very poor so initially, fire sensors were seen as an alternative method for particles detection which were caused by fumes or fire, heat etc. But the major disadvantage was, they had to be located in the area nearer to the fire or the sensing range of the fire, and the approach fails to provide precise details about the burning phase, such as fire location, intensity, rising rate, etc. Computer-based fire detection which was vision-based providentially fetches us a modern approach which overcomes the shortcomings of the above methods. The frequently used methods in fire detection is based on sensor technology which is dependent on pressure, humidity, and temperature changes. Nevertheless, running these systems in wide open spaces is restrictive for various reasons which includes high price, energy need of the sensors, and the physical damage to the sensors which is caused due to the nearness of the sensor to the fire for sensing accurately. The methods which is based on the sensors is more likely to have high number of false positives, and it also has a very long response time. Ample motivational factors exist for the use of a fire detection systems making use of image processing. With the development of digital camera technology, we can avail images of high quality at reduced costs and they provide wide coverage area and their response times are higher than those of the pre dominant sensor models. Hence the total expense of image processing models are comparatively lesser than the current ones.

II. PREVIOUSWORK

Mubarak A.I. Mahmoud and et al., came up with a model to detect the forest fire, which is implemented by the use of temporal variation and the fire rules. Originally, [1] background subtraction is exercised for the region-based movement. And also, the obtained RGB image is converted to YCbCr color image to which the five rules of fire recognition are applied. The fire and non-fire objects are segregated using the approach of temporal variation. Kumarguru et al., came up with an algorithm which is compatible with surveillance systems such as CCTV, UAV wireless camera. The algorithm presented in this study basically detects the fire color [2] which is predominantly interpreted by the intensity of the red-colored variable R. Fire growth is spotted using tracking of sober edges. Subsequently, a color-based classification method was employed to define the region of interest.

Mubarak E.I. Mahmoud and et al., Proposed a technique of forest fire detection video dependent image processing. The implemented algorithm consists of four main phases, first of [3] all the background-subtraction algorithm is used to extract moving regions. Furthermore, candidate-free regions are computed using spatial domain CIE L*a*b *. Consequently, wavelet analysis is employed. At last, to recognize the region of interest, support vector machine has been used. C. Emmy Premal and et al., Only for its less ambiguity and relevance, the proposed approach incorporates a color space based on the rules. The input RGB image [4] will be converted to color space YCbCr, mean and standard image deviation is found in the plane YCbCr. The protocols for fire detection tend to differentiate between fire and non-fire pixels. Dr.M. P Sivaram Kumar and et al., The analysis uses [5] support vector machine to identify the patterns and image segmentation is also being used. Using a gradient histogram (HOG), an inventive method, the attributes are extorted such as gradient, angle, size etc. Mahadev A. Bandi and et al, Analysis of the retrieving of flames in a video by motion and edge detection methodology is [6] presented in this paper. This scheme is updated over all prevailing ones. This technique appropriately spots the edges of the flames by removing the noise. The novel model offers an efficient way for the detection of the fire in terms of a smaller amount of false fire detection by providing the exact result of the presence of fire.

D Sathya, proposed a forest fire detection system using different color segmentation techniques and support vector machine classification algorithm. Originally, [7] spatial color segmentation is used to detect fire like objects, then the temporal segmentation is used to extract dense flow and sparse flow of fire and global motion mitigation is used for motion compensation, at last Support Vector Machine classification algorithm is used differentiate between fire and non-fire. Vipin V, developed a forest fire detection [8] algorithm using color models and fire detection rules. A color model that is YCbCr and RGB color space is used to detect fire and fire like objects. The fire rules are applied to classify image as fire and non-fire pixel.

LI Jie et al., Proposed a digital image-based control system. The system is based on the characteristics of the CCD configuration and is used to detect and locate information [9] about the fire color. Staffed lookout posts are usually located all over the world in the woods. A system capable of generating automatic fire alarms will be built in this project. The system developed will be able to approximately determine where the fire is located, and wireless communication systems are used to monitor fire. This method will reduce the number of false alarms owing to natural events. Nargess Ghassempor and et al., The proposed architecture incorporates scale-invariant transform features (SIFT) and uses them for use in fire detection. The frameworks [10] were connected to various classifiers and clusters, and various fire and non-fire image data sets were trained and tested. Implementation of accuracy and sensitivity of two classifiers was checked. Using the SVM classification, the experimental results shows accuracy of 94.7 %.

Guoli Zhang and et al., A CNN architecture was developed that is ideal for estimating forest fire susceptibility, and hyper parameters were enhanced to advance predictive accuracy. The trained model was fed with the test dataset in order to construct the forest fire vulnerability spatial prediction map in Yunnan Province. Finally, the predicted model's [11] prediction output was evaluated using various statistical measures — the Wilcoxon signed-rank scale, operating characteristic curve at the receiver, and the region under the curve (AUC). The results depicts that the accuracy of the anticipated CNN model (AUC 0.86) was higher than the support vector machine and multilayer perceptron neural network. Byoungjun Kim and et al., In this paper, they put forward a deep learning fire detection system that uses a video sequence. This technique uses the Convolutional Neural Network (R-CNN) based in the Faster Region to identify the suspected [12] fire regions (SRoFs) and non-fire regions built on their spatial characteristics. Long Short-Term Memory (LSTM) then gathers the brief features in consecutive frames within the bounding boxes to categorize whether a fire happens or not. And also, the flame and smoke areas along with their temporal changes are calculated and conveyed to interpret the dynamic behavior of the fire

Ahmad AA Alkhatib developed a Wireless sensor network where all the network nodes which only uses temperature sensors in which a particular threshold temperature is set and once this temperature value crosses the threshold limit, the sink receives an alarm message from the node. The concept implemented is dependent only on the behavior of node, where the warning message [13] is given about the likelihood of crises indicating the beginning of the wild fire or just a calm fire. This methodology implemented draws conclusions following the fire path and also analyses the reasoning that accompanies it. Michel Owayjan et al., this paper focuses on the influential characteristics of WSN as a likely elucidation of early forest fire recognition. The device [14] shown uses numerous sensors, solar recharging machines and wireless data transmission. The data collected will be sent to a nearby control unit which is analyzed and posted in online database associating the Civil Defense unit, if appropriate. The clear authorities will access this website in order to take primary action in the event of any warning. YongMin Liu et al., this paper is implemented using wireless sensor network, which is based on data accumulation method, a modern [15] technique for forest fire supervision and recognition has been produced. The projected method provides more effective response to forest fires utilizing the energy of WSN that has been authenticated and calculated in huge simulation experiments. J.R. Martinez-de Dioz et al., this paper uses the technique of computer vision for forest fire detection, where forest parameters [16] such as flame height, flame inclination angle, etc. are being analyzed. The proposed system uses a fire perception 3D model that can also be used in remote computer systems to visualize the growth of the fire. It makes use of techniques like sensor fusion which is related to GPS and sensors.

III. METHODOLOGY

Fig 1 shows flow of the model proposed. The proposed system consists of multiple stages. First, background subtraction is used to identify movable objects in videos. Second, a color detection model is used to highlight the region of interest. Finally, CNN is used for classifying the fire or non-fire images. The various stages of the proposed algorithms as shown below.

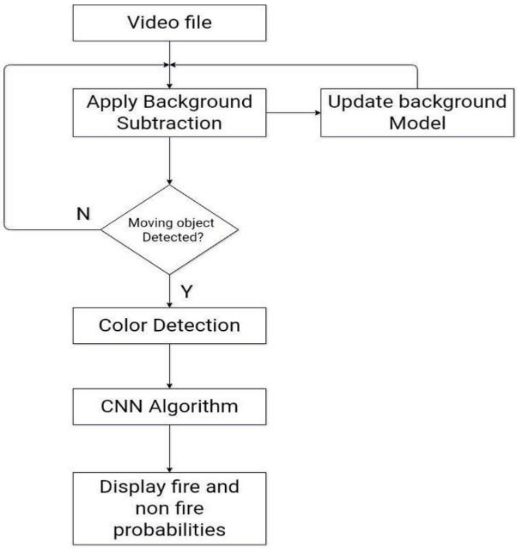

Fig 1: Flowchart of the proposed model

A. BACKGROUND SUBTRACTION

It is the most commonly used approach to analyze video and detect objects in motion. This technique identifies moving objects from the difference between the present frame and a background frame. The important step in most of the fire detection methods based on a video is detecting moving objects, because the boundaries of the fire changes continuously. Eq. (1) calculates the contrast between the present image and a background image to determine the region of motion. If eq.1 is satisfied then a pixel at the coordinates (x, y) is expected to be in movement

$$|In\ (x, y) – Bn\ (x, y)| > thr \quad (1)$$

Where In (x,y) and Bn (x,y) represents the pixel value at co-ordinates (x,y) for the present and a background frame, and thr(threshold) refers to a threshold value. The values of the background is frequently updated using Eq. (2) as follows

$$B_{n+1}(i , j) = B_n(x, y) + 1 \text{ if } I_n (x, y) > B_n(x, y)$$

$$B_{n+1}(i, j) = B_n(x, y) - 1 \text{ if } I_n (x, y) < B_n(x, y)$$

$$B_{n+1}(i, j) = B_n(x, y) \quad 1 \text{ if } I_n (x, y) = B_n(x, y) \quad (2)$$

where Bn+1(x, y) and Bn (x, y) represents intensity pixel value at co-ordinate (x, y) for the present and background frame.
Figure 1 and 2 below shows the outcome of background subtraction.

B. COLOUR DETECTION

- BGR Color space:

BGR stands for Blue Green Red. BGR color is saved in a structure with Red occupying the least significant area, Green the second least, and Blue the third least

- HSV Color Space:

Hue, Saturation, Value (HSV) model is used to detect an object with a certain color and to reduce the influence of light intensity. HSV is a color pattern that is used in graphics and paint programs, instead of the RGB color space. Black or white color is added to the color specified.

- Grayscale color space:

The different shades of Gray in an image is utilized in grayscale mode. The brightness value of each pixel in a gray scale picture ranges from 0 to 255. The number of gray shades in 16and 32-bit images is considerably greater than the 8-bit images. By computing the percentage of black coverage in an image we can find the values of grayscale mode.

C.TRAINING THE MODEL ON CNN ALGORITHM

The proposed model is trained on a classification-based algorithm, Convolutional Neural Network (CNN). In Convolutional Neural Network, to distinguish one image from the other image weights and biases are assigned to different objects within an image. Compared to other classification algorithms the pre-processing needed for convolution network is smaller.

Steps:

- Convolution
- Max Pooling
- Flattening
- Fully connected layer

IV. RESULTS

The proposed model is implemented using Spyder (Anaconda 3) and it was tested using Intel Core i5 1.6 GHz 8 GB RAM PC.

RESULTS OF BACKGROUND SUBTRACTION

Fig 2: Frames from the original videos of fire used for detection

Fig 3: Output after background subtraction and color detection where fire region is detected based on the manually given threshold value of fire color.

FINAL OUTPUT:

FIRE AND NON-FIRE PREDICTIONS AFTER TRAINING

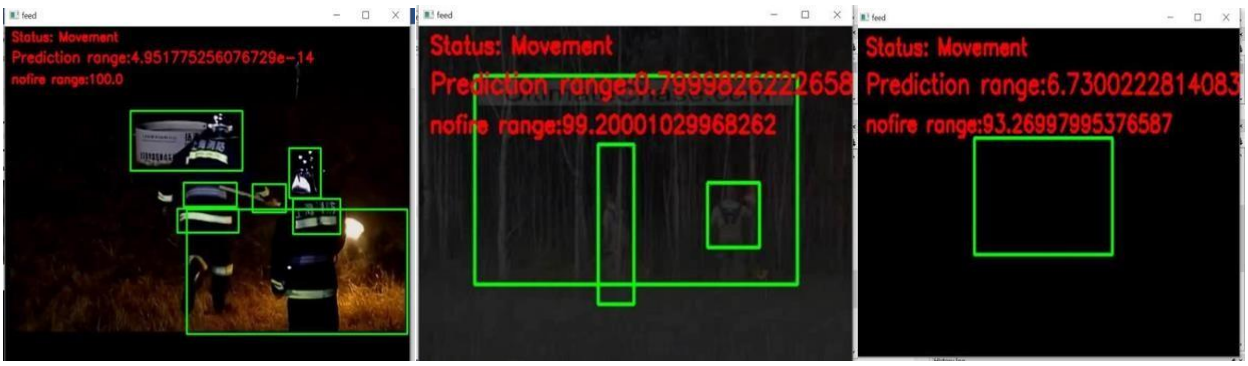

Fig 4: Detection of movement in the video is highlighted by a bounding rectangle and fire and non-fire range is displayed. Here, no fire detected. Hence the non-fire range is 100.

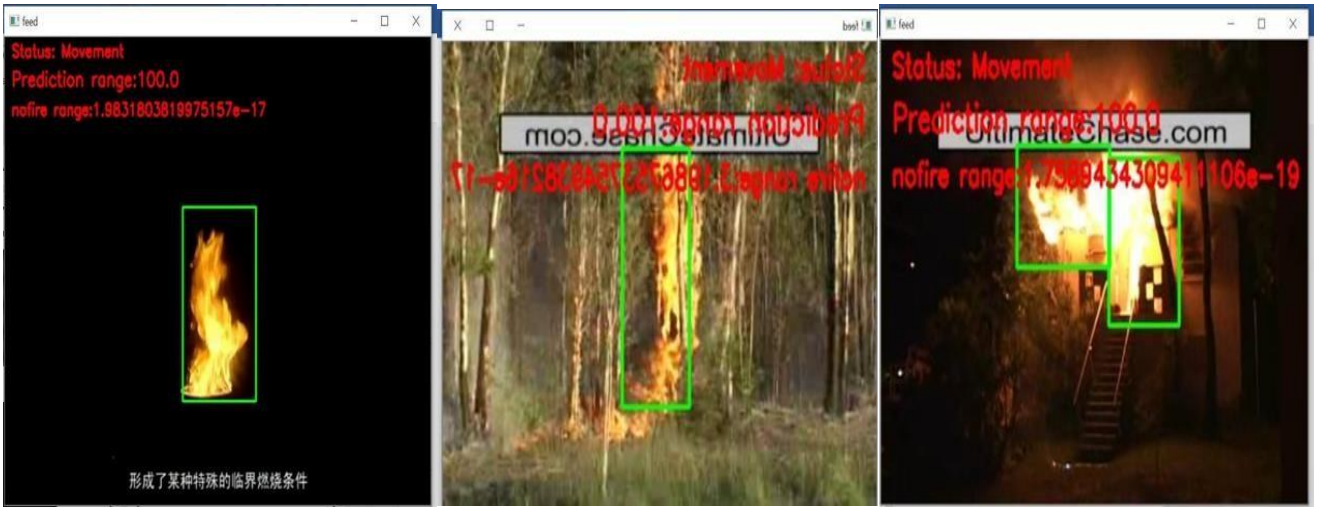

Fig 5: Fire prediction after the fire is detected. Hence the prediction range after detection is 100.

V. PERFORMANCE EVALUATION

A parameter called F-score is used to inspect the performance of the proposed algorithm

F score:

The F-score is used to analyze the performance of the forest fire detection algorithm. For a specified detection method, there are four feasible outcomes;

- True positive where an image of fire is recognized as fire by the proposed algorithm.
- False-negative where the same image is identified as non-fire by the proposed algorithm.
- True negative where an image of fire is recognized as fire by the proposed algorithm.
- False positive where the same image is identified as non-fire by the proposed algorithm.

Fire detection method is assessed with the help of following equations:

$$F = [(Precision * recall) / (precision + recall)] * 2 \quad (3)$$

$$Precision = TP / (TP+FP) \quad (4)$$

$$Recall = TP / (TP+FN) \quad (5)$$

Where F denotes F-score.
TP denotes true positive. TP rate is TP per fire image.
TN denotes true negative. TN rate is TN per non-fire image.
FP denotes false positive. FP rate is FP per non-fire image.
FN denotes false negative. FN rate is FN per fire image.
Comparison of evaluation of the proposed model with other fire detection methods

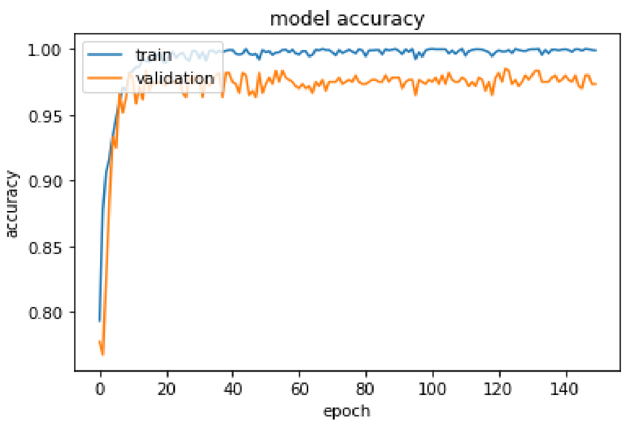

Fig 6: Model accuracy graph

The above graph is plotted between epochs and accuracy of the model showing the variations in accuracy with increasing epochs. It is plotted for training and validation set. We can infer that accuracy of the model increases as the number of epochs increase. The model is accurate with the accuracy of both training and validation set being above 95%. The training accuracy is greater than the validation accuracy and both are parallel to each other, which proves that the model isn't overfitted.

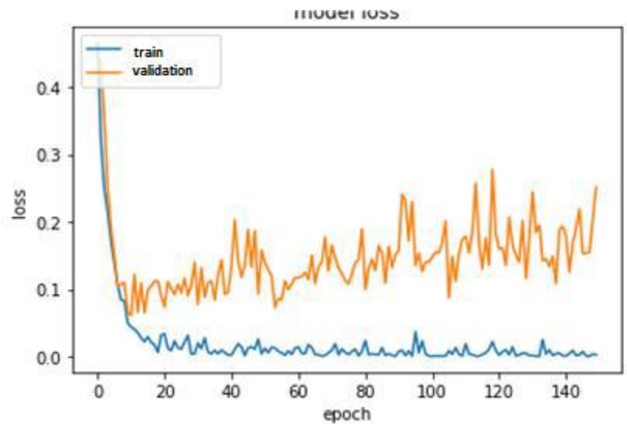

Fig 7: Model loss graph

The above graph is plotted between epochs and loss for both training as well as validation set. Loss indicates bad predictions. We can notice that as the number of epochs increase the training and validation loss drops. We can infer from the graph that the loss decreases very rapidly in the beginning, to decrease only lightly as the number of epochs increase. The training and validation loss plots are almost parallel to each other and they start to depart consistently at some point which in our case is at 150th epoch. So, we need to stop the training at that point in order to prevent overfitting.

Table 1: Comparison of the performance with existing techniques.

Methodi	True Positive Rate	False Negative Rate	True Negative Rate	False Positive Rate	Recall	Precision	F-Score
Mubarak AI Mahmoud [1]	95	7	93.4	7.6	93.13	92.29	92.86
Vipin [8]	86	9.5	82	11	90.1	88.7	89.38
Mubarak AI Mahmoud [3]	94	5	90	8	94.8	92.2	93.52
Proposed model	93.47	6.5	98.6	1.3	91.96	98.60	95.16

VI. CONCLUSION

Forest fire detection is implemented using Convolution Neural Network (CNN), a deep learning algorithm. Performance of the proposed model is computed on a number of videos downloaded from the internet (http://www.ultimatechase.com). Background subtraction method is employed to detect the region from the video that contains motion. Detection of fire based on color is performed by masking the specific frame with red color threshold. CNN algorithm is used for classifying the candidate region to real fire or non-fire. The trained model is utilized to predict the fire and non-fire probabilities of moving region in the video. The final results of the proposed model exhibits that it has an accuracy of 95.16%. The obtained result suggests that the described system is accurate.

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