FOREST FIRE DETECTION USING MACHINE LEARNING

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***Abstract*-In this paper, we propose a novel system for detecting fire using Convolutional Neural Networks (CNN). Detection of fire can be extremely difficult using existing methods of smoke sensors installed in the buildings. They are slow and cost inefficient due to their primitive design and technology. This paper critically analyzes the scope of Artificial intelligence for detection and sending alerts with video from CCTV footages. This project uses self-built dataset containing video frames with fire. The data is then preprocessed and use the CNN to build a machine learning model. The test set of the dataset is given as input for validating the algorithm and experiments are noted. The project focus on building cost efficient and highly accurate machine that can be used in almost any use case of fire detection.**

Keywords: Fire detection, Convolutional neural networks, Machine learning, CCTV, Object detection.

I. INTRODUCTION

Fire can make major hazards in this hectic world. All buildings and vehicles used in public transportation have fire prevention and fire protection systems due to the accelerated number in the fire incidents. Also, many of the firms conduct a mock fire drill in every occurrence of months to protect their employees from the fire. This would help them to understand what to do or what not to do when a fire situation happens. Forests are one of the main factors in balancing the ecology. It is very harmful when a fire occurs in a forest. But most of the time, the detection of forest fire happens when it spread over a wide region. Sometimes, it could not be possible to stop the fire. As a result, the damage of the environment is higher than predictable. The emission of large amount of carbon dioxide (CO2) from the forest fire damages the environment. As well as it would lead to complete disappearance of rare species in the world (Alkhatib, 2014). Also, it can make an impact on the weather, and this make major issues like earthquakes, heavy rains, floods and so on.

The forest is a large surface of area filled with trees, lots of dried leaves, woods and so on. These elements encourage the fire when it starts. The fire can be ignited through many reasons such as high temperature in summer seasons, smoking, or some parties which having fireworks. Once fire starts, it will remain until it distinguished completely. The damage and the cost for distinguish fire because of forest fire can be reduced when the fire detected early as possible. So, the fire detection is important in this scenario. Finding of the exact location of the fire and sending notification to the fire authorities soon after the occurrence of fire can make a positive impact. There are different types of fire detection methods used by the Government authorities such as satellite monitoring, tower monitoring, using sensors, optical cameras and so on.

There are some other techniques used for fire suppression. The major one is burning the dry areas or like in Canada; they are using flying water tanks for fire suppression. In middle east countries, these elements sweep away and burnt it in a certain unfuelled place. But, in Australia, they provide fire in these areas and wait until it dies itself without make any danger to the wildlife or humans.

A research study shows an automatic fire detection can be divided into three groups: aerial, ground and borne detection. The ground-based systems use several staring black and white video cameras are used in fire detection which detect the smoke and compares it with the natural smoke. The main benefit of using this system is high temporal resolution and spatial resolution. So that, the detection is easier (Eric den breejen, 1998). But these mechanisms still have some drawbacks in detecting the early stage of the fire.

So that, it is highly important to introduce a system to detect the fire early as possible.

II. 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 al 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 machine learning researchers. The real challenge is to minimize the error in detection of fire and sending alerts at the right time.

III. LITERATURE REVIEW

[1]. In this paper, the author uses CNN-convolutional neural networks to detect fire with the help of live video footage through anti-fire surveillance systems. The paper proposes YOLOv2 convolutional neural network is one of the best solutions for detecting fire and smoke both indoor and outdoor environment. You only look once (YOLO) is a deep learning model for object detection, YOLOv2 is the next version which has been upgraded to rectify the setbacks of YOLO namely the inaccuracy to locate and mark the region of interest in the images and the lower recall rate compared to other region-oriented algorithms. Thus, increasing the efficiency of the architecture. They started with an input image of size 128x128x3. They used convolutional layers to map the features on the input image. The features extracted are then given as input to YOLOv2 object detection subnetwork. YOLOv2 Transform layer is implemented to improve network stability for object localization.

[2] 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. This paper also strongly recommends Convolutional neural networks for identifying smoke and fire through videoframes which is taken as images. They have collected the dataset from different internet sources. They have resized the images to canonical size of 240x320. In this paper, the basic idea is to find the fire patches in an image. The authors propose two methods for the algorithm to build the model. First was to apply fire patch classifier from scratch. Second was to teach a full image classifier and apply fine-tuned patch classifier if the image contains fire. Then they compare SVM-pool5 (Support vector machines) with CNN-pool5, the accuracies recorded are 95.6% and 97.3% respectively with a detection rate of 84.8%, making CNN-pool5 network more accurate than SVM-pool5 classifier.

[3] In this paper, Environment can be destroyed by the forest fire, and it could be making a huge amount of loss. Recently, the amazon forest has had a fire and it remained for over 15 days. 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 any unusual event occurs. Sometimes, these networks can be making false alarms according to the wrong detection. In such cases, machine learning mechanism can be used to prevent such cases. Earlier, satellite-based systems are used to detecting fire. But it may not be possible to finding the distraction as it took pictures of surface of the earth in every two days. As a result, it may not be considered as an effective method. Also, the weather conditions may be affected in the quality of the pictures. Another method for the fire detection was using watch towers. It was handled manually by watching the whole forest area in a tower and finding if there any fire occurs. Another one is using optical sensors and digital camera. It would not be much effective as the vision can be distracted by the high trees or hills.

[4] 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. The CCTV camera is used for recording the video of a particular spot and it is connected to a mini-computer 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.

Also, the alarm would be turned off when the fire extinguished completely. The Virtual Network Computing is used for the execution of the program, where the details of video are transferred from the raspberry-pi to the viewing computer. This system includes detection, alert, fire extinguish, software and network modules.

[5] In fire detection, the color of the image from a camera is highly important. Sometimes, it does not possible to watch the entire forest images according to the size as it may be some difficulties in detecting the fire. So that, using Convolutional Neural Network (CNN) technology would be easier to avoid the blindness and accurate level of fire identification. It uses the support vector mechanism for the image classification. In this technique, the image is segmented based on the color of the flame and transferred to the CNN network. This would be found out more attributes and decide there is a fire occurs or not. Fire can be detected by analyzing the color of the flame in a picture. Finding the fire by using the number of pixels plotted in a picture according to the fire color and can be measure the intensity of the fire. So that, it should be easier to detect fire and stamp out the fire. The system should be trained and tested using a large amount of data. Algorithms are used for the segmentation of images and in finding the fire. This method should be more effective and reliable in identifying the fire. The accuracy should be much better than the other methods. (Yuanbin Wang, 2019)

[6] This paper the authors propose a system that mimics the human fire detection system. It uses Faster R-CNN which is a region-based algorithm to detect suspicious Point of interest. After marking the region of interest, the features extracted from the bounding boxes are passed to LSTM Long Short-Term Memory to classify if there is fire or not in short interval of time. Faster R-CNN exploits the features of CNN and introduce a region proposal network which is used to map the features in the input image. It extracts features through the ROI pooling operation and then classifies according to the class scores of the object position.

[7] In this paper, a novel method for fire detection is proposed based on ensemble learning. The dataset is created using 10581 images from various public sources like BowFire [8], FD-Dataset [9], ForestryImages[10], VisFire[11]. The dataset is preprocessed and fed into not just one but two individual object detectors, YOLOv5 and EfficientDet integrated in parallel mode to achieve better accuracy than a single object detector. Although it uses integrated object detectors, this does not take the whole image into consideration. Therefore, another classifier is introduced to solve this problem. EfficientNet takes the image as whole and evaluates the image to enable total advantage of the information. The results will be decided by a decision strategy algorithm which takes the opinion of the three individual object detectors into account which in turn improves the performance of the model and decrease the rate of False positives. This paper claims that they have achieved a superior trade-off average accuracy, average recall, false positive and latency.

[8] This paper put forward an approach in real-time forest fire detection using wireless sensor network paradigm. This method can detect and forecast the fire more accurately than the other methods used in forest fire detection. Firstly, the sensor networks acquire the details about the humidity, smoke, temperature, and wind speed as these factors affect the forest fire. The sensor nodes are placed widely in the forest, and it is arranged into clusters. The sensor nodes use GPS to track their location as they can sends these location details along with the data such as measurements of temperature to the cluster head. Then, using a neural network method, the cluster header computes the weather index and then these information sends to the manager node. The wind speed is calculated by the wind sensor nodes, which are manually placed in the forest. The users get information from the manager node when an abnormal event occurs like high temperature and smoke. As well as manager node gives information about the levels of forest fire risk rate according to the weather index from different clusters. So that, users can easily find out the exact location of fire in the forest if it occurs. Also, they could protect the forest from the fire hazard due to the early detection (Liyang Yu, 2005).

[9] According to a research method, Light detection and ranging (LIDAR) system is used for the forest fire detection with the help of neural network. LIDAR is mainly used in the environmental and atmospheric studies. A lidar contains a photo detector, radiation emitter, signal receiver and signal processing hardware and software. Here, the neural network is needed to train well with the Neyman-Pearson criterion. The committee machine trained with all possibilities including the false alarm in the validation test sets, to obtain an accurate level of detection. These committee machines are composed of neural networks.

Each committee machine having its' on duty like each one solving significant problems in a recognition problem. Different neural networks can be added together to find solutions to the complex problems as different networks can have different capabilities. In the case of committee machines, two types of neural networks are participated. One is single layer perceptrons, which have many input nodes and a neuron. The other one is using a cascade architecture with two processing neurons where one is connected to the previous neuron and the other one is connected to the input nodes. As a result, the automatic detection of forest fire using committee machine with the help of LIDAR is useful than the traditional ones (Vilar, 2003).

[10] A research study proposes a system which is a combination of using neural networks, computer vision rules, and other expert rules helps in detecting the forest fire. Different approaches are applied to build this system; visual infrared image matching, using the previous hazards memory, image processing, location, size, and geographical data. Here, infrared cameras, visual cameras, meteorological sensors are using for the collection of input data. The image processing tool is combined with the visual and infrared processing. Infrared processing is a combination of detection, oscillation, and alarm processing processes. The growing-region algorithm is used to separate the false alarms. The visual processing finds out the exact location of the visual image from the infrared analysing process. By using different algorithms, it can be detected and easily reject the false alarms. The meteorological information used to detect the humidity, temperature and other factors which affect the forest fire. So that, it is easy to estimate the possibility of fire. Using this proposed system, it can be detecting the forest fire in early stage and avoid the false detection (Begoña C. Arrue, 2000).

[11] Deep learning and wireless sensor network can be helpful in forest fire detection. The research put forward a system using these approaches can detect the forest fire in the early stages. Using the deep learning model, the system detects the fire according to the collection of data from different sensor networks placed widely in the forest. Here, the system consists of the Internet of Things used as a main concept, moving or fixed sensors and a suitable deep learning model. More accurately, there are several sensor nodes places within each 1 km distance and these nodes are transfer data to the internet servers through the gateways. Then this collected information is displayed in a dashboard with online network. Each node measures the values of humidity, carbon monoxide, temperature, carbon dioxide, and atmospheric pressure. These factors have a major role in the forest fire. In this method, firstly, it calculates the weather information from the weather detector located in forest and then find out the Fire weather index (FWI) using the sensor nodes with the help of deep learning algorithms and the metrics. If the FWI have value changes, the Unmanned Aerial Vehicle (UAV) helps to detect these sensor values more accurately to find the existence of fire. Also, the control tower act as a fire distinguisher to distinguish the fire (Wiame Benzekri1, 2020).

[12] Another research paper presents an idea for the detection of forest fire using spatial data mining and image processing. Firstly, the mining of spatial data occurs and then the digital image from these data is converted to YCbCr Color space and then divided accordingly to identify the areas with fire. A fuzzy set is generated for the fire areas with the values of color space. Color space means a creation, specification, and visualization of colours. The amount of red, blue, and green color determines a color in a computer system. This technology is used in this system. Data mining consists of database, pattern recognition, statistics, machine learning, and visualization techniques. The methods used for the segmentation and identification processes are anisotropic diffusion and the fuzzy logics. Using these rules and approaches, this system detects the forest fire using the spatial data accurately (Prof. K.Angayarkkani, 2009).

[18] In this paper, the authors focus on building a neural network fire alarm system with the data collected from the sensor. The sensor measures the temperature, smoke density, CO concentration. The paper proposes a neural network to work on the data obtained from the sensor. The decision-making algorithm use a single detector reading continuously to detect fire or smoke based on a threshold or limit. Radial basis function (RBF) network is used for the object detection. It is type of neural network which generate local response to the input using local approximations. The output is divided into fire, smouldering fire, no fire according to the output of hidden layers of the network. The results of this experimentation shows this system achieved an error rate of 2.3% chance of fire, small fire 1.8%, no fire with 1%. The authors claim the network can improve it ability to adapt to different unpredictable situations. Further scope of improvements suggested are by collaborating data from different sources.

[20] This research paper, the authors propose a cost-effective fire detection using CNN from surveillance videos. This papers critically analyses the statistics of deaths due to fire. So, their focus is to propose a system that is home friendly and commercial. This paper gives us an insight of how to carefully select the data properly, how to analyse the computational complexity and detection accuracy. They use a model called GoogleNet for extracting the features from the images. For reducing the complexity of larger patches, they reduce dimensionality. The model is tested with two different datasets for validation purposes and results are compared. They achieved an accuracy of 93.5% on the first dataset and an 86% on the next dataset.

IV. 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.

A. 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. Then these outputs of the previous layers are passed to the next layers. There is chance of overfitting since the network is fully connected. To avoid this situation, the CNN exploit the hierarchical pattern in the data and sort them according to their complexity from simpler to complex patterns engraved in the layers. The input is given as tensor with number of inputs x height x width x channels of input. Now the image is in an abstract form, then the layers convert this 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.

B. 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. Each neuron in the network gives an output by executing functions in the output of previous layers. These functions are determined by the weights of the input values. A unique feature of Convolutional neural networks is that it can share the same functions on every layer. The feature extractor used in network is called AlexNet deep CNN, which is a simple application of CNN which enables easy object detection in an image. Fig. 1 depicts the simple architecture of Convolutional neural networks.

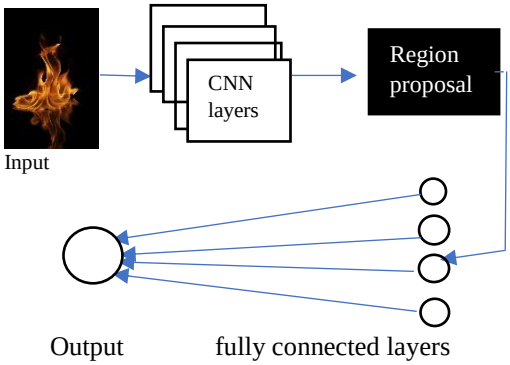

Fig 1. Architecture of CNN

The above figure Fig.1 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. The layers produce region of proposals that are later combined to build a machine learning model in the fully connected layers and the decision-making algorithm analyze output from layers to reach a conclusion.

IV. METHODOLOGY

In this paper, the proposed methodology consists of different stages. The stages include *A. Acquisition of Dataset, B. Data Preprocessing, C. Feature Extraction, D. Building model, E. Validation and testing.*

A. 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. This is to be done with great care because if the data fed to the neural network is faulty, the results will be corrupted and fail to produce an accurate system.

B. Data preprocessing

Data preprocessing is the next stage of building a quality machine 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.

C. 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. The neural network extracts these features using feature extraction network in the CNN which is powered by a custom algorithm. After extracting the features these video frames are classified into fire and non-fire scenarios. The features are extracted using bounding boxes using image descriptors.

D. 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.

E. Validation and testing

Validation of the machine 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.

V. EXPERIMENTATION 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 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 is a 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 the data more and more. When implementing the rate of false alarm should be kept to minimum.

VI. CONCLUSION

The scope of using video frames in the detection of fire using machine learning is challenging as well as innovative. 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.

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