Review for Detecting Smoke and Fire in Forest using Different Technologies

Dinesh Komarasamy¹, M. Gokuldhev², Jenita Hermina³, Gokulapriya M⁴ and Manju M⁵
¹,²Assistant Professor, ³,⁴,⁵UG Scholar
²,³,⁴,⁵Department of Computer Science and Engineering
³,⁴,⁵Kongu Engineering College, Perundurai
²AMRITA College of Engineering and Technology, Nagercoil

E-mail: dinesh.nova@gmail.com¹, m_gokuldhev@amrita.edu.in², jenihermina@gmail.com³, gokulapriya021@gmail.com⁴, manju.mm1699@gmail.com⁵

Abstract—Nature has a huge role to maintain the stability in the environment. But, natural disasters damage the environment, affect the life cycle and decline the lifetime of living beings. Nature is destroyed by different disasters namely earthquake, fire, flood, landslide, air pollution and so on. Among these, forest fire is one of the foremost dangerous natural disasters which cause several serious issues like biodiversity loss, global warming, fuel wood loss and air pollution in the environment. Therefore, prediction of fire occurring in forest plays a crucial role to save lots of the environment. Thus, researchers focused on different technologies with different methodologies for predicting the fire that occurred in forest, as early as possible. Moreover, smoke is the focal point for fire, some of the researchers pay their attention on detecting the smoke of the forest using different technologies. Therefore, this paper gives a summary for effectively detecting the smoke and fire in forest.

Keywords: Forest Fire, Smoke, Prediction, Deep Learning Technique, Video dataset, Image dataset.

I. INTRODUCTION

Earth’s surface is covered by water and land. Among these, Water occupies nearly 71% of earth surface and therefore by remaining 29% of earth land surface has continents and islands [1]. From the 29% of land surface, a large portion is roofed by forest. Forests are the terrestrial part of the earth ecosystem and distributed around the globe. Forest contains different varieties of plants that balance greenhouse gas in the atmosphere through photosynthesis. Almost 75% of plants are used for manufacturing different products like wood products and non-wood products [2]. The wood products are timber, fuelwood, pulpwood, sandalwood and so on. Plants are also used for producing non-wood based products like medicinal herbs, fruits and so on. In addition to this, plants are also used for the production of biomass which is used for energy production like electricity in the industries and so on. Therefore, plants in the forest are essential to afford oxygen for living beings [3].

Natural disasters damage the environment in several aspects like floods, earthquakes, landslide, storm, fire and so on. Among these, most of the forests are destroyed by fire in every year. Forest fire not only destroys plants and animals but also degrades the economy of the country and spoils the ecosystem of the earth. The forest fire produces an enormous amount of smoke that degrades the air quality in the atmosphere, causes global climate change, and also produces global warming. In addition to that, forest fire also increases the temperature of the earth [4]. In order to safeguard the forest and environment, researchers proposed different approaches to spot the fire in the forest. Later, some of the researchers found that early detection of smoke can predict the forest fire earlier [5]. Therefore, Researchers focussed on detecting the occurrence of smoke in forests. Smoke can be found at the earlier stage by various techniques. Therefore in this paper, the detection of forest fire and smoke techniques is categorized into Satellite Based Detection, Sensor based detection, Image processing techniques, Machine Learning techniques and Deep Learning techniques based on the datasets. The following section describes the Detection by Forest Fire and section 3 discusses the literature review.

II. DESTRUCTIONS BY FOREST FIRE

Forest is a huge area which has a variety of plants. Thus, the surface of the forest has combustible materials like dry leaves and branches. The combustible materials are highly flammable in the forest. The fire caused due to combustible material is generally called as “surface fire”. The surface fire destroys the combustible materials and gradually spreads to the forest. The spreading of fire from dry leaves to the trees is called “Crown Fire”. Crown Fire laid a path for spreading wildfire in the forest which can cause a firestorm. Firestorms are the phenomenon of spreading small flames across the forest. The spreading of fire during
Firestorms are uncontrollable in forests [6]. There are numerous cases recorded in the world. As a result, forest fires become uncontrollable. In the world, European countries have a large number of forests in which countries like Spain, Portugal, Italy, and Greece are frequently affected by forest fires. Among the European countries, Spain has reported more cases than other countries. In Spain, nearly 216,894 hectares of forest area were destroyed due to forest fires in the year of 2012 [7]. Similarly, Asia has the second largest number of forests in the world. The Asian countries also struggle to handle the forest fire. The survey shows that 1.45 million hectares of forest are destroyed due to fires in India annually [8]. In the U.S., California, wildfires were serious in the year of 2015. By the end of the year, a survey shows that over 6337 fires had been recorded in the world. The burned forest area is about 307598 acres [9]. The forest fire causes serious issues in the world. The causes may be loss of human and wildlife, loss of biodiversity and change in climatic conditions. To save the forest and the lives in the forest, the forest fire has to be detected. Forest fire detection systems can help with fire suppression and protect biodiversity. Therefore, the prediction of forest fire plays an important role to protect the environment. But, the forest fire cannot be effectively predicted by human beings through naked eye. Therefore, the detection of forest fire and smoke techniques are categorized into satellite based detection, sensor based detection, image processing techniques, machine learning techniques, and deep learning techniques based on the datasets. The following section describes the destruction by forest fire and section 3 discusses the literature review.

### III LITERATURE

Figure 1 depicts the technologies used for detecting smoke and fire in the forest. The detection of smoke and fire is broadly classified into two types namely static and dynamic technique. In the static technique, the dataset is directly submitted as input for detecting the forest fire. But in dynamic technique, the data are gathered using live streaming techniques. The live monitoring of forest is carried out by different technologies like satellite based detection, device based detection, and sensor based detection. The satellite based detection is further classified into video and image based detection. Similarly, device based detection is further classified into video and image based detection. The sensor based detection is further classified into Wireless Sensor Networks (WSN) and Internet of Things (IoT). The data are gathered and processed to predict the occurrence of smoke and fire. The different techniques used for analysing the dataset are IoT, image processing, WSN, machine learning, and deep learning.

![Figure 1. Technologies used for detecting smoke and fire in the forest](image-url)
1. Satellite based Detection

A forest fire can be detected from the sign of smoke. The primary method used for detecting forest smoke and fire was satellite based detection. Therefore, researchers introduced several techniques to effectively predict the smoke and fire occurring in forest. Among these, Vainö Kelhä at el proposed a system that captures the image through satellite and the images are sent to the acquisition station for preprocessing. After preprocessing, the extracted images are checked for the presence of hotspot areas and locate the smoke area using the coordinate system and pass alarm information. The system passes the alarm information to the nearest information center. The system has a less false alarm rate but the system accurately generates alarm only the fire within 500 metre [10]. In order to gain accuracy in a wide area using satellites, Tawanda Manyangadze at el proposed a system that detects the smoke by using Meteosat Second Generation (MSG) satellite. The system consists of an automated multi-threshold temporal algorithm. The algorithm compares the threshold value of normal background temperature with the actual fire in the satellite image. MSG satellite detects both the fire in the image as well as video. The image and video can be detected using sensor based technology. But, MSG satellite system needs higher manpower and it is more expensive [11]. In order to minimize the manpower, Casey A. Graff at el proposed an idea which detects fire at daily timescales based on Alaska’s ten year images dataset as training data. This statistical model uses Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS is an imaging sensor launched in earth orbit to monitor the earth’s land surface and water surface which is used for fire detection. Moreover, two poisson regression models had been used to represent the dynamic fire [12]. However, satellite based detection requires high manpower and expensive in detecting the smoke and fire occurring in forest. In order to minimize the man power and minimize the expense, researchers preferred sensor based technology over satellite based technology for effectively predicting smoke and fire occurring in the forest.

2. Sensor Based Detection

Sensor based technology is also used for detecting the occurrence of smoke and fire in both images and video. The Sensor based techniques are broadly clustered into two types namely Wireless Sensor Network (WSN) Techniques and Internet of Things (IoT) Techniques. Figure 2 shows different types of sensors used for monitoring the environment. The environment is monitored by deploying different sensors like smoke sensor or gas sensor, temperature sensor, microwave sensor and humidity sensor. Among these, the smoke or gas sensors sense the environment and also produce the alarm whenever there is a violation in the threshold value. Similarly, the temperature sensor senses the heat produced in the forest and produces the alert whenever there is a violation of the threshold value. Microwave sensors are used to detect any motion like smoke and fire in the forest. Humidity sensor measures and reports both moisture and air temperature in the forest. The next section describes the WSN and explains the different techniques available to detect smoke and fire.

a. Wireless Sensor Network (WSN) Technique

Sensor based technology is also used for detecting the occurrence of smoke and fire in both images and video. The Sensor based techniques are broadly clustered into two types namely Wireless Sensor Network (WSN) Techniques and Internet of Things (IoT) Techniques. Figure 2 shows different types of sensors used for monitoring the environment. The environment is monitored by deploying different sensors like smoke sensor or gas sensor, temperature sensor, microwave sensor and humidity sensor. Among these, the smoke or gas sensors sense the environment and also produce the alarm whenever there is a violation in the threshold value. Similarly, the temperature sensor senses the heat produced in the forest and produces the alert whenever there is a violation of the threshold value. Microwave sensors are used to detect any motion like smoke and fire in the forest. Humidity sensor measures and reports both moisture and air temperature in the forest. The next section describes the WSN and explains the different techniques available to detect smoke and fire.
WSN techniques are used for detecting the occurrence of smoke and fire in forest effectively. Figure 3 depicts the basic block diagram of WSN. WSN plays a vital role in sensing and detecting the smoke and fire. WSN has different components namely sensors, microcontroller, transceiver and battery. The different sensors sense the environment and produce the information or data. The information is gathered in a microcontroller and sent to the base station through a transceiver. Base station also has a transceiver, microcontroller and battery. After receiving the information, the microcontroller takes decisions about the presence or absence of smoke. The decision is sent to the user or authorized person.

WSN does not require any human intervention for locating the smoke and fire in the forest. The WSN uses the web network for monitoring and recording the physical conditions like temperature, smoke and humidity in the forest. Researchers introduced different techniques for detecting smoke and fire using WSN. Among these, Joseph Jose introduced an idea to detect the forest fire using Zigbee WSNs. The zigbee WSNs have different components like inductors, rectifiers and potentiometers. Among these, an inductor is used for charging and discharging of energy in the hardware. Rectifiers are used to convert AC to DC and potentiometers are used to control I/O voltage along with Zigbee modules. In zigbee module, temperature and pressure sensors are used to measure temperature and pressure in the surroundings. The warning messages are sent to the user when the temperature reaches above the threshold value [13]. The zigbee WSN can detect the smoke and fire in a wide area but the efficiency of detecting the smoke and fire is very less in this technique.

To improve efficiency, Antonio Molina-Pico at el proposed a system which detects the fire earlier using two nodes namely the central node and sensor node. The central nodes are used for routing and localization, whereas the sensor nodes are used for sensing the fire in the forest. The sensor nodes collect the different data like change in humidity, increase in temperature using temperature, humidity and gas sensors. The collected data are forwarded to the central nodes, the central nodes send the data to the control area. The fire indices are computed based on the Fire Weather Index (FWI) developed by Canadian Forest Service that estimates moisture content. However, the data is not collected 22x7 so the accuracy of detection is less [14]. In order to improve high accuracy, Darko Stipaničev at el proposed a system which senses the environment throughout the day. Meteorological data and video data are connected and sent to the processing center. The processing center detects the occurrence of smoke and fire in the collected data. This system is web based and it detects the fire during day and night, but the timings of day and night are problematic. The operator manually adjusts the timings in the system. The long range communication leads to more expense and the value reaches 21 Million dollars [15]. However, WSNs have battery issues in which the battery of the nodes needs to be recharged frequently. Even though the wireless sensor network and traditional sensors detect the smoke and fire, the system fails to communicate with the people about the forest fire and smoke. In order to overcome the pitfall in WSNs, Researchers move to Internet of Things (IoT) techniques. The forthcoming section discusses the different techniques introduced in IoT.

b. Internet of Things (IoT) Technique

IoT devices have different sensors that are deployed in the device itself to generate the alarming only if there is any deflection in the environment. Fig 4 shows the different kinds of devices used. Researchers used different devices for the detection of smoke and fire namely Global System for Mobile communication (GSM), Arduino and Raspberry PI. Initially, researchers used GSM for sensing the occurrence of smoke and fire in the forest. But, the GSMs have very less memory when compared to Arduino and Raspberry PI. In order to have more memory capacity, researchers move from GSM to Arduino which has kilobytes of memory. However, Arduino has only kilobytes of memory, most of the researchers focussed on Raspberry PI which has 1GB Random Access Memory (RAM). Initially, Cheng Caixia at el proposed a method which has different sensors like temperature and smoke sensor for detecting fire. The sensed values are fused together and given to the self learning simulative model. Based on the fused data, this method predicts the fire. However, this method has high false alarm rates [16].
To reduce the false alarm rate and to detect the fire in the earlier stage, Shin-Juh Chen et al. proposed a technique that detects smoke by identifying the smoke particles namely carbon dioxide, carbon monoxide, oxygen using gas sensors and smoke sensors in the environment [17]. Similarly, Wolfgang Krull at el proposed a methodology to reduce the false rate. This methodology reduces the smoke false rate by deploying different sensors namely optical smoke, gas and microwave sensors to sense the environment. This method enforces the different sensors into a Unnamed Aerial Vehicle (UAV) equipped with gas sensors and thermal camera flies. UAV equipped with a microwave radiator and sensors monitors the level of smoke from the sensor [18].

To interact with the people effectively and to get the notification easier, V. Parthipan introduced an idea that detects the smoke by using Forest Fire Detection Algorithm (FFDA) algorithm. The FFDA algorithm continuously monitors the temperature and also generates the notification to the authorized person through the GSM whenever the temperature crosses the threshold value [19]. Later, R. Niranjana et al introduced a system that detects the smoke using sensors and the sensors are connected to the Raspberry Pi kit. The above system also generates the notification to the concerned authorized person whenever the temperature value rises more than the threshold value. However, it is difficult for the authorized persons to use GSM at any time [20].

To make access easier for all people, Dr. Osamah Ibrahim Khalaf at el proposed a system to detect smoke using the Arduino. The system sends notifications via email as a text message. However, the system does not send pictures of the smoke area [21]. In order to send the status of the fire through picture, R. Angeline et al proposed a system that uses Raspberry Pi to send notifications along with pictures. But, the emails are not frequently verified by the people [22]. Therefore, Abhinav Kumar Sharma at el introduced a system to communicate through an android application installed in mobile phones instead of notifying people through email. This system has a temperature sensor, smoke sensor and buzzer. The system is triggered whenever the smoke sensor detects fire and generates an alarm through the buzzer [23]. Even though IoT techniques detect the smoke effectively, they are preferred only for small area networks because they need large hardware requirements, high maintenance cost and expensive for deploying in a wide area. In order to minimize the hardware requirements and maintenance cost, image processing techniques are used for detecting the smoke and fire in the forest. The following section describes the image processing techniques for detecting smoke and fire in the forest.

3. Image Processing Techniques

Figure 5 depicts the image processing techniques. Image processing technique is defined as to perform of extracting the features or information from the image by applying some operations on it. There are some techniques used for processing the images namely Wavelets, Image Filtering, Image Segmentation, Histogram, Image Pattern Analysis and Image Enhancement. Among these, Wavelets are the general way to represent multi-resolution images and it is mostly used for removing noise from the image. Similarly, Image filtering is used for extracting or removing certain features in an image. Image segmentation is used for partitioning the image into several pixels based on the region, feature, threshold, model and it can also detect the edges in the
image. Histogram is the graphical representation based on the intensities and the frequency of the image. Image Pattern Analysis is extracting useful information like shape, color of the image. Image Enhancement is the process of removing noise and brightening the image. Image Enhancement is further classified into spatial and feature domain. Image processing techniques are used to reduce the high hardware requirement and to reduce the cost of maintenance. The image processing techniques are used for detecting the smoke and fire occurring in the forest from image and video as offline and online.

a. Detecting Smoke from image dataset

Kumarguru Poobalan at el developed a technique to detect fire. It detects the fire by applying two techniques namely RGB color model and Sobel Edge Detection parallelly. Initially, the images are sent to RGB model which determines the intensity of images and convert into HSV images. Sobel Edge Detection detects the edge of the images. The two processes are integrated and the color segmentation technique takes place to segment the fire colored object. But, the efficiency and effectiveness of the algorithm are less in this algorithm [24]. In order to improve efficiency, Turgay Çelik introduced an approach that uses both image and video sequences. The approach uses smoke pixels which are detected using color, to detect the smoke. The smoke pixels are detected in the low temperature of fire. At the starting stage of the fire, the smoke appears in the range of white-blush to white. When temperature increases, the smoke appears in the range of black-grayish to black. The pixel has similar intensities with RGB color channels. The smoke is detected based on the color variation in the image [25]. But the images are taken from the internet for detection. To detect the fire and smoke more realistic some of the researchers used the images which are captured from the forest.

In order to detect the fire from real images, Vipin at el proposed a method which detects the forest fire by applying seven rules RGB intensity values, histogram analysis, spatial location fire detection, locating the flame regions, calculating blue component (Cb) and red component (Cr) intensity values to detect fire. The RGB images are taken as input from the camera and the intensity values are taken from the image. The input images are graphically represented in histogram analysis. After the histogram analysis, the location of the fire is used to eliminate spatial location and then the RGB images are converted into YCbCr images when the sign of fire is present. After eliminating the spatial location, the flame regions are located. Then the calculation of Cb and Cr intensity is made for segmenting the fire region. The system is cheap in computation and has a higher fire detection rate [26]. Instead of using cameras for capturing images, Ahmad Zarkasi at el developed a method that uses a quadcopter to detect forest fire. The quadcopter captures the images from the forest and the images are sent to the computers by using a tv tuner. The obtained RGB images are converted into HSV images, then HSV images are converted into black and white images for easy identification of background areas and fire objects. The process of converting images to black and white images are known as thresholding. The fire objects are detected by the process of thresholding. This method has an error rate of 8.89% [27]. But, detecting forest fire from the image is not realistic and so some of the researchers tried for detecting forest fire by using the videos.

b. Detecting Smoke from video dataset

Initially, Mubarak A.I. Mahmoud at el introduced a system called “Forest Fire Detection Using a Rule-Based Image Processing Algorithm and Temporal Variation”. In this system, the images are extracted from the video sequences. This system has four steps namely Movement Containing Region Detection Based on Background Subtraction (MRDB), Converting RGB Images to YCbCr, Fire Color Pixel Detection and Temporal Variation. MRDB subtracts the background features of the images to select the region of fires. After the four steps, RGB images are converted into YCbCr color images when the moving objects are found in the image. In the next step, the fire pixels and fire-colored objects are identified by using the fire detection rules from the image. At last, temporal variation is used to differentiate fire and fire-color objects. The images are tested with 6 videos that are taken from the internet which is publicly available. The system detects the fire in the static videos. It failed to detect fire in the real time video sequence taken from the forest directly [28]. This method has several difficulties in detecting fire in real time.

In order to detect smoke and fire with the real time videos, Turgey celik at el introduced a method to detect forest fire using computer vision based technology. In computer vision based technology, the fire videos captured from the video acquisition device. The consecutive image frames are extracted from the captured videos. From the images, the fire regions are characterized by the moving information of fire. After characterizing the information of the fire, the system analyses the characteristics with the consecutive frames for the detection of fire-colored moving pixels. The algorithm used is CIELAB color space (CIE L*a*b) to detect the fire and provide higher accuracy of 99.88% [29].
4. Machine Learning Techniques

![Machine Learning Techniques Diagram]

Figure 6. Machine Learning Techniques

Figure 6 depicts the different Machine Learning techniques used for detecting forest fire. The techniques are broadly classified into two types namely classification and regression. There are several classification algorithms namely Robust AdaBoost, Support Vector Machine (SVM), K Nearest Neighbor (KNN), Maximum a Posteriori (MAP) and Random Forest. Similarly, the regression problems are solved using linear regression and KNN. Machine learning algorithms are also used for detecting forest fire from images and videos.

a. Detecting Smoke from image dataset

Some of the researchers preferred machine learning technology to detect smoke and fire in a huge area with minimal cost. To detect the fire in the forest, Xuehui Wu et al developed a method that uses a robust AdaBoost (RBA) classifier to detect smoke. The smoke is detected by extracting the different features of the image like texture, color, edge orientation. In addition to that, motion direction and motion speed of the smoke are also analyzed using sensors. After capturing the images, RBA classifies the smoke images effectively. But, the pre-collected image dataset is used for finding the dynamic features pre-collected video dataset [30]. Similarly, Feiniu Yuan proposed a method that uses Gaussian process. To improve the smoke detection, this method sent training and test data to Local Binary Pattern (LBP) for feature extraction. The extracted feature is sent to Kernel Principal Component Analysis (KPCA) for dimension reduction and finally sent to the Gaussian process for classification. This system outperforms SVM. But, training and testing of dataset using static data has several hurdles in the real environment.

In order to consider images in the real environment, M.P Sivaram Kumar et al proposed an idea to detect fire with the aid of satellite image. The collected satellite image is converted into grayscale image. All the images are converted into fixed size by preprocessing. After preprocessing, the filtering process takes place to reduce the noise in the preprocessed image. In the images, Edges are detected by using Cannel method and background separation is also carried out by using threshold method. Later, Histogram of Oriented Gradients (HOG) finds the magnitude, gradient and angle of the fire and Support Vector Machine (SVM) is used for the classification of images. But, detecting forest fire from the image is not realistic and so some of the researchers tried for detecting forest fire by using the videos.

b. Detecting Smoke from video dataset

To detect the fire in the realistic scene, Mubarak Adam Ishag Mahmoud developed a system that takes video sequences which are collected from the internet as input. The system has four stages namely background subtraction, color-based segmentation, objects special wavelet analysis and SVM. The video is initially passed to the background subtraction to detect moving objects in the video. After the background subtraction, the color based segmentation CIE \(L^a*b^\) algorithm detects the colored moving objects. After detecting the coloured moving objects, CIE \(L^a*b^\) algorithm is used to differentiate fire images. At last Support Vector Machine (SVM) is used to classify the fire and no-fire images.
Later, Meenu Ajith et al proposed an idea that uses video datasets for detection of fire and smoke. To detect smoke and fire, captured videos are converted into Infrared (IR) video frames. The system has two processes like feature extraction and segmentation. In feature extraction, smoke regions can be extracted based on the intensity, optical flow and divergence of the IR image. In segmentation, the unsupervised approach named Maximum a Posteriori (MAP) labels the image dataset as a fire and non-fire image. By labeling the images, fire and non-fire images are separated. To detect smoke from the video dataset, ByoungChul KO et al developed a system that checks the difference between the previous and current video frames to detect the smoke. Moreover, Bag-of-Feature (BOF) approach is used for image retrieval, object detection, and image classification from the video. The smoke color model extracts the BOF features for the moving blocks. Random Forest determines BOF frame contains actual smoke or not. The system detects the smoke with the minimum number of videos.

In order to have more videos, Jianhui Zhao et al proposed a work having 11 static features and 27 dynamic features to train SVM classifiers. The system takes input videos and then the features are extracted from 20 consecutive video frames. The system detects the fire regions and also the fire like objects. But, the system fails to plot the smoke regions. In order to find smoke regions along with positions, Zhe Liu at el introduced an idea that uses ViBe background algorithm for effective extraction and motion detection of smoke in high-quality videos. The videos are publicly accessible and converted into frames for further processing like extraction and motion detection. For extraction, spatial and frequency features are taken into account and the edges are detected in the images. The detected edges are sent to the SVM which marks the smoke regions in rectangular boxes. The system identifies the smoke and also plots the smoke regions. This method has several difficulties in detecting smoke and fire in real time.

Therefore, Faming Gong et al proposed a method that detects the fire in the forest using the live videos from the forest. The camera installed in the specific area is used to monitor the area and the videos are collected from the camera. There are three steps in this method namely preprocessing, extraction flame characteristics and SVM. Among these, the preprocessing is used to extract the color and motion in the image which is identified by comparing the previous frames. The extraction of flame characteristics are used to identify the characteristics of the moving images and the current position of the motion frame in the video. Later, SVM classifier classifies the smoke image from the motion images. But, this method has less accuracy for identifying the smoke from the video.

To improve the accuracy, Luxing Qin et al proposed a method that detects smoke and fire using the dark channel and multi-threshold segmentation. The method consists of three steps namely Extracting mask regions with dark channel prior and multi-threshold segmentation, Motion detection and SVM classification. Extracting mask regions with dark channel prior and multi-threshold segmentation is used to suppress distractions like haze and sky in the image. In motion detection, Gaussian Mixture Model (GMM) and ViBe algorithm are used for identifying the location of moving objects from the background objects. Finally, features of motion frames are extracted and the extracted features are classified using SVM. The system detects the smoke and fire with good accuracy but with less number of videos in the dataset. To detect smoke with more number of videos, S.R Raji at el introduced a methodology based on Wavelet based SVM classifier (WSVM). In this work, live streaming videos are used as the dataset. Preprocessing is used to reduce the noise and reduce unnecessary features in the image. After the Image Preprocessing and feature extraction, five sub-algorithms are used to predict the existence of smoke. Finally, all the outputs from the sub-algorithms are given to the Adaptive Decision Fusion (ADF) to detect smoke. The system detects whether smoke is present or not in an image that fails to locate the position of smoke. The above works uses the video that is captured by the cameras.

Instead of using a camera for capturing videos, Sathyra at el proposed the system that uses mobile phones for capturing the video. The video streams are obtained from the live streaming of the fire using mobile phones. Temporal segmentation is used to extract the background from fire pixels. After extraction of background objects, the system detects the fire using color spatial segmentation which is used to predict the fire pixels. Similarly, the global compensation method is used for motion estimation and finally SVM is used to classify the images.

Instead of using images and videos as dataset, some researchers used the sensor values for detection. To support the statement, Uduak Umoh at el developed a system which embeds Fire Outbreak Data Capture Device (FODCD). FODCD device comprises temperature sensors, smoke sensors, flame sensors and wifi module which are connected to Arduino. The sensor values are obtained and SVM is used to classify the fire and non-fire data.
5. Deep Learning Technique

Figure 7 depicts deep learning techniques. The techniques are broadly classified into Convolutional Neural Network (CNN) and Generative Adversarial Network (GAN). CNN is further classified into Alexnet, Squeeznet, Densenet, Deep Convolution Neural Network (DCNN), Region based Convolution Neural Network (RCNN).

a. Detecting smoke from image dataset

In order to improve accuracy, some of the researchers focus on deep learning techniques that are used to detect the smoke. Yanbei Liu et al proposed a system which chooses Alexnet and CNN architecture. This work chooses RGB images to perform training as well as testing. AlexNet and CNN architecture which act as the two channels and are trained separately. From the RGB images, the dark features are extracted in the second channel of CNN architecture. This work accurately detects the smoke images for a small dataset.

In order to support a larger dataset, Zhijian Yin et al introduced "A Deep Normalization and Convolutional Neural Network for Image Smoke Detection (DCNN)". DCNN has 14 layers for classification and feature extraction. In DCNN, augmentation is used to increase the number of images for training to improve accuracy as 96.37%. Instead of increasing the number of images through augmentation, Qi-xing Zhang et al proposed a work for creating synthetic smoke images. The model acquires a good accuracy for synthetic images but acquires less for the real videos. Moreover, the smoke regions are not detected. In order to highlight the smoke regions, Tingting Li et al proposed another method which also used a sliding window to detect the smoke region. In this method, the RGB images are converted to YUV as smoke different results in different colour space. After converting images to YUV, this method removes all other backgrounds except the smoke area. To train the sample, RGB images dilated DenseNet is used and achieved 99.20% of accuracy.

To detect smoke and fire by using image datasets, Abdulaziz Namozov et al proposed a work to consider CNN architecture for training the image dataset. The images are taken during different seasons like summer and winter are created using Generative Adversarial Networks (GAN). Even though the images are taken at different times, the number of images is less in the dataset. Therefore, data augmentation is used to increase the number of images. The accuracy of detecting the smoke and fire is 97.15%. But it is not realistic because it uses only images.

b. Detecting smoke from video dataset

To make the smoke detection more reliable, a real-time smoke video dataset is used instead of synthetic images. Qingjie Zhang et al proposed an idea in which the frames of video are taken for training the dataset. After finding the fire image, this work also locates the fire region within the image using patch level accuracy. This work approximately achieves 90% accuracy.

In order to detect the smoke from the video and to increase the accuracy, Yingshu Peng et al introduced a method which considers smoke videos of the CCTV footage as a dataset. All the videos are converted into frames in which a gray image is extracted by the Gaussian mixture model. Squeezenet model is used for training and testing. The accuracy of the model reaches 91.81%. The model gives less accuracy and the testing video does not give the realistic scene. To give the realistic scene and to generate more images for training, Feiniu Yuan et al suggested a work to manually generate the smoke dataset. Unlike other works, the smoke is
simulated and is attached to the natural background images. This looks to be real-world scenes. The generated images have four channels RGBA, which is converted to RGB channels. The work gives good accuracy with less false alarm rate.

To detect smoke and fire by using image datasets, Sebastien Frizz et al introduced a method which detects smoke and fire at the same time from the real-time video. In order to differentiate smoke and fire, the sliding window algorithm has been used with the pixel size of 12 X 12. This detects the fire and smoke in a frame of video based on the intensity of the fire and smoke. Moreover, the model gives an accuracy of 97.9% with 9 convolution layers. Similarly, Rinky Dwivedi proposed a system to detect both flame and smoke by InceptionV2 with single-shot detection. The images are taken from the video containing flames and smoke. If the image does not have flames then the smoke is tested. The loss of flame detection and smoke detection is 0.9007 and 0.7175 respectively.

IV DISCUSSION

Figure 8. Technologies used for Detecting Fire and Smoke

Figure 8 shows the researches in the different technologies like Satellite based Detection, Sensor based Detection, Image Processing Techniques, Machine Learning Techniques and Deep Learning Techniques. Among these, Satellite based Detection has less number of researches in detecting forest smoke and fire. Sensor based Detection is preferred by many researchers for the live detection of smoke and fire in the forest. Due to cost factor, many researches used the Machine Learning Techniques. To improve the accuracy in detection of fire and smoke, the emerging Deep Learning Technique is used.

Figure 9 shows the research growth of forest fire and smoke detection from the year 2006 to till date. Researches before 2015 are less due to the less technology. The researches increased in the last 4 years with the evaluation of new techniques.

Figure 10 shows the growth of researches based on technology in detecting forest smoke and fire. Initially, the researchers used the techniques like Satellite based Detection and Sensor based Detection. Due evolution of new techniques like Image Processing, Machine Learning and Deep Learning, the number of researches in these techniques has increased in the recent years. Among the recent techniques, many researchers focused on Machine Learning whereas after 2015 researchers concentrated on Deep Learning for detecting fire and smoke in the forest.
V RESEARCH FINDINGS

Based on the research, it is identified that forest fire can be controlled with early prediction of smoke and fire. Moreover, smoke and fire regions are highlighted to increase the accuracy and to locate the fire occurring places. In order to reduce the cost and to process large dataset a new technique called deep learning is used instead of using the sensor based technologies.

VI SUMMARY

The technologies used in detecting fire and smoke are Satellite based detection, Sensor based Detection, Image Processing Techniques, Machine Learning Techniques and Deep Learning Techniques. Among these, Satellite Based Detection and Sensor based Detection are more expensive and difficult to identify the smoke in the huge area like forest. Hence many of the researchers use Image Processing techniques to identify the smoke and fire in the forest. Some of the researchers moved to Machine Learning Techniques to detect smoke and fire to classify the images more easily. To improve the accuracy and to reduce the error rate researchers preferred Deep Learning Techniques for the detection.
REFERENCES

[1] Fader M et al., "Internal and external green-blue agricultural water footprints of nations, and related water and land savings through trade," *Hydrol. Earth Syst. Sci. Discuss.*, vol. 8, no. 1, pp. 483–527, 2011, doi: 10.5194/hessd-8-483-2011.

[2] Pan Y, Birdsey R A, Phillips O L, and Jackson R B, "The Structure, Distribution, and Biomass of the World’s Forests," *Annu. Rev. Ecol. Evol. Syst.*, 2013, doi: 10.1146/annurev-ecolsys-110512-135914.

[3] Fernando W G D, “Plants: An international scientific open access journal to publish all facets of plants, their functions and interactions with the environment and other living organisms,” *Plants*. 2012, doi: 10.3390/plants1010001.

[4] Toledo-Castro I et al., "Forest Fire Prevention, Detection, and Fighting Based on Fuzzy Logic and Wireless Sensor Networks," *Complexity*, vol. 2018, 2018, doi: 10.1155/2018/1639715.36-43, 2008.

[5] Chen T H, Yin Y H, Huang S F, and Ye Y T, “The smoke detection for early fire-alarming system base on video processing,” in Proceedings - 2006 International Conference on Intelligent Information Hiding and Multimedia Signal Processing, IIH-MSP 2006, 2006, doi: 10.1109/IIH-MSP.2006.265033.

[6] Alkhatib A A, “Forest Fire Monitoring,” in Forest Fire, 2017.

[7] Peter Hirschberger, “FORESTS ABLAZE Causes and effects of global forest fires”, 2016.

[8] Ashutosh D K and Satendra, *FOREST FIRE DISASTER MANAGEMENT National Institute of Disaster Management*. 2014.

[9] Gao J et al., “Data-driven forest fire analysis,” in 2017 IEEE SmartWorld Ubiquitous Intelligence and Computing, Advanced and Trusted Computing, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People and Smart City Innovation, SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI 2017 - ., 2018, doi: 10.1109/UIC-ATC.2017.8397588.

[10] Vaino Kelia, Yrjo Rauste and Alessandra Buongiorno- ‘Forest Fire Detection by satellites for fire control’.

[11] Tawanda MAnyangadze-‘Forest Fire Detection for near rela-time monitoring using geostationary stations’. International Institute for Geo-information Science and Earth Observation- March 2009.

[12] Graff C A, Coffield S R, Chen Y, Foufoula-Georgiou E, Randerson J T, and Smyth P, “Forecasting Daily Wildfire Activity Using Poisson Regression,” *IEEE Trans. Geosci. Remote Sens.*, 2020, doi: 10.1109/tgrs.2020.2968029.

[13] Joseph Jose K, Kargil Joshy , Joel Abraham, Andrady ,Mithum V M, Sanju B. ‘Forest Fire Detection using zigbee wireless sensor networks’: GRD Journals- Global Research and Development Journal for Engineering National Conference, ERTE-Emerging Research Trend in Electrical and Electronics Engineering, e-ISSN: 2455-5703, May 2019.

[14] Molina-Pico A, Cuesta-Frau D, Araujo A, Alejandre J, and Rozas A, “Forest Monitoring and Wildland Early Fire Detection by a Hierarchical Wireless Sensor Network.” *J. Sensors*, 2016, doi: 10.1155/2016/8325845.

[15] Stipaničev D, Vuko T, Kristinić D, Štula M, and Bodrožić L, “Forest Fire Prevention by Advanced Video Detection System - Croatian Experiences,” Third TIEMS Work. Improv. Disaster Manag. Syst., 2006.

[16] Cheng C, Sun F, and Zhou X, “One fire detection method using neural networks,” *Tsinghua Sci. Technol.*, 2011, doi: 10.1016/S1007-0214(11)70005-0.

[17] Chen S J, Hovele D C, Peterson K A, and Marshall A W, “Fire detection using smoke and gas sensors,” *Fire Saf. J.*, 2007, doi: 10.1016/j.firesaf.2007.01.006.

[18] Krüll W, Tobera R, Willms I, Essen H, and Von Wahl N, “Earl time m fire detection and verification using optical smoke, gas and microwave sensors,” in *Procedia Engineering*, 2012, doi: 10.1016/j.proeng.2012.08.208.

[19] Parthipan V and Dhanasekaran D, “Preventing and monitoring of framework for forest fire detection and data analysis using internet of things (IoT),” *Int. J. Eng. Adv. Technol.*, 2019.

[20] Niranjana R, HemaLatha T- ‘An Autonomous IoT Infrastructure for Forest Fire Detection and Alerting System’ - International Journal of Pure and Applied Mathematics, Volume 119 No. 12 2018.

[21] Osamah Ibrahim Khalaf, Ghaida Mustashar Abdulshaih, Noor Abdul Khaleq Zghair-IOT fire detection system using sensor with Arduino’- 13 September 2019.

[22] Angelina R, Aditya S, Abishek Narayanan - ‘ Fire Alarm System Using IOT’- IJITEE- International Journal of Innovative Technology and Exploring Engineering, Volume-8, Issue-683, April 2019.

[23] Kumar Sharma A, Faiz Raza Ansari M, Firoz Siddiqui M, Ataullah Baig M, and Noida G, “IoT Enabled Forest Fire Detection and Online Monitoring System (By Using Atmega 328-P Microcontroller),” *Int. J. Curr. Trends Eng. Res.*, 2017.
[24] Poobalan K and Liew S, “Fire detection algorithm using image processing techniques,” Proc. 3rd Int. Conf. Artif. Intell. Comput. Sci., 2015.

[25] Çelik T, Özkaramanlı H, and Demirel H, “Fire and smoke detection without sensors: Image processing based approach,” in European Signal Processing Conference, 2007.

[26] Vipin V, “Image Processing Based Forest Fire Detection,” Int. J. Emerg. Technol. Adv. Eng., 2012.

[27] Zarkasi A, Nurmaini S, Stiawan D, Firdaus, Abdurahman, and Derti Amanda C, “Implementation of fire image processing for land fire detection using color filtering method,” in Journal of Physics: Conference Series, 2019, doi: 10.1088/1742-6596/1196/1/012003.

[28] Mahmoud M A I and Ren H, “Forest Fire Detection Using a Rule-Based Image Processing Algorithm and Temporal Variation,” Math. Probl. Eng., 2018, doi: 10.1155/2018/7612487.

[29] Çelik T, “Fast and efficient method for fire detection using image processing,” ETRI J., 2010, doi: 10.4218/etrij.10.0109.0695.

[30] Wu X, Lu X, and Leung H, “A video based fire smoke detection using robust AdaBoost,” Sensors (Switzerland), 2018, doi: 10.3390/s18113780.