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DEEP LEARNING-BASED FRAMEWORK FOR WILDFIRE DETECTION

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Abstract: This paper develops a comprehensive experiment on wildfire detection that organically integrates digital image processing, machine learning and deep learning technologies. Although the research on wildfire detection has made great progress, many experiments are not suitable for students to operate. Also, the detection with high accuracy is still a big challenge. In this paper, we divide the task of forest wildfire detection into two modules, which are wildfire image classification and wildfire region detection. We propose a novel wildfire image classification algorithm based on Reduce-VGGnet, and a wildfire region detection algorithm based on the optimized CNN with the combination of spatial and temporal features. The experimental results show that the proposed Reduce-VGGNet model can reach 91.20% in accuracy, and the optimized CNN model with the combination of spatial and temporal features can reach 97.35% in accuracy. Our framework is a novel way to combine research and teaching. This paper presents a comprehensive experiment on forest wildfire detection that seamlessly integrates digital image processing, machine learning, and deep learning technologies. Despite significant advancements in wildfire detection research, many experiments are impractical for student involvement, and achieving high accuracy remains a considerable challenge. In this study, we break down the forest wildfire detection task into two modules: wildfire image classification and wildfire region detection. We introduce a novel wildfire image classification algorithm based on Reduce-VGGnet and a wildfire region detection algorithm based on an optimized CNN incorporating spatial and temporal features. Experimental results demonstrate that the Reduce-VGGNet model achieves an accuracy of 91.20%, while the optimized CNN model, leveraging spatial and temporal features, achieves an accuracy of 97.35%.

I.INTRODUCTION

Fire detection is crucial task for the safety of people. To prevent damages caused by fire, several fire detection systems were developed. One can find different technical solutions. Most of them are based on sensors, which is also generally limited to indoors. However, those methods have a fatal flaw where they will only work on reaching a certain condition. In the worst-case scenario, the sensors are damaged or not being configured properly can cause heavy casualty in case of real fire. Those sensors detect the particles produced by smoke and fire by ionization, which requires a close proximity to the fire. Consequently, they cannot be used for covering large area. To get over such limitations video fire detection systems are used. Due to rapid developments in digital cameras and video processing techniques, there is a significant tendency to switch to traditional fire detection methods with computer vision-based systems. Video-based fire detection techniques are well suited for detecting fire in large and open spaces. Nowadays, closed circuit television surveillance systems are installed in most of the places monitoring indoors and outdoors. Under this circumstance, it would be an advantage to develop a video-based fire detection system, which could use these existing surveillance cameras without spending any extra cost. This type of systems offers various advantages over those standard detection methods. For example, the cost of using this type of detection is cheaper and the implementation of this type system is greatly simpler compare to those traditional methods. Secondly, fire detection system responds faster compared to any other traditional detection methods because a vision-based fire detection system does not require any type conditions to trigger the devices and it has the ability to monitor a large area. There are many technologies available for smoke and fire detection but still society is lacking reliable and accurate methods to predict smoke and fire at early stages, this deficiency may then lead to dangerous situations. This paper describes state of the art of different techniques used for smoke detection, fire detection and classification which may help to better understand the problem in hand.

In addition to preventing disasters, this study ofsmoke and fire detection and classification can be incorporated into bio-mass gasification and other real- time applications (Samanta ray and Mohanta,2015; Li et al., 2013) for commercial use. Various techniques involved in imagebased processing are more effective than utilizing specialized sensors to detect smoke. In image processing, smoke can be identified using image data and information of smoke shape. Smoke identification techniques are very important for testing in open environments (Ko et al., 2011), for example, in ports, in power plants, etc. as they can hurt users, whereas generic smoke sensors are capable of recognizing smoke effectively in closed spaces. The image information source may be a 2D image source which can be considered as parameters and it is difficult to extract the features or the qualities of smoke features (Costantini et al., 2008). Different methods of extracting arrangements of the elements can be performed by utilizing the image handling techniques. Convolutional Neural Networks (CNNs) are machine learning supervised classifiers that, in addition to characterizing spectral signatures, analyse the spatial context of the pixel. To our knowledge, CNNs have not been applied to tree species classification from airborne hyperspectral imagery. CNNs can perform concurrent analysis of spectra and shape using multiple deep layers of pattern abstraction which are learned through numerical optimization over training data. In this study, we parameterized and tested a CNN classifier applied to high-resolution airborne hyperspectral imagery of a forested area for tree species identification with sparsely distributed training labels.

II. LITERATURE SURVEY

Content-based Retrieval and Real Time Detection from Video Sequences Acquired by Surveillance Systems (2020) :
In this paper, a surveillance system devoted to detect abandoned objects in unattended environments is presented to which image processing content-based retrieval capabilities have been added for making easier inspection task from operators. Video-based surveillance systems generally employ one or more cameras connected to a set of monitors. This kind of systems needs the presence of a human operator, who interprets the acquired information and controls the evolution of the events in a surveyed environment. During the last years efforts have been performed to develop systems supporting human operators in their surveillance task, in order to focus the attention of operators when unusual situations are detected. Image sequences databases are also managed by the proposed surveillance system in order to provide operators with the possibility of retrieving in a second time the interesting sequences that may contain useful information for discovering causes of an alarm. Experimental results are shown in terms of the probability of correct detection of abandoned objects and examples about the retrieval sequences.

Robust Real-Time Periodic Motion Detection (2017) :
We describe new techniques to detect and analyse periodic motion as seen from both a static and a moving camera. By tracking objects of interest, we compute an object's self-similarity as it evolves in time. For periodic motion, the self-similarity measure is also periodic and we apply Time Frequency analysis to detect and characterize the periodic motion. The periodicity is also analysed robustly using the 2D lattice structures inherent in similarity matrices. A real-time system has been implemented to track and classify objects using periodicity. Examples of object classification (people, running dogs, and vehicles), person counting, and nonstationary periodicity are provided.

Unmanned aerial vehicle-based forest fire monitoring and detection using image processing technique (2016):
Early forest fire alarm systems are critical in making prompt response in the event of unexpected hazards. Cost-effective cameras, improvements in memory, and enhanced computation power have all enabled the design and real-time application of fire detecting algorithms using light and small size embedded surveillance systems. This is vital in situations where the performance of traditional forest fire monitoring and detection techniques are unsatisfactory. This paper presents a forest fire monitoring and detection method with visual sensors onboard unmanned aerial vehicle (UAV). Both color and motion features of fire are adopted for the design of the studied forest fire detection strategies. This is for the purpose of improving fire detection performance, while reducing false alarm rates. Indoor experiments are conducted to demonstrate the effectiveness of the studied forest fire detection methodologies.

Wireless communication-based smoke detection system design for forest fire monitoring (2016):
Based on wireless communication technology, this paper designs a smoke detection system out of the need for forest fire monitoring. Firstly, this paper designs the hardware scheme for the key functional modules, and implements the integration of the entire system, as well as the functional debugging at the platform. Based on the hardware design, the overall scheme of software system is set up, which successfully gets through the experimental debugging. For communication, the data received from the sensor nodes is collected by a router to a coordinator, and subsequently sent to the GPRS module through a serial port. Finally, the information is shown on the PC through the Internet. The overall system satisfies the particular need of forest environment monitoring, and presents a good prospect of application and promotion.

Research on user relationship networks of SNS based on the Forest Fire model (2016):
This paper aims to construct a simulation model of user relationship network in SNS. The Forest Fire model is put forward that it can achieve good results in user relationship network simulation despite some deficiency, through analysis of some existing network simulation models, and research on the regular patterns of the users' behavior in SNS. Then, the characteristic value called Reciprocity of the Forest Fire model was improved, and some parameters of the improved model are also optimized. The results of the optimization are compared with the actual data of the user relationship of the four typical social networks. The experimental results show that the improved model is more similar to the real user relationship networks, and it is proved that the improved forest fire model is more effective in the simulation of user relationship network of SNS.

Image Processing based Forest Monitoring and Counteracting System Wildfire (2020):
Forests are the indispensable resource of our life as they cover one third of the land on earth. They provide us with plenty of amenities required to sustain our life. However, for the past few decades, the forest area has been degrading immensely. Recently forest fire has become the greatest menace to our planet. In 2019 Amazon rainforest wildfire destroyed thousands hectors of forest. To get a control over it, a well-organized forest monitoring system is created. This system is based on the emerging technology of IoT and image processing. In our system, these technologies are utilized with the Wireless Sensor Network (WSN). This system provides a continuous live data of the forest environmental conditions. Utilizing this in our work helps us to detect fire intensity which enables water discharge for extinguishing fire when the conditions become unfavorable. This process will be helpful for controlling the wildfire. Forest fire monitoring system is divided in two parts. One is the transmitting part which

consists of microprocessor, camera and different types of sensors, and another is the receiving part which consists of computers and act as our base station.

Integrating Forest Fire Detection with Wireless Sensor Network Based on Long Range Radio (2018):

Forest fires are one of the most common disasters occurring during the dry season. Fires contain a variety of potential hazards for humans, property and the environment. To overcome the problem of forest fires is necessary supervision and early detection of fire. Flame Sensor Module that has been integrated in LoRa / GPS HAT can be an alternative to solve the problem of fire. Flame Sensor Module is a sensor component that can detect fire and LoRa / GPS HAT is a hardware media data transmission communication using radio frequency. By connecting every device on a network then can be created a prototype fire detector. In this modern era, technology has become more sophisticated, thus easing emote works. Integrating Wireless Sensor Network based on LoRa module can be an alternative to detect fires within the areas. LoRa (Long Range Wireless Data Telemetry) is the application of packet-radio communication using bi-directional VHF / UHF radio frequencies. By integrate LoRa module with GPS and multi-node fire detection sensors in WSN, information exchange on the fire location would be ease. This has been done by taking the coordinates data from the GPS and then sending it using the LoRa module as radio packet communication.

Forest Fire Prediction Using Machine Learning Techniques (2021):

Forest Fire Prediction is a key component of forest fire control. This is a major environmental problem that creates ecological destruction in the form of a threatened landscape of natural resources that disrupts the stability of the ecosystem, increases the risk for other natural hazards, and decreases resources such as water that causes global warming and water pollution. Fire Detection is a key element for controlling such incidents. Prediction of forest fire id expected to reduce the impact of forest fire in the future. Many fire detection algorithms are available with different approach towards the detection of fire. In the existing work processes the fire affected region is predicted based on the satellite images. To predict the occurrences of a forest fire the proposed system processes using the meteorological parameters such as temperature, rain, wind and humidity were used. Random forest regression and Hyper parameter tuning using RandomizedSearchCV algorithm we used a various sub-sample of dataset on which it fits several decision trees and uses averaging to improve the predictive accuracy and control over-fitting. Based on the analysis of the models with all the selected meteorological parameters can represent the forest fire events. This paper discusses about a comparative study of different models for predicting forest fire such as Decision Tree, Random Forest, Support Vector Machine, Artificial Neural networks (ANN) algorithms. The study of calculation of Randomized Search CV coefficient using Hyper parameter tuning gives best results of Mean absolute error (MAE) 0.03, Mean squared error(MSE) 0.004, Root mean squared error(RMSR) 0.07.

III. RESEARCH MOTIVATION

3.1 EXISTING SYSTEM

The existing system for forest fire detection typically relies on a combination of traditional surveillance methods and early warning systems. It involves the use of static cameras and satellite imagery to monitor large forested areas. These systems may incorporate smoke and heat sensors to detect potential fire outbreaks. Communication networks are employed to transmit alerts to relevant authorities. However, the limitations include delayed response times and challenges in accurately pinpointing the fire's location. Additionally, the reliance on human monitoring may result in false positives and negatives, impacting the overall effectiveness of the system.

3.2 PROPOSED SYSTEM

The proposed system for forest fire detection leverages an integrated approach combining advanced sensor technologies, satellite imagery, and machine learning algorithms. Real-time data from temperature and smoke sensors strategically deployed in forested areas are collected and transmitted to a centralized system. Satellite imagery aids in monitoring larger areas and identifying potential fire outbreaks. Machine learning algorithms analyze the collected data to distinguish between normal environmental variations and the presence of an actual forest fire. In case of a detected fire, automated alerts are sent to relevant authorities, enabling swift response and mitigation efforts. The system aims to enhance early detection accuracy, reduce response time, and minimize the environmental impact of forest fires. Fire detection is crucial task for the safety of people. To prevent damages caused by fire, several fire detection systems were developed. There are many technologies available for smoke and fire detection but still society is lacking reliable and accurate methods to predict smoke and fire at early stages, this deficiency may then lead to dangerous situations. Fire outbreak is the common issue happening everywhere and the damage caused by this type of incidents is tremendoustowards nature and human. Vision based fire detection system have recently gained popularity as compared to traditional sensor-based fire detection system. However, the detection process by image processing technique is very tedious. We proposed a fire detection algorithm using Convolutional Neural Networks to achieve highaccuracy fire image detection, which is compatible in detection of fire by training with datasets.

Fig. 3.1 Forest Fire and Smoke

Here in this project, we are creating a system to monitor fire and smoke patterns and report it to the forest offices. It plays an important role in saving environment and wild life. By considering the various aspects of the problem, we consider images including fire and smoke patterns in various situations and backgrounds to train the system and achieve higher accuracy and efficiency in detection.

IV Proposed Methodology

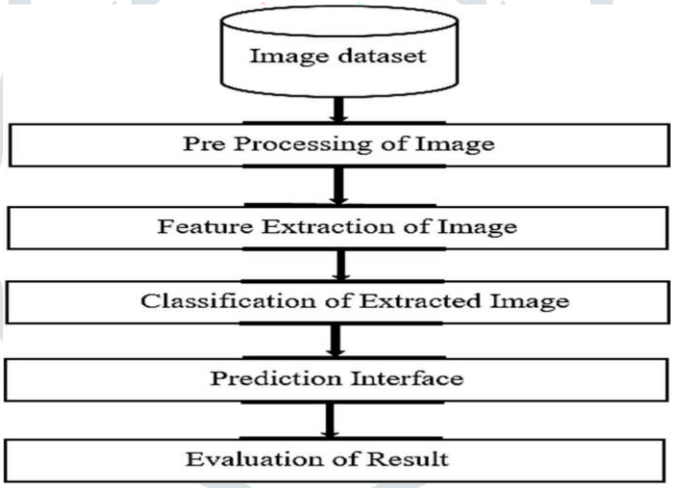


Figure 4.1 Structural chart of the proposed system.

The figure 4.1 shows that the proposed system involves the following steps. First step involves pre-processing of captured images. The pre-processed image undergoes feature extraction, where various features of the fire and smoke and fire types are extracted and certain algorithms are applied. The data that is stored is compared with the pre-processed image and approximate result is generated**.**

4.2 Convolution Neural Network:

Convolutional neural network is the special type of feed forward artificial neural network in which the connectivity between the layers are inspired by the visual cortex. Convolutional Neural Network (CNN) is a class of deep neural networks which is applied for analyzing visual imagery. They have applications in image and video recognition, image classification, natural language processing etc. Convolution is the first layer to extract features from an input image. Convolution preserves the relationship between pixels by learning image features using small squares of input data. It is a mathematical operation that takes two inputs such as image matrix and a filter or kernel. Each input image will be passed through a series of convolution layers with filters (kernels) to produce output feature maps. Here is how exactly the CNN works.

Basically, the convolutional neural networks have 4 layers that is the convolutional layers, ReLU layer, pooling layer and the fully connected layer.

4.2.1 Convolutional Layer:

In convolution layer after the computer reads an image in the form of pixels, then with the help of convolution layers we take a small patch of the images. These images or patches are called the features or the filters. By sending these rough feature matches is roughly the same position in the two images, convolutional layer gets a lot better at seeing similarities than whole image matching scenes. These filters are compared to the new input images if it matches then the image is classified correctly. Here line up the features and the image and then multiply each image, pixel by the corresponding feature pixel, add the pixels up and divide the total number of pixels in the feature. We create a map and put the values of the filter at that corresponding place. Similarly, we will move the feature to every other position of the image and will see how the feature matches that area. Finally, we will get a matrix as an output.

ReLU Layer:

ReLU layer is nothing but the rectified linear unit, in this layer we remove every negative value from the filtered images and replaces it with zero. This is done to avoid the values from summing up to zeroes. This is a transform function which activates a node only if the input value is above a certain number while the input is below zero the output will be zero then remove all the negative values from the matrix.

4.2.3 Pooling Layer:

In this layer we reduce or shrink the size of the image. Here first we pick a window size, then mention the required stride, then walk your window across your filtered images. Then from each window take the maximum values. This will pool the layers and shrink the size of the image as well as the matrix. The reduced size matrix is given as the input to the fully connected layer.

Fully Connected Layer:

We need to stack up all the layers after passing it through the convolutional layer, ReLU layer and the pooling layer. The fully connected layer used for the classification of the input image. These layers need to be repeated if needed unless you get a 2x2 matrix. Then at the end the fully connected layer is used where the actual classification happens.

Typical CNN Architecture:

CNN architecture is inspired by the organization and functionality of the visual cortex and designed to mimic the connectivity pattern of neurons within the human brain. The neurons within a CNN are split into a three-dimensional structure, with each set of neurons analyzing a small region or feature of the image. In other words, each group of neurons specializes in identifying one part of the image. CNNs use the predictions from the layers to produce a final output that presents a vector of probability scores to represent the likelihood that a specific feature belongs to a certain class. Figure 4.2 shows the Typical CNN Architecture.

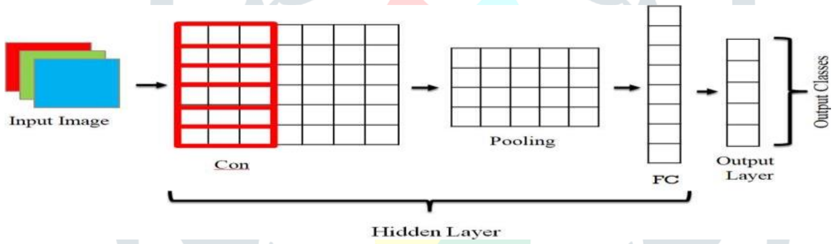
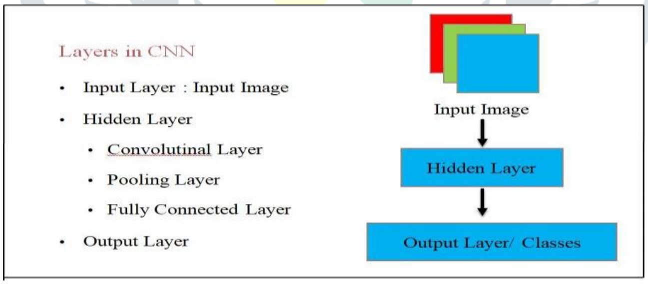


Figure 4.2 Typical CNN Architecture



V CONCLUSION

As a result of our literature review, we are able to determine that it is possible for us to build a powerful system to detect the fire and smoke with good precision and accuracy. This system can be used in forest offices to get alerts based on the threat of fire in the forest. In this project the training data is taken as huge number of images so that the system learns to classify them depending on the presence or absence of fire and/or smoke. Here the system processes the image containing fire and smoke based on RGB to grayscale conversion process. We used three CNN techniques namely LeNet-5, AlexNet, VGG-16. The forest predictor developed, was trained, and tested on all of the 3 models mentioned above and it was observed that the predictor produced a better accuracy in the LeNet 5 when compared to the rest of the models. The proposed forest fire detection technique is based on CNN. The algorithm takes a raw dataset and reshapes it according to the given specifications after which it trains the CNN model. When the images to be predicted are given to the trained model, an output as to whether the image contains forest fire or not is identified. In future this project may be extended and implemented not only for detecting fire and smoke but also for identifying different weapons used to cut trees and hunt animals, to detect illegal tree cutting and hunting, to detect animals that are crossing forest area and dwell into human society. We can even make the user choose what activities he/she needs and provide just those applications in the system according to their requirements. We can even make it available to defense units to detect suspicious activities in the forest.

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