Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7766420

REAL-TIME FIRE DETECTION SYSTEM BASED ON CNN USING TENSORFLOW AND OPENCV

Riya Singh, Shristi Sharma, Shivani Sharma, Shivanshi Kaushik
Department of Computer Science and Engineering
Meerut Institute of Engineering and Technoology
riya.singh.cs.2019@miet.ac.in, shristi.sharma.cs.2019@miet.ac.in,
shivani.sharma.cs.2019@miet.ac.in, shivanshi.kaushik.cs.2019@miet.ac.in

Abstract— Fire is among the major threats to the safety of human life, homes and the property in both industrial and domestic areas. In order to resist fire threats efficiently, depends mainly on how early the detection of fire is done. Fire produces smoke, light and heat that help in identifying the fire. Fire can be disastrous and dangerous causing loss of lives and properties. To avoid this disastrous and dangerous fire situation, there is necessity of detecting fire at the early stages and act upon immediately to handle the situation.

This paper works for the development of fire detection and alert system for early recognition and surveillance of fire with the help of CNN and machine vision techniques. The system comprises of surveillance cameras, to record the video for running the fire detection algorithm based on image processing to detect real time fire. This system is standalone and capable of transmitting recorded videos for fire detection anywhere in the world. Therefore, here we use CNN and computer vision technology to alert the user and fire station when fire is detected at the incident site. With the alert notification, a video of incident and the location of site are transmitted to user and fire station. As the area is constantly under surveillance, this video will help to perceive, how many people are trapped inside the affected area, so that the fire station can dispatch the team of competent rescuers on the basis of the video to rescue the people. The superiority of this model is that, we prevent using smoke and flame based sensors that might generate false alarms. In case, if this system triggers a false alarm then it can be verified by examining the recorded video. Hence the proposed system is used for synchronized detection of fire to properly detect fire incidents and send an alert, along with short video of fire to the remote fire alarm control unit. We correlated the execution of our method with that of recently reported fire detection approaches, using widely executed performance matrices for testing the achieved results through fire classification. This proposed system is successfully capable of detecting and notifying about the disastrous fire incidence at high speed and accurately.

Future advancement in this field will include fire detection automatically and fire alarm generation. This system can be extended for multiple and widely scattered transmission nodes.

Keywords—Tensorflow, OpenCV, Fire-detection, Machine Learning, CNN, python, fire alarm

I. INTRODUCTION

Early fire detection is a major problem of many countries; it is a challenging as well as a critical problem. According to the report from National Crime Records Bureau (NCRB) it was revealed that in India there were around 9329 fire accidents cases involving about 9110 fire accident deaths during 2020[1]. Considering the direct influence of fire on human safety and surroundings, advanced technology are required with proper approaches to detect fire flames at as earliest as possible, in order to prevent injuries and properties damages. Real time fire detection [2] can be used to prevent the life and properties. The dense residential development and entangled wires with failure in implementing the standards of fire safety and security can cause fire devastations. There are multiple researches done to detect fire with high accuracy and quickly.

The already existing fire detection systems are grouped into various fundamental categories such as sensor and vision based systems. Sensors like flame [11], smoke and thermal sensor. Sensor lacks the ability to detect static and dynamic features of the fire flames like its movement and its colour. Detectors and sensors are not suitable for acquiring multidimensional informative data concerning the fire and the smoke. Sensors could not detect the smoke, fire and flame instantly in long distance, but they can detect high temperature and smoke in short distance quickly[4]. In addition to that, the detailed sensors network, In addition to that, the detailed sensor networks costs of communication, maintenance, and sustainability are expensive. In contradiction to sensor based systems, the vision-based [23] fire-detection system provides the wider range and earliest detection services as compared to sensor-based systems. The existing vision-based fire detection methods capture the images or videos from camera; transfer them to a remote host server for central processing for detecting a potential case of fire. Thus, they require the high bandwidth internet connectivity for transferring data at high speed.

Therefore, we have proposed the vision-based fire detection and notification system that processes the live video stream to detect industrial and domestic fires. This system runs on the Machine Learning algorithm based on convolutional neural network (CNN) [2] and OpenCV [23] for real time fire detection using Tensorflow and Python When the fire is detected successfully then the registered user and fire stations are notified along with recorded video to control the situation as earliest as possible.

II. LITERATURE SURVEY

Fire detection systems are a necessity both in residential areas as well as workplaces. They are indeed required to keep people and surroundings safe from any fire incident as much as possible. Some of the major work done in the field of fire detection systems include use of smoke detectors which detect fire on the basis of smoke particles in the environment, for detecting those particles present in surrounding several techniques are used such as ionization or photoelectric effect by J. Mercado et al.[29] but this method involves various drawbacks such as distance between the position of smoke detector and the actual place of fire may be far leading to inability of smoke to reach the detector by H.Chen et al.[30]. Another case of limitation can be that the smoke might generate a bit later after the surroundings had burned which leads to latency in taking preventive measures.

Apart from above mentioned method, Thermal detectors are one of the prominently used instruments for the purpose of detecting fire. Thermal detectors [17] react to energy released in the form of heat at the incident site where the fire outbreak takes place. The detector triggers alarm only when the temperature exceeds above a threshold value. If, the temperature will not reach equal to or above the specified threshold value then alarm will not trigger making this

system not a reliable choice. Thermal detectors are available in various forms some of them are Bolometer [25], Pyro-electric detector, Radiation thermo-element etc.
Other than above mentioned systems for detection of fire, most of the systems are based on Infrared fire sensors which depend primarily on their positional distribution [3].In the Raspberry Pi [9] based fire detection model ,the system used an Infrared based sensor to trigger camera which captures image of fire [26]. During the study it was found out that the limitations of the system are its limited range of the sensor, also Infrared frequencies are influenced by hard articles such as dust, haze etc.
Hence, they are not a good choice for wide area and outdoor applications. Therefore, this gives rise to the requirement of a machine learning based system [1] for detecting fire.

III. DESIGN AND IMPLEMENTATION

The implementation of the model is based on CNN [2]. CNN is based on neural network approach, used majorly for the process of image classification and recognition. The input images are given to the CNN image classifier which are processed and classified under particular groups. Input image is converted into pixels that are stored in an array.

In CNN, every image frame given as input passes through a string of layers with encompasses input, convolution [15], Pooling and fully connected layers. All dimensions of input image data are initialized to make them zero-centered [1] by input layer. The convolutional layer evaluates the convolutional operation of these input images using kernel filters to revive the fundamental features [2]. Pooling layer decreases dimensions of the output image from Convolutional Layer. It is located among Convolutional layers. Pooling can be done using three methods: overlapping pooling, general pooling, and Spatial Pyramid Pooling (SPP) [17] .The last stage CNN architecture is usually the fully connected layers. They forward the data to the output layer, also simplifies which increases the speed of data calculation [1] as shown in the Figure.1.

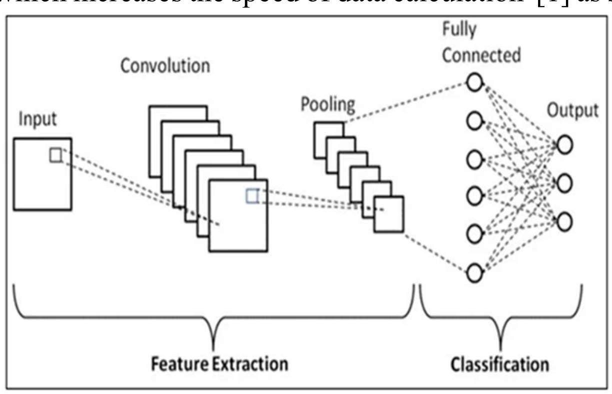

Figure.1 CNN Architecture

The CNN model for fire detection in real-time has been trained and tested with the help of Anaconda virtual environment using Tensorflow 2.11.0, Python 3.9.13, OpenCV and CUDA, cuDNN toolkits.
The real time fire monitoring system includes a set-up of surveillance cameras which are to be installed at specific regions such as factories, industrial sites, indoor locations etc. Videos are continuously captured by the surveillance cameras which are connected to the computer system

for continuous processing of image frames. The captured image frames are passed as an input to this trained model then the model converts the image frame into an array and performs feature extraction over the image array .Major features that are required for object detection are passed to the following layers for further processing. Once the processing is done the image frame is classified to be containing fire or no fire in it. Using OpenCV [9], which is an open source library containing a large set of programming functions used for machine vision and image processing [10] purposes , a bounding box is placed around the object if it is present in the image frame. If it results that the fire is detected in the image, after that an alert e-mail will be delivered to registered user as well as the fire management department along with a small glimpse of the place where fire outbreak took place which may help the fire control unit to understand the severity of the incident and take preventive measures on time.

In addition, a fire alarm will ring immediately as soon as fire is detected. If due to low network connectivity the alert [7] is not sent successfully then the system alerts the registered user via text message as well. The flow chart shown below in Figure. 2 describe the stepwise working of the system and the method of image processing done by the CNN model.

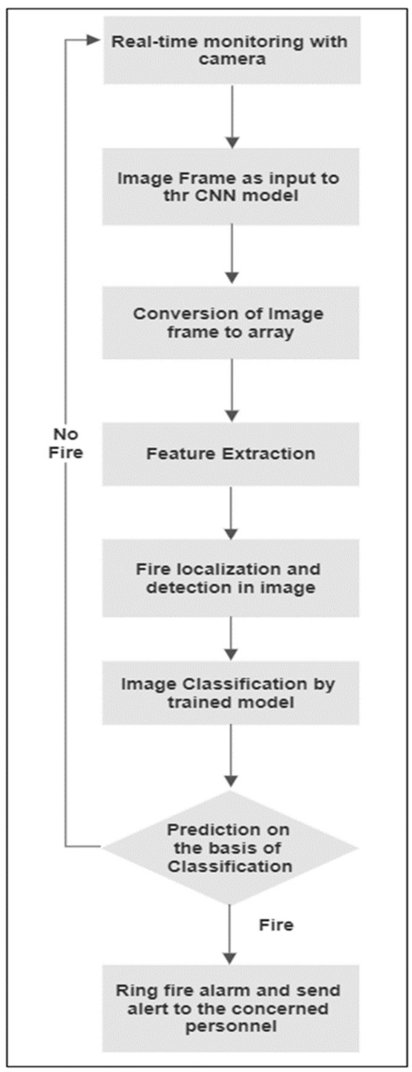

Figure.2 Workflow of Fire Detection model

IV. TRAINING AND TESTING DATASET

The dataset used to train the model has been taken from Kaggle. The dataset is divided into two groups namely training-validation group and testing group. The image dataset contains 1900 images out of which 75% is used to train the model while 25% is used for the purpose of testing and validation. The model is trained using a balanced dataset which consist of images of fire and no fire. The batch size used is 32, while the number of epochs [13] used is 5 to train the model. Some of the training images are shown in Figure.3.

Figure.3 Sample images

V. EXPERIMENTAL RESULTS AND ANALYSIS

A Deep Learning algorithm when implemented on a certain dataset produces a model that receives some input and outputs the desired result [13]. To estimate the performance of this fire detection model, an entity named loss is measured. The errors produced by this model are quantified by loss.

The loss value signifies the errors produced by the model, if it is high then it means the model is producing erroneous output while if it is low then it means few errors are present in the output. Moreover, a cost function is used to evaluate the loss that measures error in several ways. The selected cost function depends upon the problem to be analysed and the data to be used. Such as, in this for binary classification cross entropy [2] is used.

A. Training Loss

To estimate how the deep-learning model fit the training dataset is known as Training loss. Training loss assess errors of the model on training dataset. Mathematically, training loss is evaluated by inputting sum of errors [15] for each data point in training set, after each batch processing training loss is calculated that is envisioned by plotting a graph of the training loss.

B. Validation Loss

To estimate the performance of this Deep Learning model on Validation set on the basis of Validation metric is known as Validation loss [17]. Validation set is a part of the dataset kept aside to authenticate the performance of this model. Validation loss is alike to Training loss and is evaluated by inputting the sum of errors for each data point in the Validation set.

The graph between loss, validation loss on the abscissa and number of Epochs [15] on the ordinate is shown in the Figure.4.

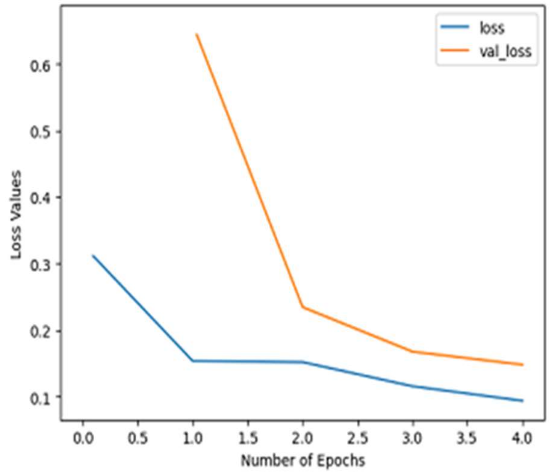

Figure.4 Graph between Loss values and Epochs

The accuracy metric is used for measuring the algorithm's performance in an illustrative manner. Accuracy score is the number of correct predictions [2] obtained from the model. When the model is tested against the testing data it was successfully able to detect fire from images and in real-time experiments, a candle was used as fire source to perform the test. The test results from real time fire detection are shown in Figure 5. The detection score was found out to be 72% in the experiment.

Figure. 5 Experimental Results

VI. CONCLUSION, FUTURE SCOPE AND LIMITATIONS

A fire detection system based on CNN has been proposed here .Contrasting to other existing systems it does not have multiple hardware requirements let alone a camera[3] .Experimental results obtained by introducing flames from matchsticks and from candle trigger the alarm which shows the system is reliable for fire detection[1] in several areas. Once the fire gets detected, the model automatically notifies to the enrolled user on their mobile device and the respective fire station along with the short video depicting the actual scenario and the site of fire outbreak. This system can prove to be an efficient and quick response to a fire outbreak and can be helpful in saving multiple lives and uncountable damages that comes with a fire hazard. The system is expected to detect even the small traces of fire. Furthermore, the requirement of appliances is minimum that is already present at most of the sites, hence saving financial expenses. It becomes cost efficient by removing the use of costly febricity and thermal sensors etc. One possibility of improvement to the system can be amalgamation of more images to the model to train the system for higher preciseness. Installation of high resolution cameras in the fire prone premises can be helpful for the system to detect fire in its early stages.

Possible prospective extent of above method is given below:

Waterproof as an additional feature can be upgraded in the system. Smoke detection can also be included as an additional feature. Systems can be optimized to a higher degree and more advanced techniques can be used to achieve Delay Reduction i.e. lesser latency. Forest fires can be detected through the system. The system can be deployed for defence purposes. This model may be helpful in carrying out various rescue operations.

REFERENCES

[1]. Pragati, Sejal Shambhuwani, Piyusha Umbrajkar et al., "Forest Fire Detection Using Machine Learning", Proceedings of International Journal Of Advance Scientific Research and Engineering Trends, vol. 4, pp. 6-12, 2019-20

[2]. H. Saygın Sucuoğlua , İsmail Böğrekci a , Pınar Demircioğlua, “Real -time fire detection using faster RCNN model” International Journal of 3D Printing technologies and digital industry (2019)

[3]. Md.Saifudaullah Bin Bahrudin and Rosni Abu Kassim, "Development of fire alarm system using Raspberry Pi and Arduino Uno", 2013 International Conference on Electrical Electronics and System Engineering, December 2013.

[4]. Ahmed Imteaj, Tanveer Rahman, Muhammad Kamrul Hossain, Mohammed Shamsul Alam and Saad Ahmad Rahat, "An IoT based fire alarming and authentication system for workhouse using Raspberry Pi 3", International Conference on Electrical Computer and Communication Engineering (ECCE), February 2017.

[5]. Rajeshkumar Kallur and Rohini Kallur, "Fire detection with a wireless video camera using Matlab", International Journal of Recent Trends in Engineering & Research, vol. 02, no. 04, April 2016.

[6]. Chandrakant Shrimantrao, SK Mahesh and Vivekanand M Bonal, "Fire deteCtion system using Matlab", International Journal for Research in Applied Science & Engineering Technology, vol. 5, no. VII, July 2017.

[7]. B. Shravani Vijayalaxmi and G. Sree Ram, "Fire detection and Alert system using image processing", Global Journal of Advanced Engineering Technologies. Special Issue (CTCNSF-2014).

[8]. K.S. Shilpashree, H Lokesha and Hadimani Shivakumar, "Implementation of Image Processing on Raspberry Pi", International Journal of Advanced Research in Computer and Communication Engineering, vol. 4, no. 5, May 2015.

[9]. R. Dhanujalakshmi, B. Divya, C. Divya@sandhiya and A. Robertsingh, "Image Processing based fire detection system using Raspberry Pi system", SSRG International Journal of Computer science and Engineering (JCSE), vol. 4, no. 4, April 2017.

[10]. Amit Hatekar, Saurabh Manwani, Gaurav Patil and Akshat Parekh, "Fire detection on a surveillance system using Image processing", International Journal of Engineering Research & Technology(ijERT), vol. 6, no. 05, May 2017.

[11]. J. Shi, W. Wang, Y. Gao and N. Yu, "Optimal placement and intelligent smoke detection algorithm for wildfire-monitoring cameras", IEEE Access, vol. 8, pp. 72326-72339, 2020.
[12]. X. Ye, F. Yu, C. Zhou and M. Jiang, "A blurry image recognition method for straw burning detection", Proc. IEEE 5th Int. Conf. Signal Image Process., pp. 323-327, 2020.
[13]. S. Wang, F. Yu, C. Zhou and M. Jiang, "Straw burning detection method based on improved frame difference method and deep learning", Proc. IEEE 5th Int. Conf. Image Vis. Comput., pp. 29-33, 2020.
[14]. W. Li, S. Xiaobo, C. Jun and L. Ying, "Research on forest fire image recognition algorithm based on color feature statistics", Proc. 6th Int. Conf. Intell. Comput. Signal Process., pp. 346-349, 2021.
[15]. H. Tao and X. Lu, "Smoke vehicle detection based on spatiotemporal bag-of-features and professional convolutional neural network", vol. 30, no. 10, pp. 3301-3316, Oct. 2020.
[16]. W. Thomson, N. Bhowmik and T. P. Breckon, "Efficient and compact convolutional neural network architectures for non-temporal real-time fire detection", Proc. 19th IEEE Int. Conf. Mach. Learn. Appl., pp. 136-141, 2020.
[17]. H. Ullah, K. Muhammad, M. Irfan, B. Z. Muhammad and S. Anwar, "Light-DehazeNet: A novel lightweight CNN architecture for single image dehazing", IEEE Trans. Image Process., vol. 30, pp. 8968-8982, Oct. 2021.
[18]. S. Verma, S. Kaur, D. B. Rawat, C. Xi, L. T. Alex and N. Zaman Jhanjhi, "Intelligent framework using IoT-based WSNs for wildfire detection", IEEE Access, vol. 9, pp. 48 185-48 196, 2021.
[19]. K. Kaur, S. Garg, G. Kaddoum, S. H. Ahmed and M. Atiquzzaman, "KEIDS: Kubernetes-based energy and interference driven scheduler for industrial IoT in edge-cloud ecosystem", IEEE Internet Things J., vol. 7, no. 5, pp. 4228-4237, May 2020.
[20]. J. Zhang, C. Xu, Z. Gao, J. J. Rodrigues and V. H. C. de Albuquerque, "Industrial pervasive edge computing-based intelligence iot for surveillance saliency detection", IEEE Trans. Ind. Informat., vol. 17, no. 7, pp. 5012-5020, Jul. 2020.
[21]. Z. Gao, C. Xu, H. Zhang, S. Li and V. H. C. de Albuquerque, "Trustful Internet of surveillance things based on deeply represented visual co-saliency detection", IEEE Internet Things J., vol. 7, no. 5, pp. 4092-4100, May 2020.
[22]. D. Połap and M. Woźniak, "Meta-heuristic as manager in federated learning approaches for image processing purposes", Appl. Soft Comput., vol. 113, 2021.
[23]. A. Jha, S. Vedak, K. Mundada, R. Walnuskar, U. Chopade and A. Iyer, "Early fire detection using deep learning", 2021 International Conference on Artificial Intelligence and Machine Vision (AIMV), pp. 1-6, 2021
[24]. W. Liu, Y. Yang and J. Hao, "Design and research of a new energy-saving uav for forest fire detection", 2022 IEEE 2nd International Conference on Electronic Technology Communication and Information (ICETCI), pp. 1303-1316, 2022.
[25]. R. Krisna Astuti Sakir et al., "UAV-Assisted Real-Time Data Processing Using Deep Q-Network for Industrial Internet of Things", Proc. 2020 Int'l. Conf. Artificial Intelligence in Information and Communication (ICAIIC), pp. 208-11, 2020.

[26]. Z.-J. Zhang, J.-S. Fu, H.-P. Chiang and Y.-M. Huang, "A novel mechanism for fire detection in subway transportation systems based on Wireless Sensor Networks", International Journal of Distributed Sensor Networks, vol. 2019, 2019.
[27]. M. J. N. V. S. K. Asrith, K. P. Reddy and Sujihelen, "Face Recognition and Weapon Detection from Very Low Resolution Image", 2018 International Conference on Emerging Trends and Innovations In Engineering And Technological Research (ICETIETR), pp. 1-5, 2018.
[28]. A. Mutar and H. Dway, "Smoke Detection Based On Image Processing by Using Grey and Transparency Features", Journal of Theoretical and Applied Information Technology, vol. 96, no. 21, pp. 6995-7006, 2018.
[29]. J. Mercado, K. Medina, G. Perez, A. Suarez, H. Meana, A. Orozco, et al., "Early Fire Detection on Video Using LBP and Spread Ascending of Smoke", Sustainability, vol. 11, no. 3261, pp. 1-16, 2019.
[30]. S. Ye, Z. Bai, H. Chen, R. Bohush and S. Ablameyko, "An effective algorithm to detect both smoke and flame using color and wavelet analysis", Pattern Recognition and Image Analysis, vol. 27, no. 1, pp. 131-138, 2017.

.