FIRE DETECTION WITH SURVEILLANCE CAMERA USING OPEN SOURCE COMPUTER VISION

A PROJECT REPORT

Submitted by

J.JEYANANDHINI (910719104013)

I.PRIYALAKSHMI (910719104019)

K.SURYAPRAKASH (910719104028)

M.V.VARSHA (910719104030)

in partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE ENGINEERING

K.L.N.COLLEGE OF INFORMATION TECHNOLOGY

SIVAGANGAI DISTRICT – 630612

ANNA UNIVERSITY :: CHENNAI 600025

MAY 2023

ANNA UNIVERSITY :: CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report **"FIRE DETECTION WITH SURVEILLANCE CAMERA USING OPEN SOURCE COMPUTER VISION"** is the bonafide work of **"J.JEYANANDHINI(910719104013), I.PRIYALAKSHMI(910719104019), K.SURYAPRAKASH(910719104028), M.V.VARSHA(910719104030)"** who carried out the work under my supervision.

SIGNATURE	**SIGNATURE**
Prof.N.M.RAMKUMAR,M.A,M.Phil	**Prof.B.K.HEMALATHA,M.E**
HEAD OF THE DEPARTMENT(i/c)	**SUPERVISOR**
Department Of CSE K.L.N. College Of Information Technology,Pottapalayam SIVAGANGAI-630 612.	Department Of ECE K.L.N College of Information Technology,Pottapalayam, SIVAGANGAI-630 612.

Submitted for Viva-voce examination held on _____________

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

We, first of all would like to thank **GOD and our PARENTS** for giving us this wonderful opportunity to express our real talent.

Our sincere thanks to our honourable Principal and Professor & Head/Civil **Dr.K.R.YOGANATHAN.M.E.Ph.D.,** for giving us an opportunity to complete this project successfully.

We would like to express our special thanks and gratitude to our guide **Prof.B.K.HEMALATHA.M.E.,** Head of the Electronics and Communication Engineering Department, K.L.N. College of Information Technology who gave constant encouragement, guidance, ideas, assistance and support to successful completion of our project.

We would like to extend our special thanks to all our **TEACHING** and **NON-TEACHING STAFF MEMBERS** for their constant encouragement and support which motivated us to complete our project on time.

Last but not least, our heartfelt thanks to **OUR FRIENDS** who helped and supported us to complete our project work successfully.

ABSTRACT

Fire detection with a surveillance camera using open-cv is a detector which automatically detects fire.By this we can prevent earlier causes of disastrous hazards that can occur at any workplace such as schools,colleges,hospitals or any public area. Fire leads to major losses and can be harmful in many situations,so there is a need to control this as soon as possible,otherwise it will create a huge loss.In order to control this, a system should be there which can take note of this mishap before it expands to a larger platform. Here the existing target detection algorithms are difficult to detect sudden fire with high precision in real-time in the complex public environment, an improved fire detection algorithm based on YOLOv5 is proposed by us.The proposed system uses Deep learning and Yolo technology to detect the fire and OpenCV technology to capture the images.This system basically detects fire at an early stage, generates an automatic alarm and notify the remote user and fire control station about the fire outbreak.YOLO is a type of deep learning model for processing data that has a grid pattern, such as images, which is inspired by the organisation of animal visual cortex and designed to automatically and adaptively learn spatial hierarchies of features, from low-to high-level patterns. The pixels from the image are fed to the layer that performs the convolution operation. It results in a convolved map. The convolved map is applied to a ReLU function to generate a rectified feature map.The image is processed with multiple convolutions and ReLU layers for locating the features.The best system must have the ability to detect even a small amount of fire. It is evident to see that the fire alarm system is significant for commercial buildings and public places.With the help of a fire detection system, you can easily prevent the fire from conflagration.OpenCV is a Python library that allows you to perform image processing and computer vision tasks also it is fast and efficient.The main motto of this project is to reduce the huge loss by fire accident.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AI	**A**rtificial **I**ntelligence
DL	**D**eep **L**earning
Open-CV	**O**pen **S**ource **C**omputer **V**ision **L**ibrary
YOLO	**Y**ou **O**nly **L**ook **O**nce
ML	**M**achine **L**earning
ANN	**A**rtificial **N**eural **N**etworks
RNN	**R**ecurrent **N**eural **N**etworks
CNN	**C**onvolutional **N**eural **N**etworks
ReLU	**R**ectified **L**inear **U**nit
IOU	**I**ntersection **O**ver **U**nion
RL	**R**einforcement **L**earning

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

Fire outbreak is a very dangerous accident and brings great loss in life and properties.These causes due to the lack of automation and emerging alert systems.Yearly thousands of accidents related to fire happen all over the world due to power failure, accidental fire, natural lightning. So to control fire, various systems are being developed.

Fire alarms alert building occupants of a fire that alert emergency public responders (police and fire) through a central station link to initiate appropriate responses. The primary motivation for fire alarm system requirements in building and fire codes is to provide early notification to building occupants so they can exit the building, and to notify the fire service so it can respond to the fire. This is a challenging task for the computer to identify and recognize the image from the surroundings because humans have a better understanding of an object around their surroundings.

From the beginning of human evolution, humans have had huge memory and data of an environment and surroundings from thousands of years which computers don’t have.But due to advancements in computer technologies, there are billions of stored data in a computer, which helps to make computers advanced on recognizing the images.Usually,computer vision refers to artificial intelligence as a computer must compare and interpret the surrounding what it sees around it and must perform the appropriate tasks of analysing the object, process it, and compare from the memory of the computer and give the result.

For an example of a jigsaw puzzle to make clear how computer vision works. At first, while solving the puzzle first, humans have to make a mind or visualise how the final result is going to look like, how the neural network in the computer takes action. Firstly, the computer analyses different pieces of images and then identifies the edges and corners of the puzzle and tries to organise the pieces through the deep network layers as humans. Object detection is the computer vision that deals with the identifying of the object and locating the object with certain classes in it with the help of the pictures, videos, or the camera feed. Object detection technology is used almost everywhere these days to make work easy, safe, and fast to do.

The purpose of the project is to solve the existing problem of unreliable fire detection systems used in industrial warehouses. The project is aimed at using surveillance cameras in order to detect and monitor the occurrence of fire. Since the cameras are already installed in places, this system is aimed at diminishing the disadvantages of false alarm, making the system cost effective and a fast method of detecting fire. The system uses Open Source Computer Vision, also known as OpenCV, is an open source freeware which is aimed at computer vision.

1.1 DEEP LEARNING

Since the 1950s, a small subset of Artificial Intelligence (AI), often called Machine Learning (ML), has revolutionised several fields in the last few decades. Neural Networks (NN) is a subfield of ML, and it was this subfield that spawned Deep Learning (DL). Since its inception DL has been creating ever larger disruptions, showing outstanding success in almost every application domain.

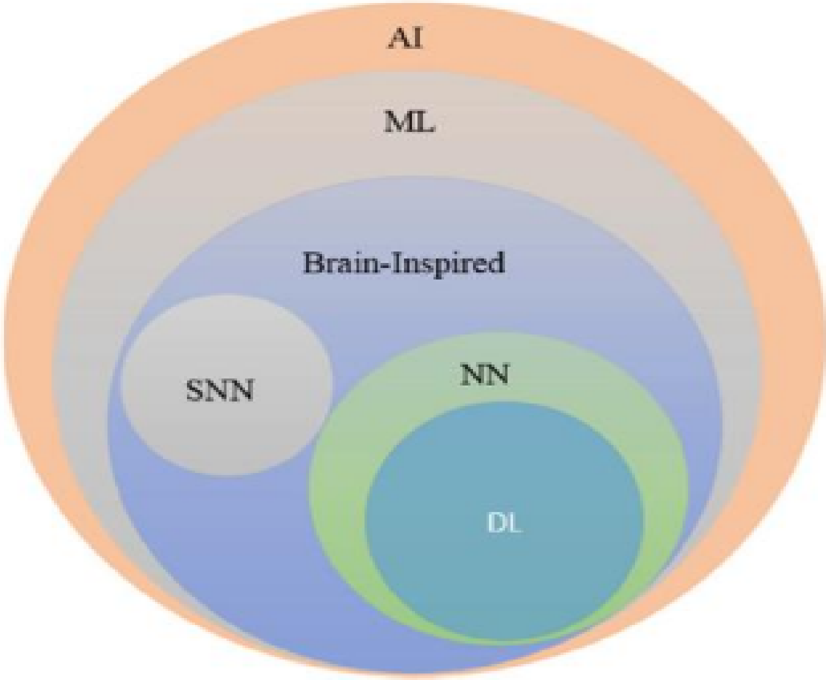

Fig.1.1. The Taxonomy of AI

Fig1.1 shows the taxonomy of AI. DL which uses either deep architectures of learning or hierarchical learning approaches), is a class of ML developed largely from 2006 onward. Learning is a procedure consisting of estimating the model parameters so that the learned model (algorithm) can perform a specific task. For example, in Artificial Neural Networks (ANN), the parameters are the weight matrices. DL, on the other hand, consists of several layers in between the input and output layer which allows for many stages of non-linear information processing units with hierarchical architectures to be present that are exploited for feature learning and pattern classification.

Learning methods based on representations of data can also be defined as representation learning. Recent literature states that DL based representation learning involves a hierarchy of features or concepts, where the high-level concepts can be defined from the low-level ones and low-level concepts can be defined from high-level ones. In some articles, DL has been described as a universal learning approach that is able to solve almost all kinds of problems in different application domains. In other words, DL is not task specific.

1.2. Type of Deep Learning Approaches

Deep learning approaches can be categorised as follows: Supervised, semi supervised or partially supervised, and unsupervised. In addition, there is another category of learning approach called Reinforcement Learning (RL) or Deep RL (DRL) which are often discussed under the scope of semi-supervised or sometimes under unsupervised learning approaches. Fig.1.2. shows the pictorial diagram.

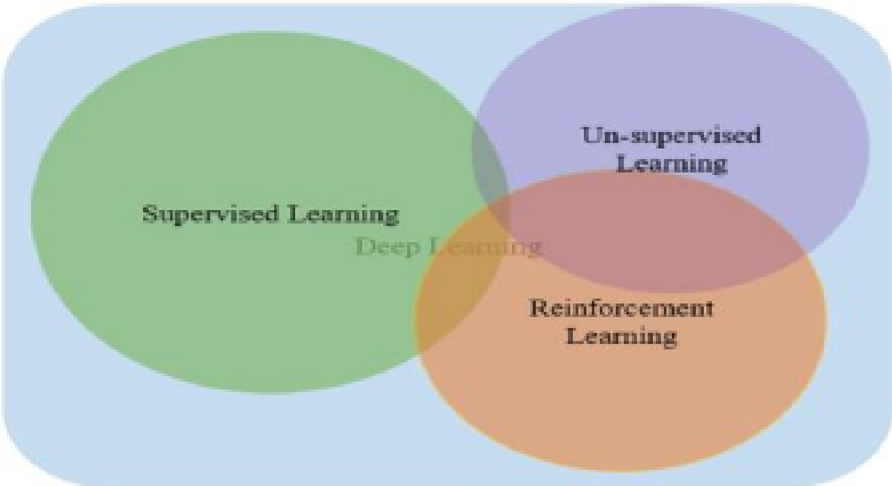

Fig.1.2. Category of Deep Learning Approaches

AI: Artificial Intelligence; ML: Machine Learning; NN: Neural Networks; DL: Deep Learning; SNN: Spiking Neural Networks.

1.3. Deep Supervised Learning

Supervised learning is a learning technique that uses labelled data. In the case of supervised DL approaches, the environment has a set of inputs and corresponding outputs (xt,yt)~ρ. For example, if for input xt, the intelligent agent predicts yt = f(xt), the agent will receive a loss value l(yt, y't). The agent will then iteratively modify the network parameters for a better approximation of the desired outputs. After successful training, the agent will be able to get the correct answers to questions from the environment.

There are different supervised learning approaches for deep learning, including Deep Neural Networks (DNN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), including Long Short Term Memory (LSTM), and Gated Recurrent Units (GRU). These networks will be described in detail in the respective sections.

1.4. Deep Semi-supervised Learning

Semi-supervised learning is learning that occurs based on partially labelled datasets. In some cases, DRL and Generative Adversarial Networks (GAN) are used as semi-supervised learning techniques.

1.5. Deep Unsupervised Learning

Unsupervised learning systems are ones that can do without the presence of data labels. In this case, the agent learns the internal representation or important features to discover unknown relationships or structure within the input data. Often clustering, dimensionality reduction, and generative techniques are considered as unsupervised learning approaches.

There are several members of the deep learning family that are good at clustering and non-linear dimensionality reduction, including Auto-Encoders (AE), Restricted Boltzmann Machines (RBM), and the recently developed GAN. In addition, RNNs, such as LSTM and RL, are also used for unsupervised learning in many application domains. Sections 6 and 7 discuss RNNs and LSTMs in detail.

1.6. Deep Reinforcement Learning (RL)

Deep Reinforcement Learning is a learning technique for use in unknown environments. DRL began in 2013 with Google DeepMind. From then on,several advanced methods have been proposed based on RL. Here is an example of RL: If environment samples inputs:xt~ρ, agent predict:yt = f(xt) , agent receive cost: ct~P(ct|xt,yt) where *P* is an unknown probability distribution, the environment asks an agent a question, and gives a noisy score as the answer. Sometimes this approach is called semi-supervised learning as well. There are many semi-supervised and unsupervised techniques that have been implemented based on this concept. In RL, we do not have a straight forward loss function, thus making learning harder compared to traditional supervised approaches.

The fundamental differences between RL and supervised learning are: First, you do not have full access to the function you are trying to optimise; you must query them through interaction, and second, you are interacting with a state-based environment: Input xt depends on previous actions. Depending upon the problem scope or space, one can decide which type of RL needs to be applied for solving a task. If the problem has a lot of parameters to be optimised, DRL is the best way to go. If the problem has fewer parameters for optimization, a derivation free RL approach is good.

CHAPTER-2

LITERATURE SURVEY

2.1. Forest-Fire Response System Using Deep-Learning-Based Approaches with CCTV Images and Weather Data:

Author Name: Dai Quoc Tran,Minsoo Park,Yuntae Jeon And Seunghee Park.
Journal :IEEE Transaction on The National Research Foundation of Korea through the ministry of science.

METHODOLOGY:

BNN(Bayesian Neural Network)Immediate action and prevention from the major cause.This section discusses the many research efforts that have been conducted to build models for detecting fire and smoke detection systems. With the growth of AI, numerous research attempts have been made to detect the presence of fire/smoke in images using machine learning and deep learning models. However, in this work, we examined CNN-based models for fire/smoke detection.

A large-scale fire dataset with approximately 400,000 images is used to train and test object-detection models. Then,the searched light-weight backbone is compared with well-known backbones, such as ResNet, VoVNet,and FBNetV3. In addition, we propose a damage area estimation method using Bayesian neural network(BNN), data pertaining to six years of historical forest fire events are employed to estimate the damaged area.Subsequently, a weather API is used to match the recorded events. A BNN model is used as a regression model to estimate the damaged area.Compared with other regression models, the BNN estimates the damage area with less error and increased generalisation.

2.2. IoT-based Fire Alerting Smart System:

Author Name: Ibtehal Mahfoodh Muhammad Al Hasani, Syed Imran Ali Kazmi, Reehan Ali Shah, Raza Hasan, and Saqib Hussain.

Journal: Third World Conference on Smart Trends in System Security and Sustainability.

METHODOLOGY:

The proposed system could meet the primary goal, which was to create an effective IoT-based fire alarm system capable of detecting fire, humidity, temperature, smoke, and flame. It's also capable of sending and receiving SMS and messages, as well as obtaining precise sensor data. The paper discussed and the proposed system is based on the Internet of Things technology. Technology has taken over the globe and people's lives, and we use it in all aspects of our everyday life; it is continuously evolving and giving significant benefits to society.

Apart from causing tragic loss of lives and valuable natural and individual properties including thousands of hectares of forest and hundreds of houses, fires are a great menace to ecologically healthy grown forests and protection of the environment. Every year, thousands of forest fires across the globe cause disasters beyond measure and description. This issue has been the research interest for many years; there are a huge amount of very well studied solutions available out there for testing or even ready for use to resolve this problem Sowah et. al. designed and implemented a fire detection system for vehicles using fuzzy logic. They used temperature, flame and smoke sensors for sensing fire. The system also can extinguish fire in 20 seconds and they used the air-conditioning system for extinguishing fire.

2.3. Towards a Smart Elevator-Aided Fire Evacuation Scheme in High-Rise Apartment Buildings for Elderly:

Author Name: HONG QIANG FANG , HONG PENG QIU , PENG LIN, S. M. LO , AND J. T. Y. LO
Journal : ieee

METHODOLOGY:

The academic research and engineering application have been investigated for many years, elevator evacuation has not been widely used for many reasons. One of the greatest concerns is the safety issue of using elevators in fire emergencies. Additionally, the EAE efficiency is also a concern of building engineers and facility managers. Implementing EAE operations improperly may harm evacuees and significantly delay the evacuation process. Therefore, an enabling solution for SEABFE was proposed in this paper.The SEABFE provides a safe and efficient EAE to help a wide range of occupants by allowing elevator groups to respond to the calls from every floor. In order to assure a safe and efficient EAE operation with the SEABED, strategic planning and optimization is enabled by using local sensors (e.g., fire detector, visual-based camera) to collect fire ground and evacuation progress information on-site.

The proposed system will be able to work in a real-time manner as an additional layer on the existing evacuation architectures as well as individually. The functioning of our proposed system is as follows.The block diagram of the proposed system. This agent-based system consists of a central coordinator agent and three major modules,i.e., sensors, optimization and a real-world operation module. Also, these mod-rules have been further divided into sub-modules based on the functionality and connected to a central coordinator agent which is the system's decision-making module.

2.4. A Wireless Sensor Network for Fire Detection and Alarm System:

Author Name: Patrick Jason Y. Piera, Joseph Karl G. Salva

Journal : 7th International Conference on Information and Communication Technology

METHODOLOGY:

This paper based on The wireless fire detection and control system is generally composed of a fire detection node, fire alarm node, and fire alarm control panel. The main module to make the entire system communicate wirelessly is the XBee module from Digi International, Inc. One feature of the XBee module that stands out most is the automatic mesh network.To increase the fire detection capability, 1Cappellini et al introduce the colour video to recognize the fire flame from smokes. Recent colour-video based researches, such as Yamagishi and Yamaguchi propose some enhanced colour image processing techniques for achieving a real-time detection of fire flame. However, the above methods all focus on recognition of a fire but can't provide any information about whether the flame will burn up or low. This is very important when the commercial cost is considered, since human operators must manually validate each false alarm.

Ever process the colour video input to identify a burning jet fuel tire through the spectral, spatial, and temporal properties of fire events. But it requires a complex decision procedure for validating a fire's burning and some constraints, such as a stationary camera and specific environment. To reduce false alarm rate in forest-fire detection, 3Arme developed a complex hybrid system with multiple inputs provided by the visual camera, the infrared camera, meteorological sensors and a geographical information database. Furthermore, the average response time of each detection node with respect to the fire alarm control panel is below the standard of 10-second as stated by the National Fire.

2.5. IOT-Based Fire Alarm System:

Author Name: Asma Mahgoub, Nourhan Tarrad, Rana Elsherif, A. Al-Ali, Loay S. Ismail

Journal: IEEE Transaction on Third World Conference on Smart Trends in System Security and Sustainability.

METHODOLOGY:

This paper is based on an IoT- based fire alarm system that is capable of detecting the presence of fire, communicating with the concerned parties by calling them when a fire is detected, and receiving and responding to SMS requests from the user. As an improvement, the sensing nodes could depend on a rechargeable battery source instead of a power supply. Iot must be self-contained for search operation, decision making based on the real-time data or current condition (object detection), intelligent decision (software program) for the immediate surrounding environment or condition is to perform the task or mission IoT systems combine physical and digital components that collect data from physical devices and deliver actionable, operational insights. These components include: physical devices, sensors, data extraction and secured communication,gateways, cloud servers, analytics, and dashboards

The IOT Based Fire alert framework utilises two sensors, to be specific, temperature and smoke sensors. There is an ADC converter,which changes over the simple signs at the sensor end to computerised and afterward transmits them to the small-scale controller and Arduino. The small-scale controller is modified to turn on the bell, when the temperature and the smoke arrive at a limit esteem. As the smoke is identified, the fumes fan is gone on to release the smoke out of shop floor territory. The user can also get information about the status of his home via sending an SMS to the system. The sensing nodes create a mesh network and they are linked to the central node via a bridge node.

2.6. CNNs in smoke and fire detection were examined in a survey:

Author Name: K. Manoj, P. Suniti, K. Maruthi Durga Karthik, K. Nikhil Kumar , K. Raghu Vamsi ,K. V. Ranjith Varma.

Journal: International Journal Of Advanced Research In Engineering & Technology.

METHODOLOGY:

Further, this effort also discussed current datasets and overviews of modern computer vision approaches. In conclusion, the authors highlighted the obstacles and potential solutions for furthering the development of CNNs in this field.

Sousa et al. summarised recent research attempts to present the common challenges and limitations of these approaches, as well as issues about the dataset quality. Furthermore, they devised a method for transfer learning and utilising data augmentation techniques that were validated using a tenfold cross-validation scheme. The proposed framework enabled the use of an open-source dataset containing images from over 35 real-world fire events. Unlike video-based works, this dataset contains a high degree of variation between samples, allowing us to test the method in a variety of real-world scenarios.

Fernandez et al.demonstrated a system that can acquire real-time images and process them to perform object detection tasks using RetinaNet and Faster-RCNN. To help contain wildfires, this system is capable of detecting smoke plumes over a large area and communicating with and alerting authorities. Luo et al. developed a smoke detection system using a CNN and the motion characteristics of smoke. To begin, they identified candidate regions using a combination of the background dynamic update and a priori dark channel technique. Following that, using a CNN, the candidate region's features were extracted automatically.

2.7. A time-efficient fire detection system using CNN and transfer learning:

Author Name: Hanan A. Hosni Mahmoud, Amal H. Alharbi, Norah S. Alghamdi.

Journal: International Astronomical Search Collaboration.

METHODOLOGY:

This model leveraged a CNN architecture with an acceptable computing time for real-time applications and asserted that the proposed model required less training and classification time than existing models in the literature due to the use of transfer learning. Bari et al. (Bari 2021) used their curated v3-base dataset of online and recorded videos to fine-tune the InceptionV3 and MobileNetV2 models. The authors found that when trained on a small dataset, transfer learned models outperform fully trained models. The authors of (Cheng 2021) developed an approach using a Fast Regional Convolutional Neural Network (Fast R–CNN).

Most of the research in fire detection is focused on features engineering which can be time consuming with degraded performance. Feature engineering methods usually produce false alarms with high rate especially in video surveillance that contains shadows and varying illuminations, and also can falsely detect rigid objects with colours resembling flames as fires. For these reasons, we extensively investigated convolutional learning models for flame detection in an early stage. We explored different CNNs to enhance the performance of fire detection to minimise the false positive rate. The block diagram of the proposed flame detection model in surveillance videos is depicted.The detection of fires in surveillance videos are usually done by utilizing deep learning.

2.8.A CNN-based fire detection system appropriate for power-constrained devices:

Author Name: Faisal Saeed,Anand Paul,Karthi Kumar,Anand Nayyar.

Journal: International Journal of Advanced Research in Science ,communication and Technology.

METHODOLOGY:

To decrease the computational cost of a deep detection network while attempting to maintain its original performance, this method involves training the network and then eliminating its less crucial convolutional filters. Dampage (2022) presented a system and technique for using a wireless sensor network to identify forest fires in their earliest stages. In addition, for more precise fire detection, a machine learning regression model is proposed. In their work, Dogan et. al.(2022) suggested deep learning models using ResNet and InceptionNet to detect fire from images.These models have been used for extracting the features and these features have been classified using SVM. The authors demonstrated that ResNet gave better performance.

The fire and smoke monitoring systems are useful in numerous industries like military, Social Security and economics. The recent methods for fire and smoke detection are using only motion and colour characteristics thus many wrong alarms are happening and this often decreases the performance of the systems. During this study, we will observe the way we are able to divide the smoke columns with object detection and a deep learning-based approach and convolutional neural network (CNN) model for extracting smoke features and smoke detection. The colour, motion and disorder are useful characteristics in fire and smoke detection algorithms. Smoke from the fireplace will blur the entire or a part of the photographs.

2.9. The use of optical images and retrained VGG16 and ResNet50 models:

Author Name: N. N. Mahzan, N. I. M. Enzai, N. M. Zin, and K. S. S. K. M. Noh.

Journal: International Journal of Computer Engineering and Data Science.

METHODOLOGY:

The authors of (Sharma 2017) were able to distinguish between images that included and did not contain the fire. It's worth noting that they created an unbalanced training dataset that included a higher proportion of non-fire images. Many researchers have proposed numerous types of Skin lesion detection systems. Those are mostly based on various CNN techniques such as AlexNet, ResNet, GoogLeNet. However, there are just a few automated skin lesion classification systems on the market, the most of which are PC-based and require additional peripherals and/or regulated settings to gather data. Ganster et al. developed an integrated system, Automated Melanoma Recognition.

A fusion of the outputs of three algorithms was used to achieve automated picture segmentation; as a consequence, 96 percent of the pictures were successfully segmented. When classifying into three classes, a 24-NN classifier has shown a melanoma detection rate of 73 percent, and 87 percent sensitivity and 92 percent specificity for the "not benign" class in a two-class situation. Ercal et al. developed a technique that combined using a commercial Neural Network classifier, dermatologists determined lesion boundaries that used computed characteristics to indicate irregularity and asymmetry in lesion forms, in addition to colours that are similar. Artificial neural networks have already been widely applied in medical imaging, but a special type of neural networks known as Deep Networks, especially CNN (Convolution Neural Networks), produce impressive results.

2.10.Fire detection and disaster management:

Author Name: Q. Khalid, M. Lujak, A. Fernández and A. Doniec

Journal: International Conference on Electrical,Electronics and Optimization Techniques.

METHODOLOGY:

The authors of (Muhammad et al. 2018) integrated AlexNet as a foundation architecture. This system incorporated an adaptive priority mechanism for surveillance cameras, enabling high-resolution cameras to be activated to confirm the fire and assess the data in real time. Inspired by GoogleNet architecture, Muhammad et al. (2018) proposed a fine-tuned CNN model for fire detection in surveillance systems.The tests demonstrated that the suggested architecture outperformed both existing hand-crafted feature-based and AlexNet-based fire detection systems.

The authors of (Nguyen et al. 2021) suggested a unique approach for fire detection based on the use of CNN to extract both spatial and temporal information for fire classification from video image sequences. The system extracted image features using a CNN network and then classified them using short- and long-term stages. Experiments on readily accessible public datasets indicated encouraging performance outcomes when compared to prior studies.Disaster management plays an important role in saving wild life in forest, when they exposed to fire. To protect wild life timely report and responses are important for reducing the number of sufferers and damages from incidents.We have first discussed the wireless sensor network standards that can be employed for the different disaster situations. Finally, we propose a model for disaster management for detecting fire in forest.

2.11.A Fire Detection System for SmartHome Based on loT Data Analytics:

Author Name: Sourav Kumar Bhoi,Sanjaya Kumar Panda,Biramchi Narayan Padhi,Manash Kumar Swain**.**

Journal : International Conference on Information Technology.

METHODOLOGY:

In this paper, an Internet of Things based Fire Detection System (FireDS-IoT) is designed to prevent people from fire by providing an alert message in the event of an emergency. The system is designed using MQ-135 (C02), MQ-2 (smog), MQ-7 (CO) and DHT-11 (temperature) sensors embedded with Arduino to get the fire event information in the surrounding more accurately.

This research distinguishes the conditions in a surrounding as fire, no fire, and may be fire. This classification is performed using the K-Nearest Neighbors (K-NN) and decision tree machine learning algorithms in Python. Several scenarios were recorded in the experiment for training. Results show that K-NN and decision tree shows an accuracy of 93.15% and 89.25%, respectively. As a result, we were able to prove that K-NN provides more accuracy in detecting fire. Therefore, it is used for classification, and if fire conditions arise then a safety message is sent to the registered mobile number using Python programming. The proposed model in this paper employs different integrated detectors, such as heat, smoke, and flame. The signals from those detectors go through the system algorithm to check the fire's potentiality and then broadcast the predicted result to various parties using GSM modem associated with the system.

CHAPTER 3

EXISTING SYSTEM

In the existing system,an effective forest-fire response is critical for minimising the losses caused by forest fires. The purpose of this study is to construct a model for early fire detection and damage area estimation for response systems based on deep learning.First, we implement neural architecture search-based object detection (DetNAS) for searching optimal backbone. Backbone networks play a crucial role in the application of deep learning-based models, as they have a significant impact on the performance of the model. A large scale fire dataset with approximately 400,000 images is used to train and test object-detection models.

Then, the searched light-weight backbone is compared with well-known backbones, such as ResNet, VoVNet, and FBNetV3. In addition, we propose a damage area estimation method using Bayesian neural network (BNN), data pertaining to six years of historical forest fire events are employed to estimate the damaged area. Subsequently, a weather API is used to match the recorded events. A BNN model is used as a regression model to estimate the damaged area. Additionally, the trained model is compared with other widely used regression models, such as decision trees and neural networks. The Faster R-CNN with a searched backbone achieves a mean average precision of 27.9 on 40,000 testing images, outperforming existing backbones. Compared with other regression models, the BNN estimates the damage area with less error and increased generalisation. Thus, both proposed models demonstrate their robustness and suitability for implementation in real-world systems.

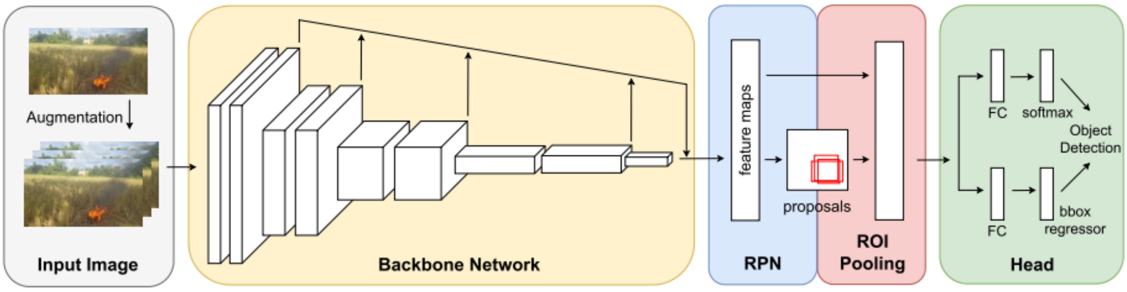

Fig.3.1.Faster R-CNN architecture

Faster RCNN is an object detection architecture presented by Ross Girshick,Shaoquing Ren, Kaiming He and Jian Sun 2015, and is one of the famous object detection architectures that uses convolution neural networks like YOLO (You Look Only Once) and SSD (Single Shot Detector).

Let’s explain how this architecture works,Faster RCNN is composed from 3 parts

Part 1 : Convolution layers

In this layers we train filters to extract the appropriate features the image, for example let’s say that we are going to train those filters to extract the appropriate features for a human face, then those filters are going to learn through training shapes and colours that only exist in the human face.so we can assimilate convolution layers to coffee filters , coffee filter don’t let the coffee powder pass to the cup so our convolutions layer that learn the object features and doesn't let anything else pass, only the desired object.

Part 2 : Region Proposal Network (RPN)

RPN is a small neural network sliding on the last feature map of the convolution layers and predicting whether there is an object or not and also predicting the bounding box of those objects.

Part 3 : Classes and Bounding Boxes prediction

Now we use another Fully connected neural network that takes as an inpt the regions proposed by the RPN and predict object class (classification) and Bounding boxes (Regression).

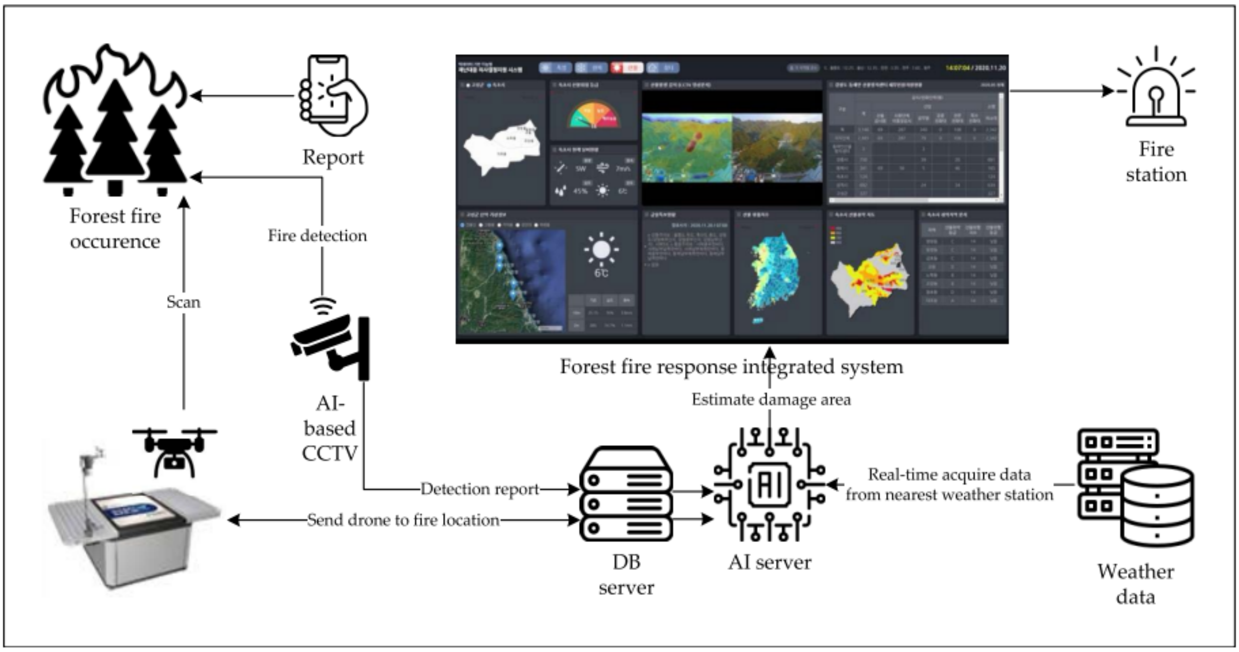

Fig.3.2.Proposed deep-learning-based forest fire management system.

As shown in Figure 3.2, if smoke or fire occurs, AI-powered CCTV cameras detect smoke and fire in the forest in real time and then send the results to a database server. Subsequently, the server sends a UAV to the forest fire location to scan for damage. Then, the regression model gathers data on the extent of the damage area and weather data from the fire location to estimate and visualise it in an integrated system. The most critical aspect of a forest-fire response system is the rapid and accurate detection.

To achieve this, we propose a novel forest fire detection backbone network derived from NAS. Previous research on forest fire detection has relied exclusively on various object detection models that perform well on the COCO dataset , not on a forest fire detection dataset.

Because our backbone is tailored to the large-scale forest fire dataset, our detection model with a searched backbone outperforms other fire detection models. Additionally, the ShuffleNetV2 block is used as a searchable component for searching for the backbone.

Therefore, the searched backbone can be considered as a light-weight model capable of real-time inference and deployable on edge devices. After a forest fire is detected early, the next step is to estimate the damage area in real time. To estimate the damage area, a BNN-based regression model is constructed using historical forest fire records and weather data. BNNs are well-known for handling uncertainty in datasets. Consequently, the trained model can generate a distribution representing the probability of the damage area. Additionally,using a UAV and segmentation algorithm, we could estimate the total damage area and create a 3D forest fire damage map using our previous research.

3.1.Disadvantages:

- Using sensors can sometimes mislead information about fire due to some causes(dust particles,insects and so on…)
- Setup cost is high
- Accuracy is minimal
- Signal problems arouse in most cases

CHAPTER 4

PROPOSED SYSTEM

The Proposed System consists of two parts. They are Fire Detection and Alarm Notification System. In Fire Detection, we can detect the fire through the Yolo Technology with the help of image processing by using Open Source Computer Vision (openCV) along with Python. In the Alarm Notification System, we use Twilio ApI for alerting the Control room, Manager,Fire station corresponding to the place where the fire detection happens. The buzzer will be controlled by the playsound module.

This project will lower the false alarm rate. This system uses CCTV for detecting fires. So we do not need any other sensors to detect fire. System processes the video as a sequence of images as input for detection and then the model predicts them to detect fires. The fire patterns are detected in images. if it is a fire and take action accordingly. On detecting fire, the system goes into emergency mode and sounds an alarm.

A YOLO is a kind of network architecture for deep learning algorithms and is specifically used for Image Recognition and tasks that involve the processing of pixel data.If the fire is detected the Alarm is triggered and SMS or Message is notified corresponding to the admin,using Twilio Api.We can send outgoing messages from your twilio phone number to mobile phones around the globe.It is a paid application .

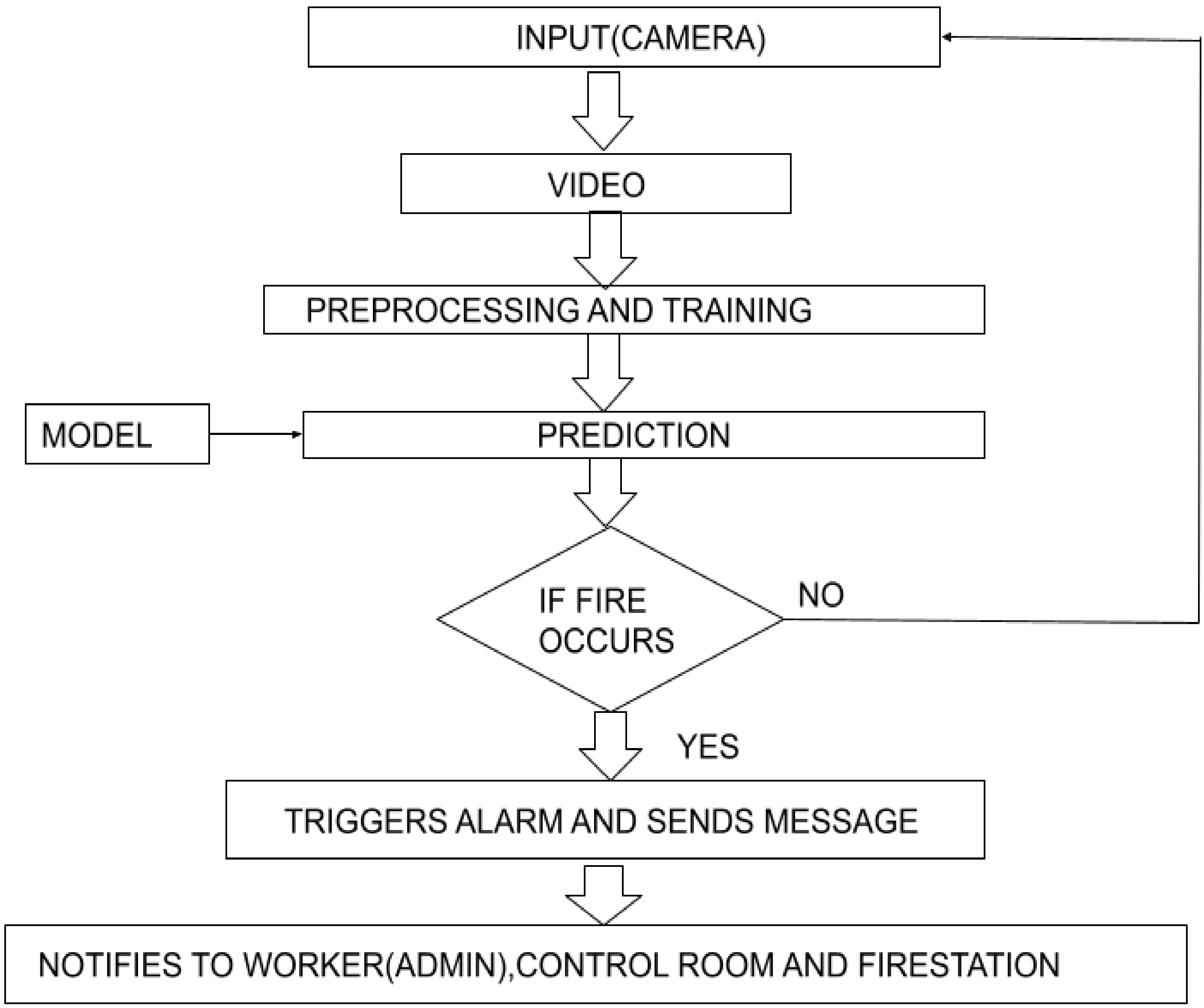

Figure 4.1.FLOW DIAGRAM

4.1.FIRE DETECTION MODULE:

Fire is detected using Open-CV and YOLO technology for tracking the entire technique. Twilio is an api used to send the alert message to the corresponding admin.Collecting the data-set is the primary step.Then we must preprocess the dataset and train the dataset. After training the data-set, the model is created and stored in the respective folder.Now create a python file and import required library.After library is imported then the created model is loaded.Using OpenCV , we can access the camera and get a live video streaming. It converts the video into frames and compares the Frame with the trained model using YOLO.

A YOLO is a kind of network architecture for deep learning algorithms and is specifically used for Image Recognition and tasks that involve the processing of pixel data.If the fire is detected the Alarm is triggered and SMS or Message is notified corresponding to the admin,using Twilio Api.We can send outgoing messages from your twilio phone number to mobile phones around the globe.It is a paid application.

4.2.OPENCV MODULE:

OpenCV is the huge open-source library for computer vision, machine learning, and image processing and now it plays a major role in real-time operation which is very important in today's systems. By using it, one can process images and videos to identify objects, faces, or even handwriting of a human. When integrated with various libraries, such as NumPy, python is capable of processing the OpenCV array structure for analysis.To Identify image pattern and its various features we use vector space and perform mathematical operations on these features.

4.3.YOLO ALGORITHM MODULE:

YOLO is an abbreviation for the term 'You Only Look Once'. This is an algorithm that detects and recognizes various objects in a picture (in real-time). Object detection in YOLO is done as a regression problem and provides the class probabilities of the detected images. The YOLO algorithm employs convolutional neural networks (CNN) to detect objects in real-time. As the name suggests, the algorithm requires only a single forward propagation through a neural network to detect objects.

This means that prediction in the entire image is done in a single algorithm run. The CNN is used to predict various class probabilities and bounding boxes simultaneously.

The YOLO algorithm takes an image as input and then uses a simple deep convolutional neural network to detect objects in the image. The architecture of the CNN model that forms the backbone of YOLO. It has overall 24 convolutional layers, four max-pooling layers, and two fully connected layers.

The first 20 convolution layers of the model are pre-trained using ImageNet by plugging in a temporary average pooling and fully connected layer. Then, this pre-trained model is converted to perform detection since previous research showcased that adding convolution and connected layers to a pre-trained network improves performance. YOLO's final fully connected layer predicts both class probabilities and bounding box coordinates.

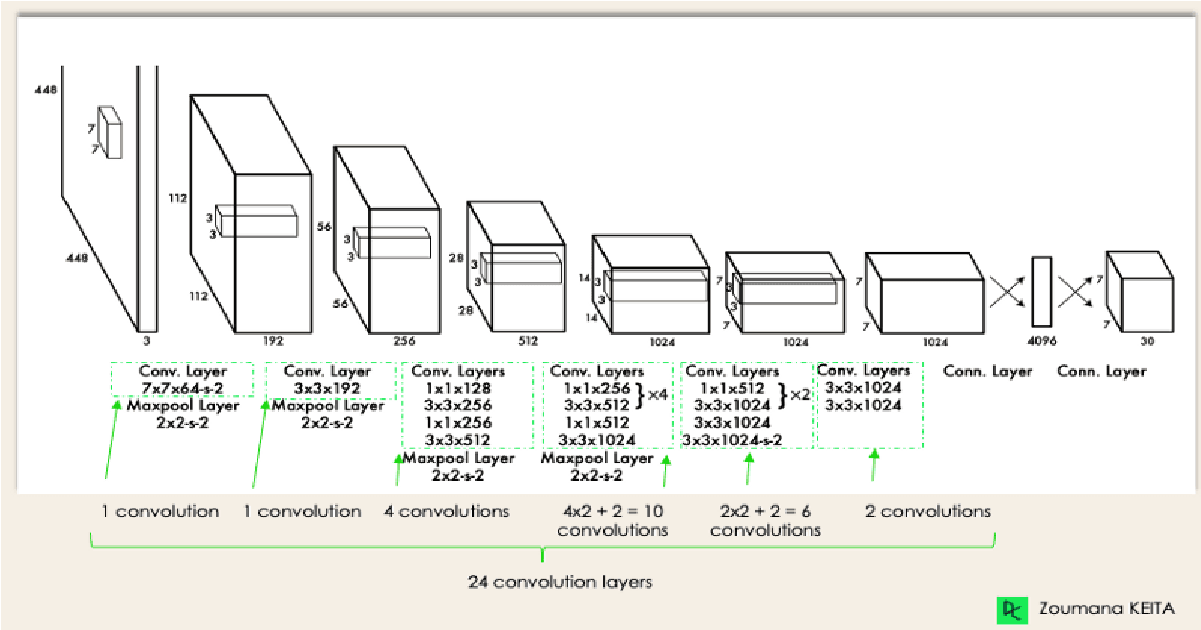

Fig 4.2.Architecture of YOLO

YOLO divides an input image into an S × S grid. If the centre of an object falls into a grid cell, that grid cell is responsible for detecting that object. Each grid cell predicts B bounding boxes and confidence scores for those boxes.

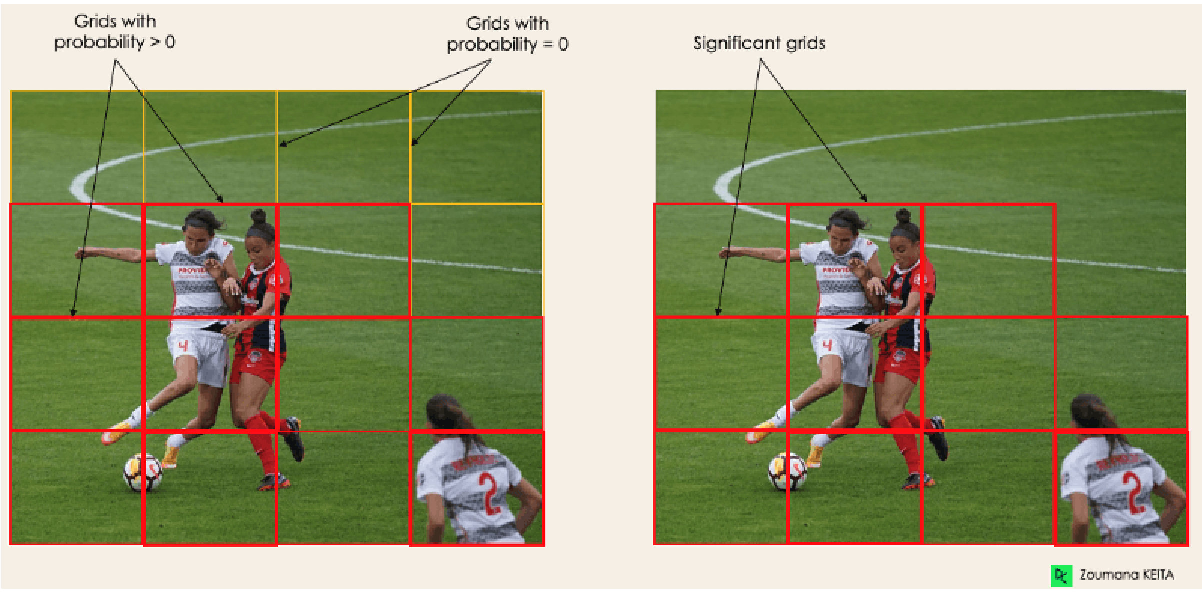

Fig.4.3.Residual Blocks

These confidence scores reflect how confident the model is that the box contains an object and how accurate it thinks the predicted box is.

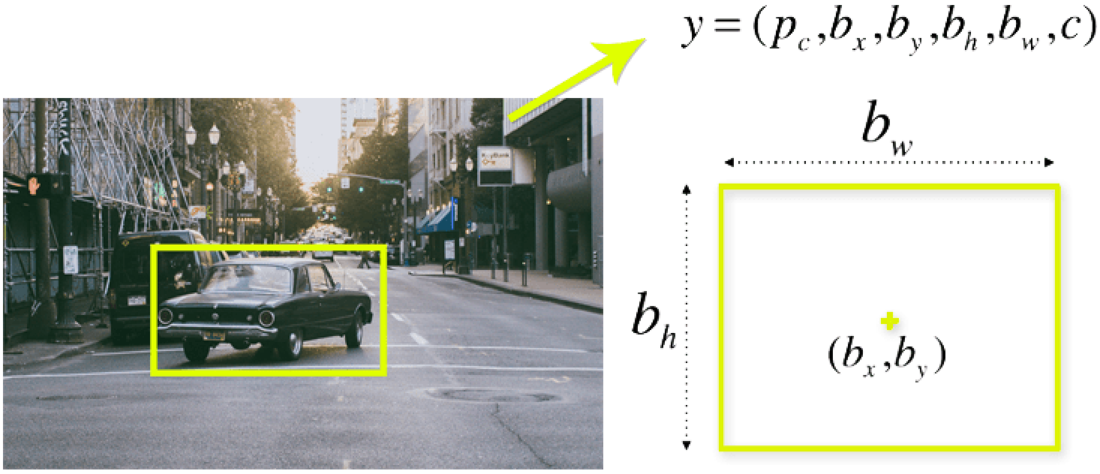

Fig.4.4.Bounding Box Regression

YOLO predicts multiple bounding boxes per grid cell. At training time, we only want one bounding box predictor to be responsible for each object. YOLO assigns one predictor to be “responsible” for predicting an object based on which prediction has the highest current IOU with the ground truth. This leads to specialisation between the bounding box predictors. Each predictor gets better at forecasting certain sizes, aspect ratios, or classes of objects, improving the overall recall score.

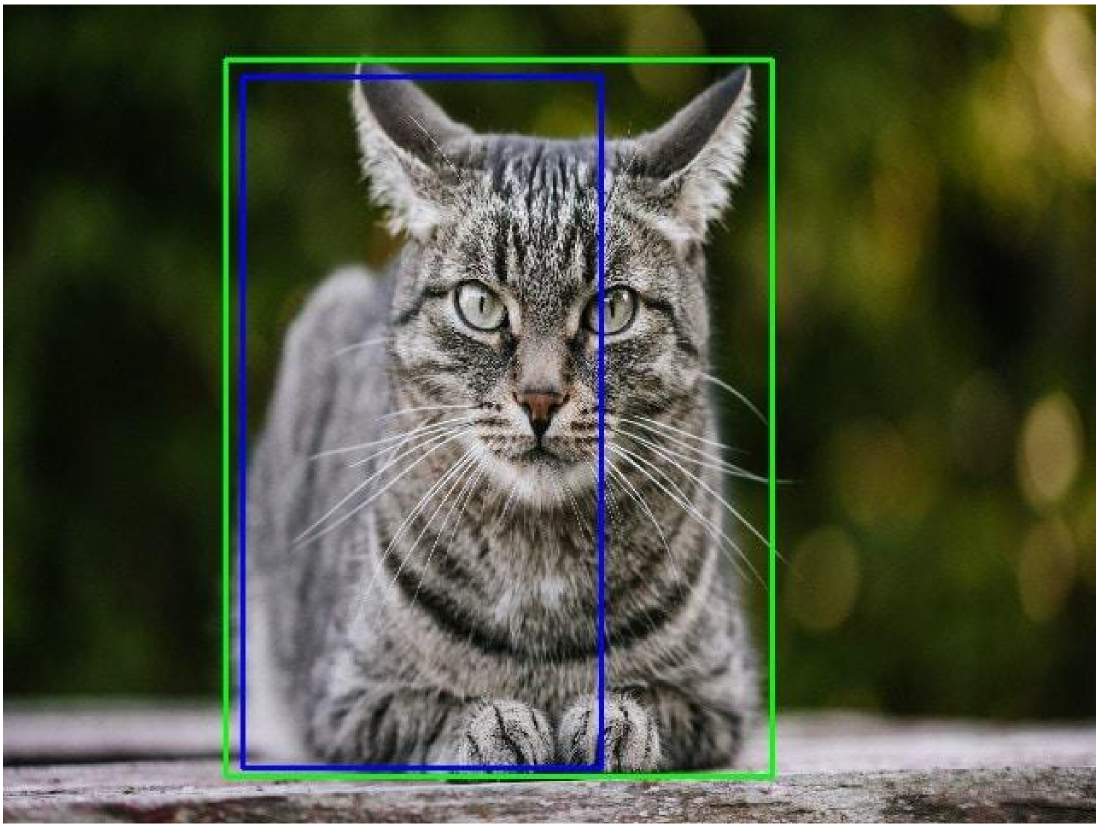

Fig.4.5.Intersection Over Union (IOU)

One key technique used in the YOLO models is non-maximum suppression (NMS). NMS is a post-processing step that is used to improve the accuracy and efficiency of object detection. In object detection, it is common for multiple bounding boxes to be generated for a single object in an image. These bounding boxes may overlap or be located at different positions, but they all represent the same object. NMS is used to identify and remove redundant or incorrect bounding boxes and to output a single bounding box for each object in the image.

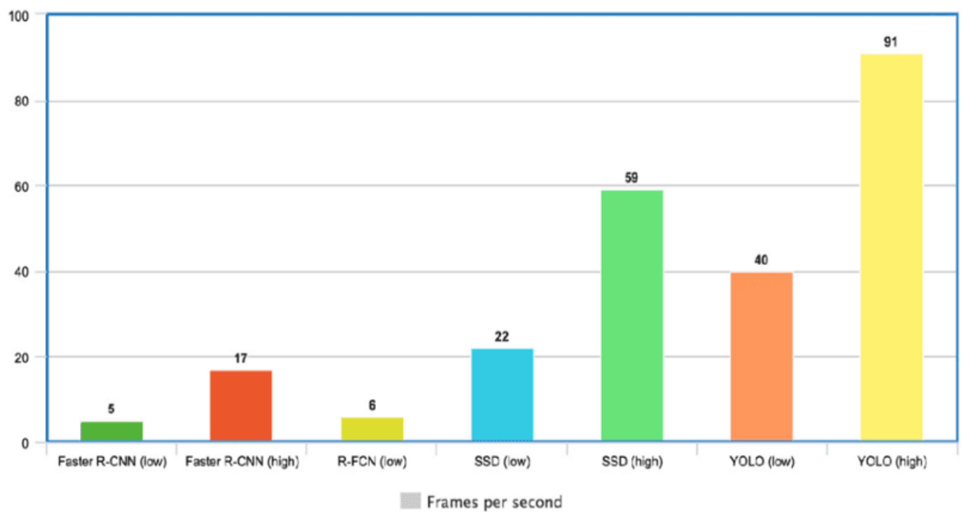

Fig.4.6.YOLO Speed compared to other object detectors

YOLO is extremely fast because it does not deal with complex pipelines. It can process images at 45 Frames Per Second (FPS). In addition, YOLO reaches more than twice the mean Average Precision (mAP) compared to other real-time systems, which makes it a great candidate for real-time processing. From the graphic below, we observe that YOLO is far beyond the other object detectors with 91 FPS.

4.4.ALARM NOTIFICATION MODULE:

The playsound module is a cross platform module that can play audio files.Implementation is different on platforms. It uses windll.winmm on Windows, AppKit.NSSound on Apple OS X and GStreamer on Linux.It works with both WAV and MP3 files.

Twilio is a customer engagement platform used by hundreds of thousands of businesses and more than ten million developers worldwide to build unique, personalised experiences for their customers.

4.5.ADVANTAGES:

- Open cv is used instead of sensors which is good in accuracy
- Setup cost is cheap
- Accuracy is high
- 24/7 increased protection from fire

CHAPTER 5

RESULTS AND DISCUSSION

5.1.SOFTWARE SPECIFICATION

SOFTWARE REQUIRED:

- Python 3.10
- Anaconda Navigator
- Jupyter notebook
- VS code

HARDWARE REQUIRED:

System : Windows 10

Processor : 2.20 GHz

Memory : 200 GB RAM

5.1.1.PYTHON:

Python is a popular programming language. It was created by Guido van Rossum,and released in 1991.It is used for web development (server-side),software development,mathematics,and system scripting.

We are currently using python version 3.10. It has efficient high-level data structures and a simple but effective approach to object-oriented programming.It has new features compared to the previous versions.

5.1.2.ANACONDA NAVIGATOR:

Anaconda is an open-source distribution of the Python and R programming languages for data science.Thus, the main difference between Python and Anaconda is that the former is a programming language and the latter is software to install and manage Python and other programming languages (such as R).The Anaconda distribution includes the Conda package manager in addition to the preconfigured Python packages and other tools.

5.1.3.JUPYTER NOTEBOOK:

The Jupyter Notebook is an open source web application that you can use to create and share documents that contain live code, equations, visualisations, and text. The Jupyter Notebook is maintained by the people at Project jupyter.Jupyter Notebooks are a spin-off project from the IPython project, which used to have an IPython Notebook project itself.

The name, Jupyter, comes from the core supported programming languages that it supports: Julia, Python, and R. Jupyter ships with the IPython kernel, which allows you to write your programs in Python, but there are currently over 100 other kernels that you can also use.

5.1.4.VS CODE:

Visual Studio Code is a streamlined code editor with support for development operations like debugging, task running, and version control. It aims to provide just the tools a developer needs for a quick code-build-debug cycle and leaves more complex workflows to fuller featured IDEs, such as Visual Studio IDE.Its simple user interface is an additional perk, and the neatly sectioned editor makes coding and troubleshooting much easier. These features clearly show why VS Code is so universally popular among developers, and we will present five more reasons why this tool is so unique.

Visual Studio Code, also commonly referred to as VS Code, is a source-code editor made by Microsoft with the Electron Framework, for Windows, Linux and macOS. Features include support for debugging, syntax highlighting, intelligent code completion, snippets, code refactoring, and embedded Git.

Visual Studio Code is a free source code editor that fully supports Python and useful features such as real-time collaboration. It's highly customizable to support your classroom the way you like to teach.

5.2PERFORMANCE METRICS:

- FPS (frames per second)
- Recall
- Precision
- mAP(mean average Precision)

5.2.1.Formulas Used:

FPS:

FPS = 1 / time per frame

Recall:

Recall = true positives / (true positives + false negatives)

Precision:

Precision = true positives / (true positives + false positives)

mAP

mAP = 1/N * sum(i=1 to N) AP_i

5.2.2.Comparison Table:

Algorithm	mAP	Precision	Recall	FPS
YOLO v5	0.5	0.900	0.500	170
YOLO v4	0.43	0.886	0.423	63
Faster R-CNN	0.42	-	-	25
RetinaNet	0.39	0.800	0.383	33
SSD	0.33	0.782	0.329	46

Fig.5.2.1. Comparison Table

5.3.RESULTS:

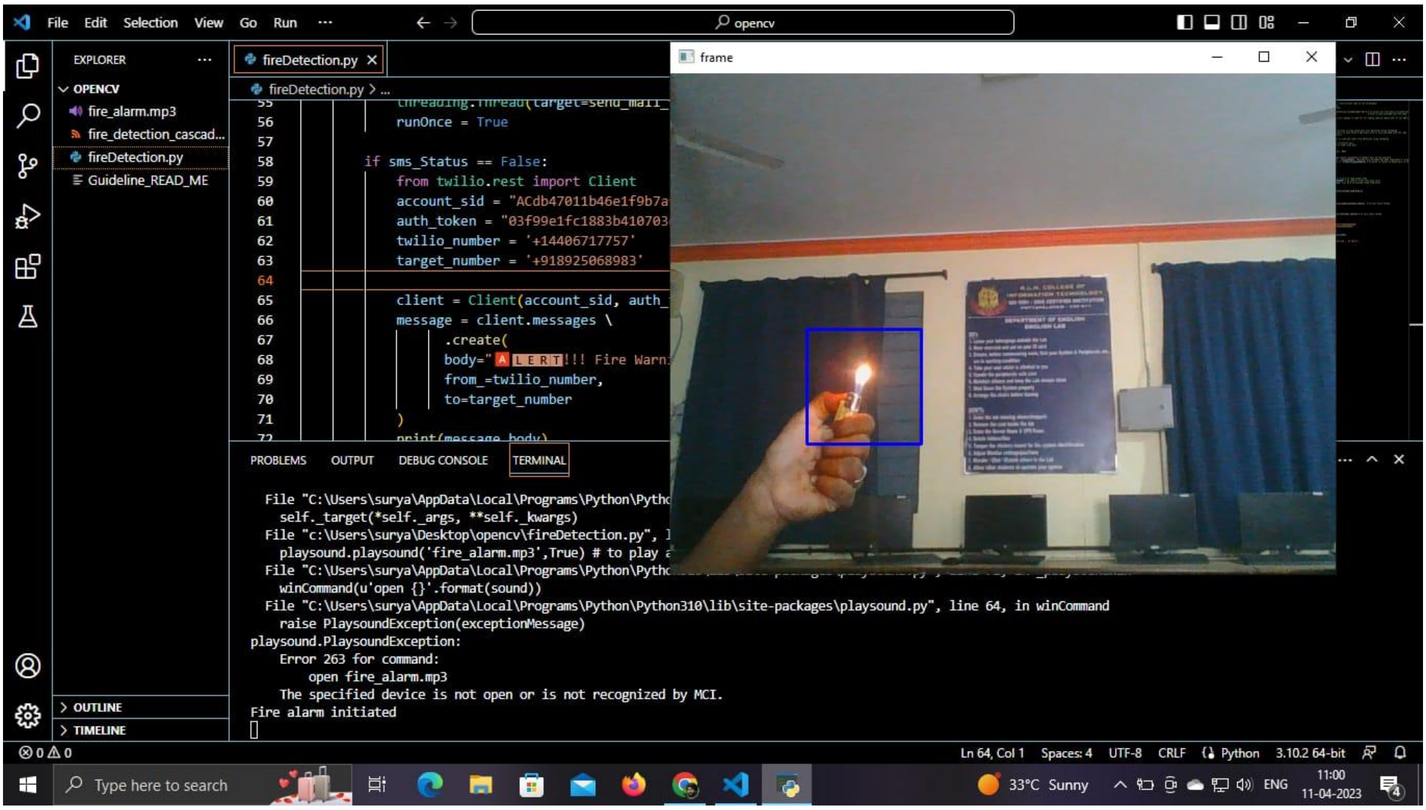

Fig 5.3.1.Fire Detection

The fire detection system is a security system. The primary function of this system is to detect fires and turn on alarms to warn of fire accidents. This system is written in python with OpenCV computer vision module. It is using the YOLO algorithm to detect fires.

Using OpenCV , we can access the camera and get a live video streaming. It converts the video into frames and compares the Frame with the trained model using YOLO.

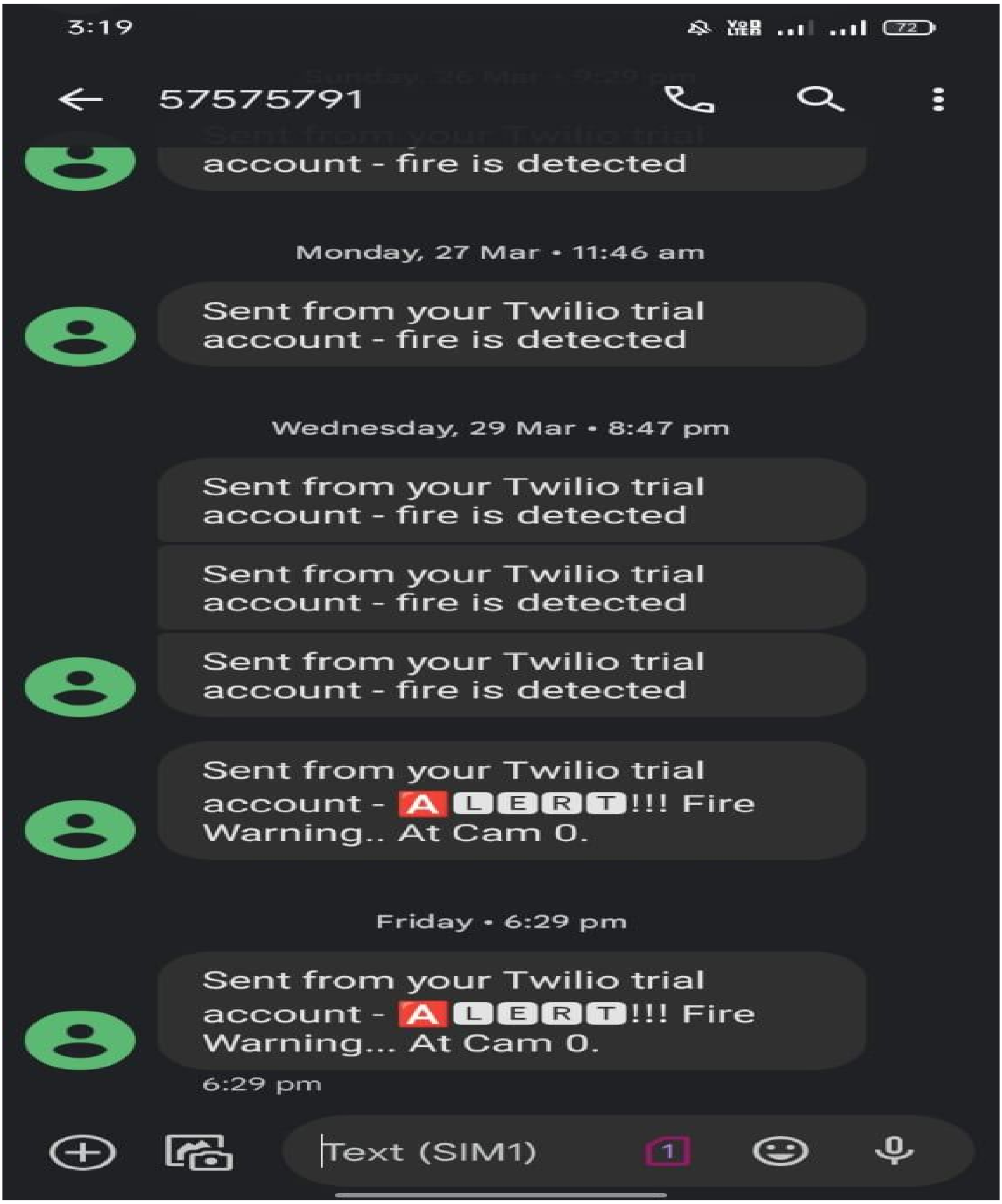

Fig.5.3.2.Alert Message

Fire alarms alert building occupants of a fire that alert emergency public responders (police and fire) through a central station link to initiate appropriate responses. The primary motivation for fire alarm system requirements in building and fire codes is to provide early notification to building occupants so they can exit the building, and to notify the fire service so it can respond to the Fire.

Twilio is a customer engagement platform used by hundreds of thousands of businesses and more than ten million developers worldwide to build unique, personalised experiences for their customers.

CHAPTER-6

SOURCE CODE

Detect.py

import cv2   # Library for openCV

import threading

Library for threading -- which allows code to run in backend

import playsound

Library for alarm sound

from plyer import notification

fire_cascade = cv2.CascadeClassifier('fire_detection_cascade_model.xml')

 # To access an xml file which includes positive and negative images of fire. (Trained images)

 # File is also provided with the code.

vid = cv2.VideoCapture(0)

 # To start camera this command is used "0" for laptop inbuilt camera and "1" for USB attached camera

runOnce = True

```
 # created boolean
Alarm_Status = False
sms_Status = True
def notify_firealert():
    notification.notify(
        title = "Fire Alert... !!!",
        message="In CCTV camera 0 is under fire...",
        timeout =6
  )
def play_alarm_sound_function():
# defined function to play alarm post fire detection using threading
    playsound.playsound('fire_alarm.mp3',True)
# to play alarm
 # an mp3 audio file is also provided with the code.
    print("Fire alarm end")
 # to print in consol
def send_mail_function():
# defined function to send mail post fire detection using threading
```

```
  recipient mail = "add recipients mail"

# recipients mail

   recipient email = recipient email.lower()

# To lowercase mail

      try:

       server = smtplib.SMTP('smtp.gmail.com', 587)

       server.ehlo()

       server.starttls()

       server.login("add senders mail", 'add senders password')

# Sender's mail ID and password

        server.sendmail('add recipients mail', recipient mail, "Warning fire accident
has been reported")

# recipients mail with mail message

       print("Alert mail sent successfully to {}".format(recipient mail))

# to print in console to whom mail is sent

       server.close()

## To close server
```

```
  except Exception as e:
      print(e)
 # To print error if any
while(True):
  ret, frame = vid.read()
 # Value in ret is True # To read video frame
   grey = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
 # To convert frame into grey colour
 fire = fire_cascade.detectMultiScale(frame, 1.2, 5)
 # to provide frame resolution
  ## to highlight fire with square
   for (x,y,w,h) in fire:
      cv2.rectangle(frame,(x-20,y-20),(x+w+20,y+h+20),(255,0,0))
      # font
      font = cv2.FONT_HERSHEY_SIMPLEX
  # org
      org = (50, 50)
  # fontScale
```

```
        fontScale = 1

    # Blue colour in BGR

        colour = (238, 75, 43)

   # Line thickness of 2 px

        thickness = 2

    # Using cv2.putText() method

        image = cv2.putText(frame, 'Fire', org, font,

                    fontScale, colour, thickness, cv2.LINE_AA)

        #cv2.putText(frame,'Fire',(50,50),cv2.FONT_HERSHEY_SIMPLEX,(255,
0, 0))

              roi_gray = grey[y:y+h, x:x+w]

        roi_color = frame[y:y+h, x:x+w]

 if Alarm_Status == False:

           print("Fire alarm initiated")

           threading.Thread(target=play_alarm_sound_function).start()

# To call alarm thread


 Alarm_Status = True
```

```
if runOnce == False:

        print("Mail send initiated")

        threading.Thread(target=send_mail_function).start()

# To call alarm thread

        runOnce = True

      if sms_Status == False:

        from twilio.rest import Client

        account_sid = "ACdb47011b46e1f9b7aff33661dba5a4e8"

        auth_token = "03f99e1fc1883b410703e516d218fde1"

        twilio_number = '+14406717757'

        target_number = '+918925068983'

    client = Client(account_sid, auth_token)

        message = client.messages

            .create(

            body="🅰🅻🅴🆁🆃!!! Fire Warning... At Cam 0.",

            from_=twilio_number,

            to=target_number

       )
```

```
            print(message.body)

            sms_Status = True

        cv2.imshow('frame', frame)

    if cv2.waitKey(1) & 0xFF == ord('q'):

            break
```

Twilio.py

```
from twilio.rest import Client

import keys

#Client = Client(keys.account_sid,keys.auth_token)

account_sid = "ACdb47011b46e1f9b7aff33661dba5a4e8"

auth_token = "03f99e1fc1883b410703e516d218fde1"

twilio_number = '+14406717757'

target_number = '+918925068983'

client = Client(account_sid, auth_token)

message = client.messages \

        .create(

            body="fire is detected",
```

```
        from_=twilio_number,
        to=target_number
)
print(message.body)
```

CHAPTER 7

CONCLUSION AND FUTURE WORK

Using smart cameras you can identify various suspicious incidents such as collisions, medical emergencies, and fires. Of such, fire is the most dangerous abnormal occurrence, because failure to control it at an early stage can lead to huge disasters, leading to human, ecological and economic losses. Inspired by the great potential of Yolos, we can detect fire from images or videos at an early stage.Considering the fair fire detection accuracy of the Yolo model, it can be of assistance to disaster management teams in managing fire disasters on time, thus preventing huge losses.This project proposed a fire detection algorithm which is free from sensors as the ordinary fire detection systems contain.It also saves cost by getting rid of expensive temperature measuring equipments and heat sensors etc. Based on the results produced, the system has proven to be effective at detecting fire.

APPENDIX

PUBLICATION DETAILS

We **(J.JEYANANDHINI, I.PRIYALAKSHMI, K.SURYAPRAKASH, M.V.VARSHA)** of **K.L.N COLLEGE OF INFORMATION TECHNOLOGY** presented the paper entitled "**FIRE DETECTION WITH SURVEILLANCE CAMERA USING OPEN SOURCE COMPUTER VISION**" in One Day Virtual National Conference on **"NATIONAL CONFERENCE ON RECENT TECHNOLOGIES AND COMPUTING SCIENCES-NCRTCS 23"** organised by "Department of information technology-VELAMMAL ENGINEERING COLLEGE (An Autonomous Institution)" **on 11th April 2023.**

VELAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

NCRTCS'23

Certificate of Appreciation

This is to certify that ~~Dr/Mrs/M~~r/Ms. JEYA NANDHINI.J of cse from KLN COLLEGE OF Info' Tehnology has presented a paper entitled Fire Detection with Surveillance Camera using open-CV in the **NATIONAL CONFERENCE ON RECENT TECHNOLOGIES AND COMPUTING SCIENCES - NCRTCS'23** organized by "Department of Information,Technology" ,Velammal Engineering College on 11th April 2023.

COORDINATOR	COORDINATOR	COORDINATOR	CONVENOR	PRINCIPAL
MRS. C M NALAYINI	MR. MOHANRAJ KR	MRS. A R SATHYABAMA	DR. JEEVAA KATIRAVAN	DR. S SATISH KUMAR
ASST.PROF	ASST.PROF	ASST.PROF	HOD	

VELAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

NCRTCS'23

Certificate of Appreciation

This is to certify that ~~Dr/Mrs/Mr~~/Ms. PRIYALAKSHMI.I of CSE from K L N College of Info' Technology has presented a paper entitled Fire Detection with Surveillance Camera using OPENCV in the **NATIONAL CONFERENCE ON RECENT TECHNOLOGIES AND COMPUTING SCIENCES - NCRTCS'23** organized by "Department of Information Technology" ,Velammal Engineering College on 11th April 2023.

C.M.Nalayini	K.R.Mohanraj	[illegible]	[illegible]	S.Satish
COORDINATOR	COORDINATOR	COORDINATOR	CONVENOR	PRINCIPAL
MRS. C M NALAYINI	MR. MOHANRAJ KR	MRS. A R SATHYABAMA	DR. JEEVAA KATIRAVAN	DR. S SATISH KUMAR
ASST.PROF	ASST.PROF	ASST.PROF	HOD	

VELAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

NCRTCS'23

Certificate of Appreciation

This is to certify that Dr/~~M~~rs/Mr/~~M~~s. SURYA PRAKASH.K. of CSE from K L N College of Info' Technology has presented a paper entitled Fire Detection with Surveillance Camera Using OPEN CV in the **NATIONAL CONFERENCE ON RECENT TECHNOLOGIES AND COMPUTING SCIENCES - NCRTCS'23** organized by "Department of Information Technology" ,Velammal Engineering College on 11th April 2023.

C.M.Nalayini	K.R. Mohanraj			S. Satish
COORDINATOR	COORDINATOR	COORDINATOR	CONVENOR	PRINCIPAL
MRS. C M NALAYINI	MR. MOHANRAJ KR	MRS. A R SATHYABAMA	DR. JEEVAA KATIRAVAN	DR. S SATISH KUMAR
ASST.PROF	ASST.PROF	ASST.PROF	HOD	

VELAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

NCRTCS'23

Certificate of Appreciation

This is to certify that ~~Dr/Mrs/Mr~~/Ms. VARSHA.M.V of CSE from KLN College of Info' Technology has presented a paper entitled Fire Detection with Surveillance Camera using OPEN CV in the **NATIONAL CONFERENCE ON RECENT TECHNOLOGIES AND COMPUTING SCIENCES - NCRTCS'23** organized by "Department of Information Technology" ,Velammal Engineering College on 11th April 2023.

C.M.Nalay	K.R. M			
COORDINATOR	COORDINATOR	COORDINATOR	CONVENOR	PRINCIPAL
MRS. C M NALAYINI	MR. MOHANRAJ KR	MRS. A R SATHYABAMA	DR. JEEVAA KATIRAVAN	DR. S SATISH KUMAR
ASST.PROF	ASST.PROF	ASST.PROF	HOD	

REFERENCES

[1] W. H. Dong, L. Wang, G. Z. Yu, and Z. Bin Mei, “Design of Wireless Automatic Fire Alarm System,” Procedia Eng., vol. 135, pp. 413–417, 2016.

[2] A. Imteaj, T. Rahman, M. K. Hossain, M. S. Alam, and S. A. Rahat, “An IoT based Fire Alarming and Authentication System for Workhouse using Raspberry Pi 3,” ECCE 2017 - Int. Conf. Elective.. Eng., no. February 2010, pp. 899–904, 2017.

[3] A. Mahgoub, N. Tarrad, R. Elsherif, A. Al-Ali, and L. Ismail, “IoT-Based Fire Alarm System,” in 2019 Third World Conference on Smart Trends in Systems Security and Sustainability (WorldS4), 2019, pp. 162–166.

[4] N. N. Mahzan, N. I. M. Enzai, N. M. Zin, and K. S. S. K. M. Noh, “Design of an Arduinobased home fire alarm system with GSM module,” J. Phys. Conf. Ser., vol. 1019, no. 1, 2018.

[5] W. L. Hsu, J. Y. Jhuang, C. S. Huang, C. K. Liang, and Y. C. Shiau, “Application of Internet of Things in a kitchen fire prevention system,” Appl. Sci., vol. 9, no. 17, 2019.

[6] J. Ma, W. G. Song, W. Tian, S. M. Lo and G. X. Liao, "Experimental study on an ultra high-rise building evacuation in China", *Saf. Sci.*, vol. 50, no. 8, pp. 1665-1674, Oct. 2012.

[7] Z. Fang, Q. Xu, W. Song, L. Chen and Y. Leng, "Experiment study on super high-rise building evacuation (in Chinese)", *China Saf. Sci. J.*, vol. 28, no. 3, pp. 185-190, 2018.

[8] M. Kinateder, H. Omori and E. Kuligowski, The use of elevators for evacuation in fire emergencies in international buildings, Gaithersburg, MD, USA, Jan. 2014.

[9] Q. Khalid, M. Lujak, A. Fernández and A. Doniec, "On the use of elevators during emergency evacuation" in Distributed Computing and Artificial Intelligence Special Sessions 15th International Conference, Cham, Switzerland:Springer, pp. 149-156, 2019.

[10] N. Cai and W. K. Chow, "Numerical studies on fire hazards of elevator evacuation in supertall buildings", *Indoor Built Environ.*, vol. 28, no. 2, pp. 247-263, Feb. 2019.

[11] Y. Chen, L. Yang, Z. Fu, L. Chen and J. Chen, "Gas flow behaviour and flow transition in elevator shafts considering elevator motion during a building fire", *Building Simul.*, vol. 11, no. 4, pp. 765-771, Aug. 2018.