ISSN: 2584-0495 Vol. 2, Issue 8, pp. 1105-1111

International Journal of Microsystems and IoT

ISSN: (Online) Journal homepage: https://www.ijmit.org

A Machine Vision Based Fire Fighting Robot with Real-Time Fire Localization

Nancy Noella R S, K D N Sai Kumar, K Krishna Madhava Reddy, Jeslin Shanthamalar and Nithya S.

Cite as: Noella R S, N., Sai Kumar, K. D. N., Reddy, K. K. M., Shanthamalar, J., & Nithya, S. (2024). A Machine Vision Based Fire Fighting Robot with Real-Time Fire Localization. International Journal of Microsystems and IoT, 2(8), 1105-1111. https://doi.org/10.5281/zenodo.13709793

Published online: 20 August 2024

DOI: https://doi.org/10.5281/zenodo.13709793

International Journal of Microsystems and IoT
Vol. 2, Issue 8, pp.1105-1111; DOI: https://doi.org/10.5281/zenodo.13709793

A Machine Vision Based Fire Fighting Robot with Real-Time Fire Localization

Nancy Noella R S, K D N Sai Kumar, K Krishna Madhava Reddy, Jeslin Shanthamalar and Nithya S

Department of Computer Science and Engineering, Sathyabama Institute of Science and Technology, Chennai, India

ABSTRACT
This paper presents an analysis of deep learning algorithms, particularly YOLOv8, into an intelligent robotic system aimed at detecting and pinpointing fires in camera imagery. Our method has achieved a noteworthy 94.5% accuracy in classifying fire detection, representing a significant achievement in real-time object recognition. While recognizing this achievement, the research acknowledges significant opportunities for further enhancement in the detection of fire types. The implementation of machine vision in the advanced robot establishes the ground-work for adaptability in response to different fire situations. This initial milestone signifies a promising advancement in the direction of more efficient fire response, and also highlights the ongoing progress in the convergence of deep learning and robotics. The results suggest practical uses for intelligent robots in real-life scenarios, particularly in emergency response and public safety situations.

KEYWORDS
You Only Look Once (YOLO); Global System for Mobile Communication (GSM); Integrated Development Kit (IDE); Simultaneous Localization and Mapping (SLAM).

1. INTRODUCTION

The intersection of advanced technologies has spurred revolutionary advancements across a range of fields, with important implications for essential applications. In this particular setting, the current study focuses on the creation of a robot designed to control fires, using the effective YOLOv8 algorithm in combination with the computational capabilities of a Raspberry Pi platform. The emergence of deep learning algorithms, exemplified by the You Only Look Once (YOLO) approach, has significantly transformed the field of computer vision, especially in the area of real-time object detection.

This study aims to leverage the capabilities of YOLOv8 for immediate fire detection and accurate pinpointing, introducing a new approach for implementation on the resource-efficient and widely available Raspberry Pi architecture. The convergence of YOLOv8 and Raspberry Pi not only ensures timely and precise object recognition but also envisages a practical and cost-efficient solution for enhancing fire control systems. This introduction provides the justification for examining the potential synergies between YOLOv8 and Raspberry Pi, with the goal of enhancing the capabilities of fire-controlling robots and making a significant contribution to the development of intelligent systems in emergency response situations

This paper is organized as follows: Section 2 contains related works, including its advantages and disadvantages. In section 3, Proposed methodology is explained. In section 4, working procedure of the Robot is explained. In Section 5, Conclusion is given along with the robot is shown. Finally, References are provided for future enhancements.

Below Block diagram explains the hardware working process of our robot, which consists of Raspberry Pi board, Camara Module, DC Motors, L293D Driver and GSM Module for communication purposes.

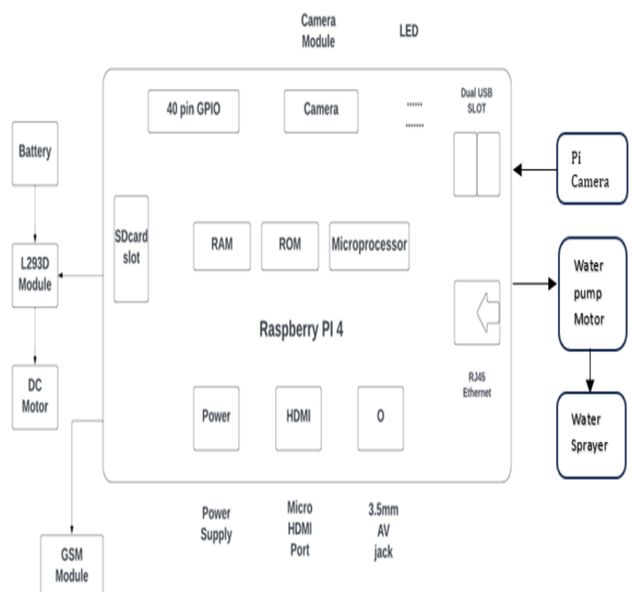

Fig. 1 System Block of the Fire Fighting Robo

2. RELATED WORKS

Ligang Chen [1] introduced a model centered around the stm32f103zet6 MCU, chosen for its efficacy in low power consumption and robust performance. This particular model integrates a portable fire extinguish-er. The robot is outfitted with a camera in its head, enabling image capture and data collection. To facilitate wireless communication, the robot employs the NRF24L01 wireless trans-mission module.

A. Hassanein et al. [2] suggested a model that involves the utilization of both a PIC microcontroller and an Arduino Mega microcontroller, along with the incorporation of a supplementary Bluetooth module. The robot's guidance is facilitated by a digital compass GY-26, aiding in determining the degree of rotation from its initial position. The specific Bluetooth module employed, the Kootek BT2s, interfaces with MATLAB. Notably, a significant drawback identified in this model was the lack of precision in the robot's movement.

M.A. Hossain et al. [3] introduced a model comprising a camera for data collection alongside various sensors. This combined setup is responsible for gathering data and subsequently transmitting it to the Node MCU, which then relays the information to a server. Following an analysis of the situation based on a programmed proto-col, the resulting information is forwarded to the con-troller.

M. Kanwar and L. Agilandeeswari [4] introduced a model wherein the robot trans-mits a fire alert to the cloud, pinpointing the fire's location. An accompanying application utilizes this data to provide individuals with an exit route out of the building. Furthermore, sensors integrated into the system provide information regarding the level of carbon di-oxide. Authorized personnel can then manually choose between water or CO2 for extinguishing the fire based on this data.

L. Mingsong and L. Tugan [5] developed a model, includes a 360-degree rotatable camera to enable continuous video streaming. Additionally, IR sensors have been integrated to detect obstacles while the robot is in motion. This model provides both manual and automatic control features.

Ambadkar and colleagues [6] suggested a model using Arduino as the main controller for the robot, connected to a fire detection system that consists of temperature and gas sensors. The robot has a wireless camera that sends its front view to a receiving unit with an XBEE 3, an Arduino computer, and a camera receiver. Operators have the option to use a graphical user interface (GUI) to evaluate the front view and give commands. Moreover, the robot is equipped with an Arduino-controlled motor driving unit, a sprinkler pump for firefighting, and a relay driver circuit.

Prasojo et al. [7] devised a fire controlling robot, leveraging the AT89S52 as its controller. A relay was employed for extinguishing fires, and a fire sensor was utilized to detect their presence. The robot utilized a DC motor for movement and featured an ultrasound-based navigation system to detect surrounding obstacles. Upon obstacle detection by the ultrasound system, the robot could identify fires within a range of up to 5 meters and effectively extinguish them.

AlHaza et al. [8] proposed that the firefighting robot that can operate inside dangerous fire environments and perform both firefighting and rescue tasks. It can go upstairs, handle temperatures up to 700°C for about 60 minutes, and uses thermal isolation methods. With gas masks, oxygen bottles, fire extinguishing cylinders, flame detection sensors, and IR camera units, it employs sensor-based technologies and machine learning for cognitive function and motor activity.

Dhumatkar et al. [9] proposed a model incorporating a thermostat to sense system temperatures, regulate heating or cooling devices, or control heat transfer fluid flow to maintain specific temperatures. A DC motor adjusts voltage through on-off cycles at low voltages. Additionally, a pump facilitated fluid movement through mechanical action, and wireless remote navigation was achieved using IC7442. Furthermore, a wire-less camera enabled live demonstrations in remote locations where human presence was not feasible.

Anantha Raj P et al. [10] presented a model consists of multiple nodes, each containing sensors and an Arduino microcontroller. These nodes are strategically placed within indoor spaces susceptible to fire incidents and communicate wirelessly with a central coordinator node. The primary controller, powered by a Raspberry Pi processor, oversees the complete Indoor Fire-fighting and Rescue Team (IORT) system. In the event of a fire being detected, the relevant node will notify the central coordinator, who will then alert fire safety personnel and activate the mobile firefighting robot.

Fan et al. [11] introduced a model that integrates the Gmapping SLAM algorithm with a fire source identification image pro-cessing algorithm. This combination enables the firefighting robot to autonomously navigate and detect fire sources. The SLAM construction involves the RBPF algorithm, with a specific focus on utilizing an optimal number of particles for effective mapping. Meanwhile, the using a series of image pro-cessing methods, fire sources can be detect-ed and located.

Tawfiqur Rakib. [12] suggested a fire-fighting robot design with a base made of ‘Kerosene wood’. It has an LM35 sensor to measure temperature changes, flame sensors to find fires, and a 1-liter water tank made of strong, waterproof cardboard. The robot's movement relies on two wheels.

S. Jakthi Priyanka. [13] proposed a firefighting robot that can be controlled by an Android device using the Arduino UNO R3. The robot has a gas sensor to find fires, a gear motor and a motor drive to move around, and a Bluetooth module to connect with an Android device for smartphone control. It also has a water pump and a sprinkler system. The Arduino UNO is programmed using the free Arduino IDE soft-ware to write and execute functions in the microcontroller.

Nagesh MS. [14] suggested a fire-fighting robot that can be controlled by DTMF (Dual Tone Multi Frequency Tones) technology for moving around. The robot has a flame sensor that can find fires within the wavelength range of 760 to 1100 nm, with a sensitivity range from 10cm to 1.5 feet.

Khaled Sailan. [15] suggested a robot that can avoid obstacles on land and water using a fuzzy controller. This robot can steer and dodge fixed obstacles in real time, making sure it follows its planned route while avoiding any obstacles on its way.

Table 1 Summary of literature survey

Author(s)	Title	Proposal	Advantages	Disadvantages	Proposed Work
Ligang Chen	Firefighting Robot with stm32f103zet6 MCU	A robot that uses stm32f103zet6 MCU as the main controller, which is low-power and strong. It has a portable fire extinguisher. The robot's head has a camera for taking pictures and gathering data. It uses NRF24L01 wireless module for communication.	Efficient and powerful MCU, low power consumption, portable fire extinguisher.	Limited information about the model's accuracy and capabilities.	Enhancing the navigation algorithms for precise and efficient firefighting operations.
Hassanein	Firefighting Robot with PIC and Arduino	A model using a PIC microcontroller and Arduino Mega with an additional Bluetooth module. A digital compass guides the robot. The Bluetooth module interfaces with MATLAB. The model faces issues with accurate movement.	Integration of PIC, Arduino, and Bluetooth for control.	Accuracy issues with robot movement.	Implementing advanced control algorithms to improve the accuracy of the robot's movement.
M.A. Hossain	Firefighting Robot with Camera and Sensors	A model with a camera and sensors sending data to NodeMCU, then to the server. Situation analyzed programmatically, and information sent to the controller.	Data collection through sensors and camera, server analysis.	Limited details about the specific sensors used.	Upgrading sensor technologies for enhanced data accuracy and exploring advanced analytics for improved situation analysis.
M. Kanwar and L. Agilandeeswari	Cloud-Connected Fire Alert Robot	The robot sends a fire alert to the cloud, providing fire location for an exit route. Sensors gauge carbon dioxide levels for manual fire extinguishing decisions.	Cloud connectivity, real-time fire location data.	Limited information on the types of sensors used.	Investigating cutting-edge sensor technologies for more accurate data and exploring machine learning algorithms for intelligent decision-making.
L. Mingsong and L. Tugan	Multi-Functional Firefighting Robot	Equipped with a 360-degree rotatable camera and IR sensors for obstacle detection. Manual and automatic control options.	Versatility with manual and automatic control.	Specifics on obstacle detection capabilities are unclear.	Advancing obstacle detection features through the incorporation of AI-based algorithms for improved safety.
Ambadkar	Arduino-Controlled Firefighting Robot	Arduino-controlled robot with fire sensing unit, wireless camera, motor driving unit, sprinkler pump, and relay circuit.	Arduino-based control system with various functionalities.	Limited details on the robot's autonomous decision-making.	Enhancing the autonomy of the robot by integrating advanced decision-making algorithms and improving communication capabilities.
Prasojo	AT89S52-Based Fire Extinguisher Robot	Designed using AT89S52 as a controller, with relay for fire extinguishing. DC motor for movement, ultrasound-based navigation, obstacle detection, and fire detection up to 5 meters.	Utilization of AT89S52 for control, ultrasound navigation.	Limited information on the ultrasound-based navigation system.	Enhancing the ultrasound-based navigation system for better obstacle detection and exploring advanced firefighting strategies.

Author(s)	Title	Proposal	Advantages	Disadvantages	Proposed Work
AlHaza	Advanced Firefighting Robot	A robot capable of entering dangerous fires, climbing stairs, withstanding high temperatures, and providing safety equipment. Equipped with fire extinguishing cylinders and IR cameras.	Capable of high-temperature operation and complex environments.	Complexity and maintenance challenges in extreme conditions.	Researching material sciences for improved robot durability and exploring self-maintenance mechanisms for extreme conditions.
Dhumatkar	Thermostat-Controlled Firefighting Robot	A model using a thermostat for temperature sensing, DC motor for adjustments, and a pump for fluid flow. IC7442 for wireless navigation and a wireless camera for live demonstration.	Precise temperature control with thermostat.	Limited information on the specific thermostat and pump used.	Investigating advanced thermostat technologies and pump systems for enhanced temperature control and fluid flow management.
Anantha Raj P	Wireless Sensor Network for Fire Safety	Nodes with sensors and Arduino microcontroller placed in locations prone to fire accidents. Connected to a central coordinator (Raspberry Pi) through wireless communication.	Extensive sensor network for fire detection and central coordination.	Details about specific sensor nodes and their capabilities are unclear.	Developing advanced sensor nodes with improved fire detection capabilities, enhancing central coordination system for real-time decision-making.
Fan et al	SLAM-Based Autonomous Firefighting Robot	A method that uses Gmapping SLAM algorithm and fire source identification image processing algorithm to make a robot move by itself and find fires. SLAM construction uses RBPF algorithm and effective particle number.	Autonomous navigation and fire source identification.	Limited details on SLAM construction and image processing techniques.	Advancing SLAM algorithms and image processing techniques for more accurate navigation and precise fire source identification.
Tawfiqur Rakib, M. A. Rashid Sarkar	Kerosene Wood-Based Firefighting Robot	A fire-fighting robot that has a base made of 'Kerosene wood,' a temperature sensor, fire detectors, and a water tank.	Eco-friendly base platform and sensors for fire detection.	Limited information on the robot's mobility and firefighting efficiency.	Researching innovative materials for enhanced mobility and firefighting efficiency, and optimizing water delivery mechanisms.
S. Jakthi Priyanka. Sangeetha	Android-Controlled Firefighting Robot	Arduino UNO R3 controlled robot with gas sensor, Bluetooth module, water pump, and sprinkler. Controlled via an Android device using Arduino IDE.	Android-controlled robot with various functionalities.	Limited information on the gas sensor's sensitivity and range.	Improving gas sensor capabilities for better fire detection and exploring advanced control interfaces for enhanced user experience.
Nagesh MS, Deepika T V, Stafford Michahial, Dr M Sivakumar	fire-fighting robot that uses DTMF tones for control.	DTMF technology for robot navigation, flame sensor for fire detection, and central coordination for firefighting actions.	DTMF technology for efficient navigation.	Specifics on central coordination and firefighting actions are unclear.	Enhancing central coordination mechanisms and exploring advanced technologies for firefighting actions to improve the robot's overall effectiveness.
Khaled Sailan, Prof. Dr.-Ing. Klaus-Dieter Kuhnert, Simon Hardt	Fuzzy-Controlled Obstacle Avoidance Robot	An obstacle avoidance robot using a fuzzy controller to guide the robot along its path and avoid obstacles in real time.	Fuzzy control for real-time obstacle avoidance.	Limited details on the effectiveness of the fuzzy controller.	Researching and fine-tuning the fuzzy controller for optimal obstacle avoidance and exploring additional sensor technologies for improved path planning.

3. PROPOSED SYSTEM

In the Propose system, the YOLOv8 algorithm executes fire detection through a four-step process, seamlessly integrating Backbone, Neck, and Prediction stages.

Initially, In the "Backbone" phase, YOLOv8 establishes its core architecture using a potent neural network like Darknet, extracting hierarchical features from input images. The subsequent "Neck" refines these features, enhancing the model's ability to discern intricate details, crucial for recognizing specific characteristics in fire detection. The final "Prediction" stage utilizes learned features for accurate predictions. YOLOv8 divides the image into cells, predicting bounding boxes and class probabilities for real-time fire detection.

3.1. Hardware Configuration

Optimize YOLOv8 to function effectively on a Raspberry Pi, taking into ac-count computational limitations and prioritizing real-time processing. Guarantee a smooth integration of YOLOv8 with the hardware architecture of the Raspberry Pi to enable the efficient implementation of fire detection and suppression processes. Outfit the fire-fighting robot with strategically positioned high-resolution cameras and temperature sensors to ensure comprehensive coverage.

Create a strong, real-time communication system between the sensors and the Rasp-berry Pi, allowing for quick data collection
and analysis. Incorporate a dependable fire suppression system into the robot's design, such as a water spraying system or deploy-able fire extinguisher. Create synchronization algorithms to guarantee a prompt and coordinated reaction to identified fires, smoothly incorporating the abilities for fire detection and suppression.

3.2. Fire Detection

Utilize YOLOv8 for the purpose of fire detection by employing pre-existing models and adapting them to a wide-ranging and annotated dataset encompassing a variety of fire situations. Modify the algorithm to effectively function in real-time on the Rasp-berry Pi, with a focus on maximizing both accuracy and computational efficiency.
Perform thorough testing in controlled set-tings to assess the algorithm's precision in detecting various types of fires and their respective conditions. Confirm the strength and dependability of the fire detection system in different lighting and environmental conditions, ensuring its efficiency in real-world use.

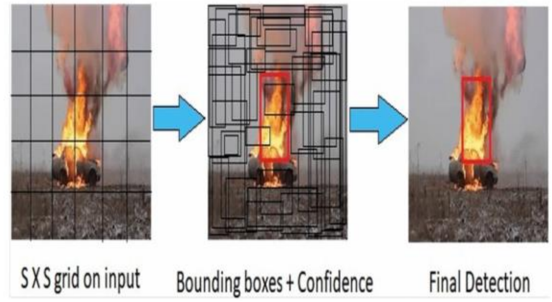

Fig. 2 Fire Detection

3.3. Fire Extinguishing Process

Efficiently integrate the fire detection system with the fire suppression mechanism to ensure a timely and efficient response. Utilize algorithms to activate the fire suppression process upon detection, in order to enhance the response time and minimize potential harm.

Continuously improve the entire system by utilizing testing results and real-world implementations, adjusting parameters to achieve improved performance. Establish continuous monitoring mechanisms in order to ensure that the fire-fighting robot is able to adapt to changing conditions, ensuring that timely updates are provided and emerging challenges in the field are addressed.

4. WORKING MODEL

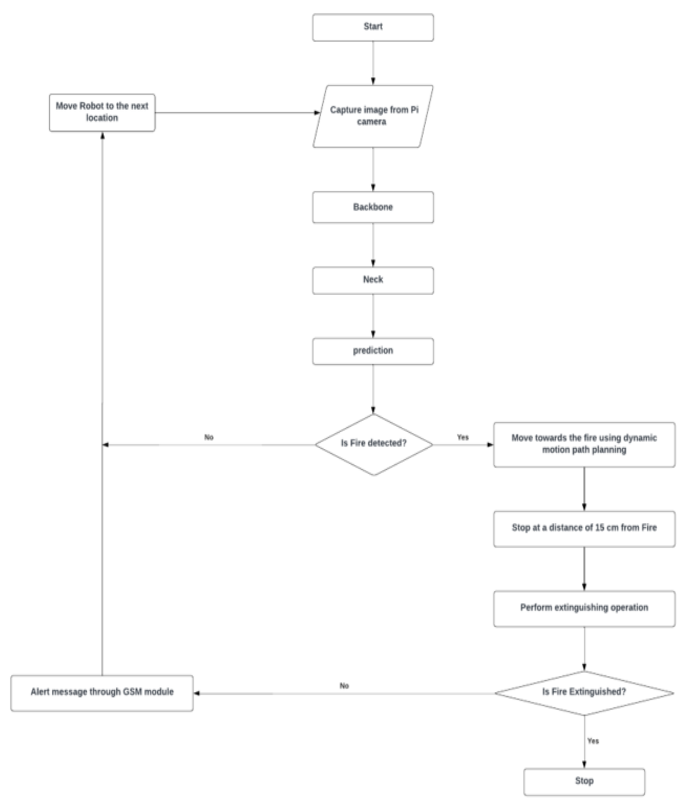

Fig. 3 Working Model for Fire Fighting Robot

Utilize an advanced navigation system to enable the robot to independently navigate to identified fire locations. Integrate algorithms for obstacle avoidance to ensure safe navigation in dynamic and complex environments, thus improving the robot's ability to adapt during emergency situations. Create a user-friendly interface for real-time monitoring and control, which can be accessed through both web and mobile applications. Implement strong communication protocols to facilitate remote control and coordination with emergency response systems, thereby improving the robot's effectiveness and ability to respond promptly.

5. CONCLUSION

The proposed system showcases an advanced implementation of the YOLOv8 algorithm in a fire-fighting robotic system has achieved a remarkable accuracy rate of 94.5% in detecting and responding to fires. The efficient design incorporates DC motors, a dependable battery, Raspberry Pi 4, Pi Camera, and a specialized motor pump, showcasing effective navigation, immediate fire detection, and proactive involvement in fire suppression. The successful implementation of this integration demonstrates the potential for YOLOv8 to revolutionize emergency response systems. It presents significant developments in the integration of deep learning and robotics, which have the potential to improve the accuracy and efficiency of firefighting and other essential functions.

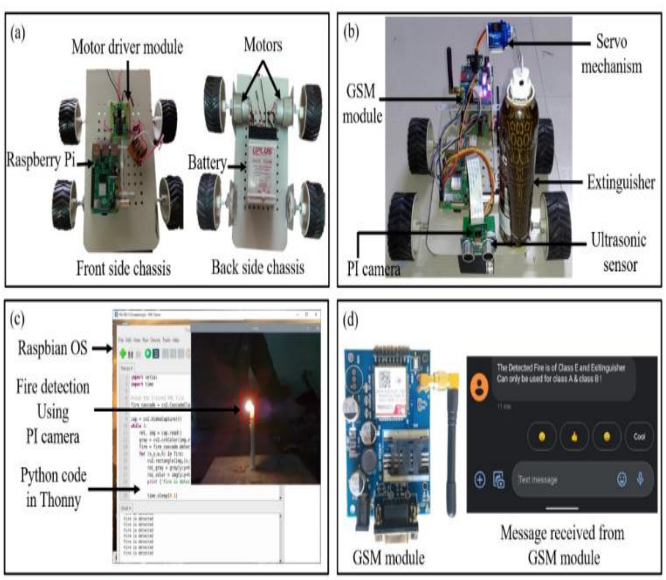

Fig. 4 Reference Image

REFERENCES

1. J. Guo, Z. Hou, X. Xie, S. Yao, Q. Wang, X. Jin, (2019), IEEE Symposium Series on Computational Intelligence (SSCI), pp. 1390–1395. https://researchr.org/publication/ssci-2019
2. P. Liu, H. Yu, S. Cang, L. Vladareanu, (2016) Proc. Automation and Computing (ICAC), pp. 395–401. https://researchportal.northumbria.ac.uk/en/publications/robot-assisted-smart-firefighting-and-interdisciplinary-perspecti
3. P. Pouladzadeh, P. Kuhad, S. V. B. Peddi, A. Yassine and S. Shirmohammadi (2016). Food calorie measurement using deep learning neural network, Proc. IEEE International Instrumentation and Measurement Technology. https://ieeexplore.ieee.org/document/7520547
4. Taichi Joutou and Keiji Yanai (2009). A food image recognition system with Multiple Kernel Learning, Proc. IEEE Inter-national Conference on Image Processing (ICIP), Cairo, Egypt. https://www.researchgate.net/publication/224114535_A_food_image_recognition_system_with_Multiple_Kernel_Learning
5. Saponara, Sergio & Elhanashi, Abdussalam & Gagliardi, Alessio. (2021). Real-time video fire/smoke detection based on CNN in antifire surveillance systems. Journal of Real-Time Image Processing. 18. 1-12. 10.1007/s11554-020-01044-0. https://www.researchgate.net/publication/346516990_Real-time_video_firesmoke_detection_based_on_CNN_in_antifire_surveillance_systems
6. Shamili, K & Devi, & Akhileswar, K & Vinayaka, C & Karthik, M & Yadlapalli, Kasiviswanadham. (2020). Fire Fighting Robot. https://www.researchgate.net/publication/348929351_FIRE_FIGHTING_ROBOT
7. Taha, Ihsan & Marhoon, Hamzah. (2018). Implementation of controlled robot for fire detection and extinguish to closed areas based on Arduino. TELKOMNIKA Indonesian Journal of Electrical Engineering. 16. 654-664. https://www.researchgate.net/publication/324161129_Implementation_of_controlled_robot_for_fire_detection_and_extinguish_to_closed_areas_based_on_Arduino
8. Rasheduzzaman, Md & Awal, Abdul & Gulib, Asadulla & Golam Mostafa, Sk. Md. (2022). Development and Implementation of Fire Fighting Robot. https://www.researchgate.net/publication/360672669_Development_and_Implementation_of_Fire_Fighting_Robot
9. Singh, H. & Mahajan, Akanshu & Naga-rajan, Sukavanam & Budhraja, Veena & Singh, Swarn & Kumar, Amit & Vashisht, Anadi. (2015). Control of an autonomous industrial fire-fighting mobile robot. DU Journal of Undergraduate Research and In-novation. https://www.researchgate.net/publication/281610305_Control_of_an_autonomous_industrial_fire_fighting_mobile_robot
10. Patil, Sakshi & Deshmukh, Sangmesh & Talmale, Mehek & Gadhe, Makarand & Devkar, Utkarsha. (2023). Fire Fighting Robot, SSRN Electronic Journal. https://www.researchgate.net/publication/376673039_Fire_Fighting_Robot

AUTHORS

Nancy Noella R S is currently working as Assistant Professor in Department of Computer Science and Engineering, Sathyabama Institute of Science and Technology, Chennai. She had completed her PhD program in School of Computer Science and Engineering, VIT Chennai, India as a full time scholar. She has more than 8 years of experience in Teaching and Research. Her areas of interest are Artificial Intelligence, Image Processing, Machine Learning and Deep Learning.

E-mail: nancynoella.cse@sathyabama.ac.in

K D N Sai Kumar pursuing his B.E degree in Computer Science and Engineering from Sathyabama Institute of Science and Technology, Chennai, India. His areas of interests are working on Deep Learning, Computer Vision, Artificial Intelligence.

E-mail: saikumarkatepalli89@gmail.com

K Krishna Madhava Reddy pursuing his B.E degree in Computer Science and engineering from Sathyabama Institute of Science and Technology, Chennai, India. His areas of interests are Programming in Python, Developing and Testing IOT Devices

E-mail: krishnamadhav735000@gmail.com

Jeslin Shanthamalar J is currently working as Assistant Professor in Department of Computer science and Engineering, Sathyabama Institute of Science and Technology, Chennai. She had Completed her Ph.D programme in Department of Information Science and Technology, Anna University, Chennai, India as a full time scholar. She has more than 10 years of experience in Teaching, Research and Industry. Her areas of specialization include Data Mining, Image Processing, Machine Learning, Deep Learning and Medical Image analysis.

E-mail: jeslinshanthamalar.cse@sathyabama.ac.in

Nithya S working as Assistant Professor in Department of Computer science and Engineering, Sathyabama Institute of Science and Technology, Chennai. She is pursuing her research in Machine Learning and Deep Learning domain. She has more than 4 years of experience in Teaching, Research and Industry.

E-mail : nithya.cse@sathyabama.ac.in