FIREFIGHTING ROBOT WITH HUMAN DETECTION

PROJECT REPORT

Submitted by

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To

The APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of
Bachelor of Technology
In

Computer Science and Engineering

Department of Computer Science and Engineering

Musaliar College of Engineering & Technology
Pathanamthitta, Kerala – 689653

APRIL 2024

DECLARATION

I undersigned hereby declare that the project report “FIREFIGHTING ROBOT WITH HUMAN DETECTION”, submitted for partial fulfilment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Prof. Athira B. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. I understand that any violation of the above will be cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University

PATHANAMTHITTA
11/04/2024

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CERTIFICATE

This is to certify that the report entitled **"FIREFIGHTING ROBOT WITH HUMAN DETECTION"** is a bonafide record of the project carried out by **ASHMINA SHAMNAD (MCK20CS017)** during the year 2024, in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science & Engineering of APJ Abdul Kalam Technological University Thiruvananthapuram is a bonafide record of the Project work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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GOPIKA S

ABSTRACT

Firefighters risk their lives when responding to dangerous fire scenarios. Robotic technology has been increasingly used in hazardous environments such as firefighting in recent years. Firefighter robots with human detection and alert capabilities are a new robotics application that has the potential to transform firefighting and rescue operations. The proposed system detects fire in all three directions. left, right, front. The robot has a special ability to detect and avoid obstacles. The robot reacts quickly, making firefighting more efficient and successful. Additionally, this robot uses cutting-edge computer science methods like computer vision, machine learning, and sensor fusion to detect human presence in dangerous environments and notify firefighters of their whereabouts. Cameras, gas sensor are among the sensors installed on the robots, which provide real-time data to the robot's onboard computer system. Identifying and locating humans even in low-light conditions can be achieved by processing data with specialized algorithms.. When a human is detected, the robot can use audio and visual feedback to alert firefighters to their presence, allowing for faster and more efficient rescue operations. It also uses a water tank and a spray mechanism to put out the fire .This robot, equipped with a water spray nozzle mounted on a servo motor and supplied with water from a main tank via a pump, is capable of performing tasks that pose significant risks to human safety. Comparing with traditional firefighting robots, our robot provides 85% accuracy in its operations, making it more faster and effective in extinguishing fires and ensuring better safety outcomes.

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ABBREVIATION

- **AI** – Artificial Intelligence
- **MAV -** Micro-scale Unmanned Aerial Vehicle
- **UAV -** Unmanned Aerial System
- **IoT -** Internet of Things
- **UAV -** Unmanned Aerial System
- **LDRs -** Light Dependent Resistors
- **IR –** Infrared
- **YOLOv8 –** You Only Look Once Version 8
- **USB –** Universal Serial Bus
- **LNG** – Liquified Natural Gas
- **DC MOTOR** – Direct Current Motor
- **HCL -** Hardware Compatibility List
- **TP** – True Positive
- **FP** – False Positive
- **TN** – True Negative
- **FN** – False Negative

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the relentless pursuit of advancing technology for the betterment of society, the field of robotics has emerged as a transformative force, reshaping industries and redefining our approach to various challenges. Among the myriad applications, one area where the fusion of robotics and artificial intelligence has shown remarkable promise is in firefighting. The development of firefighting robots equipped with automatic fire detection and human sensing capabilities represents a paradigm shift in emergency response strategies. As the global community grapples with an increasing frequency and intensity of disasters, the integration of these robotic systems into firefighting and rescue operations stands as a beacon of innovation, offering unprecedented advantages in risk mitigation and human safety.

At the heart of these cutting-edge firefighting robots lies the capability of automatic fire detection, a technological breakthrough that significantly enhances the speed and efficiency of emergency response. These robots are equipped with advanced sensors and artificial intelligence algorithms that can swiftly identify and assess the magnitude of a fire outbreak. The seamless integration of real-time data analysis enables these machines to detect fires in their early stages, providing a crucial time advantage for responders to deploy resources strategically. By automating the initial phase of fire detection, these robots not only minimize response times but also contribute to the reduction of property damage and, more importantly, the preservation of human life

In addition to their prowess in identifying and combatting fires, these firefighting robots incorporate sophisticated human detection capabilities. With a keen awareness of the importance of human safety in emergency scenarios, these robots utilize advanced sensors and artificial intelligence to locate and rescue individuals trapped in hazardous environments. The integration of human detection technology not only streamlines the rescue process but also mitigates the risks associated with sending human responders into perilous situations. As these robots can navigate through smoke-filled spaces and unstable structures, their deployment minimizes the exposure of human responders to potentially life-threatening conditions, exemplifying a transformative approach to ensuring the safety of both those in need of rescue and those executing the rescue operation.

1.2 PROBLEM STATEMENT

Human-detection firefighting robots have emerged as crucial assets in rescue operations, addressing the inherent risks faced by firefighters in hazardous environments. Traditional firefighting methods, while commendable, often struggle to adapt to the dynamic and unpredictable nature of fires. These robots represent a transformative solution by leveraging advanced sensors and artificial intelligence. Navigating through challenging conditions, such as smoke-filled spaces, they swiftly locate and assess the positions of individuals in need. This adaptability significantly enhances overall safety for both victims and human responders, addressing challenges beyond the scope of traditional methods.

The primary role of these robots is to complement human efforts in emergency response scenarios. Their autonomous navigation and sensor capabilities enable them to enter high-risk areas, providing real-time data and support to human responders. By doing so, they not only improve the effectiveness of rescue operations but also reduce the risks faced by firefighters. As indispensable allies, human-detection firefighting robots contribute to a paradigm shift in emergency response, ushering in an era where collaboration between humans and machines ensures a safer and more efficient approach to the unpredictable challenges posed by fires.

Fig 1 : Fireman in Rescue Missions

1.3 OBJECTIVES

The objective of this robot is to comprehensively explore the evolution, current advancements, and future potential of firefighter robots equipped with human detection and alert capabilities. The primary aim is to illuminate how these robotic technologies are revolutionizing firefighting and rescue operations in hazardous environments.

- Fire Detection: The primary objective is to detect fires autonomously using sensors such as cameras, thermal imaging, or smoke detectors. The robot should be able to identify the presence of fire in various environments and under different conditions.

- Human Detection: Another key objective is to detect the presence of humans in hazardous environments, such as burning buildings or industrial accidents. This capability allows the robot to alert firefighters to the presence and location of individuals who may require assistance or evacuation.

- Navigation and Mobility: The robot should be equipped with the ability to navigate through complex environments, such as cluttered indoor spaces or rough outdoor terrain. It should be able to move efficiently and effectively to reach fire locations or areas where humans are detected.

- Fire Suppression: The robot should be capable of extinguishing fires using appropriate methods, such as water spraying, foam deployment, or chemical suppression. This objective involves designing and implementing effective firefighting mechanisms that can be deployed autonomously by the robot.

- Remote Operation and Control: An objective is to enable remote operation and control of the robot by firefighters or emergency responders. This includes developing intuitive interfaces and communication systems that allow operators to monitor the robot's activities and intervene when necessary.

- Safety and Reliability: Ensuring the safety and reliability of the robot is a critical objective. This involves designing robust hardware and software systems, implementing fail-safe mechanisms, and conducting rigorous testing and validation procedures to mitigate risks associated with robot malfunctions or errors.

- Integration with Emergency Response Systems: The robot should be designed to seamlessly integrate with existing emergency response systems and protocols. This includes interoperability with firefighting equipment, communication networks, and command and control infrastructure to enhance overall effectiveness and coordination during firefighting operations.

- Scalability and Adaptability: The robot should be scalable and adaptable to different scenarios and environments. This involves designing modular components, flexible configurations, and versatile capabilities that can be customized or upgraded based on specific needs or emerging challenges.

- By addressing these objectives, a firefighting robot with human detection capability can significantly enhance firefighting capabilities, improve safety for both responders and civilians, and mitigate the impact of fire-related incidents.

1.4 SCOPE

The scope of firefighting robots with human detection capability is vast and promising, offering numerous opportunities for enhancing fire safety and rescue operations. Some of the key scopes include:

- Enhanced Safety in Hazardous Environments: Firefighting robots equipped with human detection capabilities can navigate through hazardous environments such as burning buildings, chemical spills, or industrial accidents where human intervention is risky. By detecting humans in distress, these robots can assist in rescue operations without exposing human responders to immediate danger.

- Early Detection and Rapid Response: With advanced sensors and AI algorithms, firefighting robots can detect fires at an early stage, even before they escalate into major disasters. This early detection enables prompt response, potentially preventing the spread of fire and minimizing property damage.

- Autonomous Fire Suppression: Firefighting robots can autonomously suppress fires using various methods such as water sprays, foam, or chemical agents. By integrating human detection capabilities, these robots can prioritize extinguishing fires in areas where human lives are at risk, optimizing their firefighting efforts.

- Remote Monitoring and Control: The incorporation of camera systems and real-time communication technology allows firefighting robots to provide remote monitoring and situational awareness to human operators. Emergency responders can remotely control and coordinate multiple robots deployed in different locations, enhancing overall firefighting efficiency.

- Adaptability to Challenging Terrain: Firefighting robots with human detection capabilities are designed to operate in diverse and challenging terrains, including confined spaces, rough terrain, and areas with limited visibility. Their mobility and agility enable them to access hard-to-reach areas where traditional firefighting methods may be impractical.

- Integration with Smart Building Systems: In smart building environments, firefighting robots can be integrated with building management systems to receive real-time data on fire alarms, smoke detection, and occupancy status. This integration enables seamless collaboration between robots and building infrastructure for more effective firefighting strategies.

- Continuous Innovation and Research: The field of firefighting robotics is constantly evolving with advancements in AI, sensor technology, and materials science. Ongoing research and development efforts aim to enhance the capabilities of firefighting robots, making them more reliable, efficient, and adaptable to evolving fire scenarios.

Overall, firefighting robots with human detection capability represent a significant advancement in fire safety technology, offering a proactive and effective approach to mitigating fire-related risks and saving lives in emergency situations.

CHAPTER 2

LITERATURE SURVEY

2.1 Development and Implementation of Fire Fighting Robot smart cities

The research paper "Development and Implementation of Fire Fighting Robot" focuses on the design, development, and practical implementation of a firefighting robotic system. The study's primary goal is to address the challenges posed by fire-related emergencies, with an emphasis on the need for advanced technologies to improve the efficiency and safety of firefighting operations. **Md. Rasheduzzaman, Abdul Awal, Asadulla Hil Gulib, and S. M. G Mostafa delve** into the complexities of developing a robotic solution capable of autonomously navigating through fire-affected areas and carrying out firefighting tasks.

The primary objective of the suggested model is to create a firefighting robot that can be operated manually or automatically using apps for smartphones or Android devices. Because of this, the suggested model made use of the ESP-32 microcontroller, which comes with an integrated Wi-Fi system by default. The robot is controllable through the smartphone's Wi-Fi. In addition, the robot has other benefits that it can manually operate. The suggested model made use of a very effective motor control device, the L298D motor driver, to regulate the motor's speed and direction. This robot is capable of locating the fire and calming the light more quickly. It is capable of detecting human presence and transmitting information to the Adafruit Web. This proposed prototype has seen a number of developments. The suggested initial model. The objective of the suggested model is to use the ESP-32 microcontroller to create a highly applicable, fully automated, and manual firefighting robot. This intelligent firefighting system has the ability to completely put out fires and detect them more accurately. Additionally capable of detecting human presence in the fireplace is the developed system. The suggested FF robot is extremely controllable via an Android app or smartphone[1]

Even with the improvements discussed in the paper, there might be some drawbacks or restrictions to take into account. These can involve issues with the robot's ability to adjust to various environments, the precision and range of its sensors, or the efficiency of its firefighting system in various fire situations. Furthermore, elements like price, upkeep needs, and possible technical issues could be mentioned as possible disadvantages. Understanding the developed firefighting robot's limitations helps direct future research and advancements in this field and offers a more thorough understanding of its applicability.

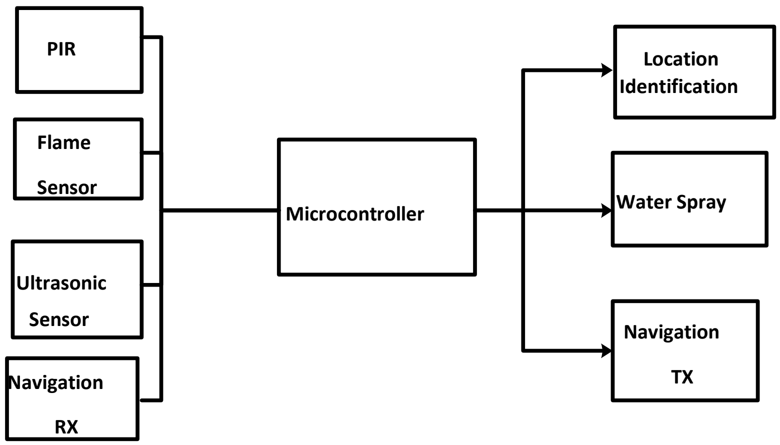

Fig.2 Block diagram of Firefighting Robot using ESP-32 microcontroller[1]

2.2 Arduino based firefighting Robot

The research paper titled "Arduino-based Firefighting Robot" explores the development and implementation of a firefighting robot utilizing Arduino technology. The primary objective is to design a robot capable of autonomously detecting and extinguishing fires, enhancing the efficiency and safety of firefighting operations. The authors, **S. Kirubakaran, S. P. Rithanyaa, S. P. Thanavarsheni, and E. Vigneshkumar,** leverage the versatility and accessibility of Arduino microcontrollers to create an intelligent robotic system for firefighting applications.

In the first part of the paper, the authors delve into the design aspects of the firefighting robot. They discuss the incorporation of essential components such as gas sensors for fire detection, gear motors, and motor drivers for movement control, and a relay driver for pump control. The use of an Arduino microcontroller serves as the central processing unit, receiving signals from various sensors and controlling the robot's actions accordingly. Additionally, the inclusion of a Bluetooth module enables remote control, allowing operators to manage the robot's movements and firefighting capabilities from a distance.[2].

The second part of the paper focuses on the operational aspects of the firefighting robot. When the gas sensor detects the presence of fire, it sends a signal to the Arduino, triggering the firefighting mechanism. The robot stops at the fire-affected area, activates the pump, and sprays water through a sprinkler system until the fire is extinguished. The authors emphasize the significance of real-time fire detection and automated response in minimizing the impact of fires. The integration of Arduino technology facilitates a seamless and responsive firefighting process. The research paper highlights the successful implementation of an Arduino-based firefighting robot as an efficient and automated solution for fire management. The authors demonstrate how the combination of Arduino microcontrollers and various sensors creates a responsive and intelligent robotic system. The presented firefighting robot showcases the potential of accessible and cost-effective technologies, like Arduino, in addressing real-world challenges and improving safety measures in critical situations.

While the research paper emphasizes the potential of Arduino-based firefighting robots, certain drawbacks must be considered. The reliance on Bluetooth for remote control is one potential disadvantage. Bluetooth technology may have range and signal stability limitations, which may affect the robot's responsiveness in large or obstructed environments. Furthermore, the paper may not thoroughly address the proposed system's scalability and adaptability to various firefighting scenarios. Future research could look into ways to improve communication technologies and address scalability issues for broader application.

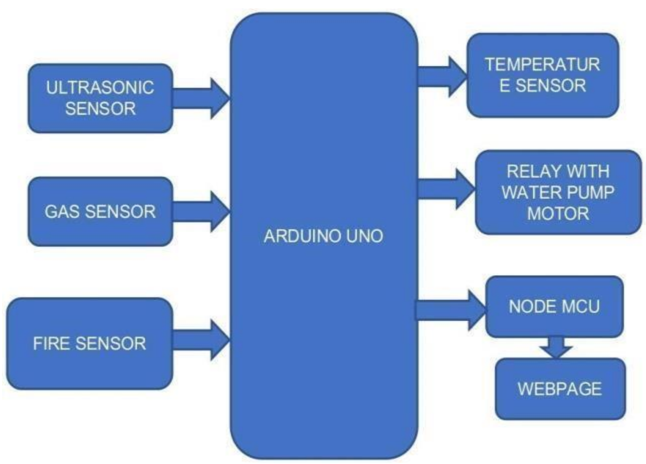

Fig.3 Block diagram of Arduino based Robot[2]

2.3 Autonomous Firefighting Inside Buildings by an Unmanned Aerial vehicle

The research paper, titled "Autonomous Firefighting Inside Buildings by an Unmanned Aerial Vehicle," introduces an innovative approach to firefighting using a Micro-scale Unmanned Aerial Vehicle (MAV) within indoor environments. The authors **Vojtech Spurny, Vaclav Pritzl, Viktor Walter, Matej Petrlik, Tomas Baca, Petr Stepan, David Zaitlik and Martin Saska** try to covers various key aspects of this autonomous firefighting system. Firstly, it discusses the control and estimation of the MAV's state, addressing the challenges of manoeuvring within confined indoor spaces. The authors also explore the detection of building entrances, multi-modal MAV localization during the transition from outdoor to indoor environments, interior motion planning and exploration, fire detection, and position estimation. A comprehensive evaluation of the system's performance is presented, including simulations and field tests conducted in diverse real-world conditions.

The second aspect of the paper emphasizes the successful integration of these individual elements into a cohesive and functional system. The MAV's ability to autonomously navigate, detect fires, and perform firefighting tasks is a crucial component of the proposed solution. The authors highlight the real-world applicability of their approach by discussing its performance in demanding conditions, showcasing its effectiveness in simulations and field tests. Additionally, the paper mentions that this autonomous firefighting system is part of a larger multi-MAV solution, which achieved success in the Mohamed Bin Zayed International Robotics Challenge 2020 (MBZIRC 2020) competition. The proposed system serves as the core of a fire-fighting Unmanned Aerial System (UAS) industrial platform currently under development[3].

Despite the innovative nature of the presented solution, it's essential to consider potential drawbacks. One potential disadvantage of this system may be its dependence on the availability of accurate and up-to-date environmental information. Real-world conditions can be dynamic, and relying on precise data for MAV localization and fire detection may pose challenges in unpredictable scenarios. Additionally, the limitations of MAV technology, such as restricted payload capacity and flight time, could impact the system's overall effectiveness, particularly in large-scale firefighting scenarios. It is crucial for future developments to address these challenges to ensure the robustness and reliability of the proposed autonomous firefighting solution.

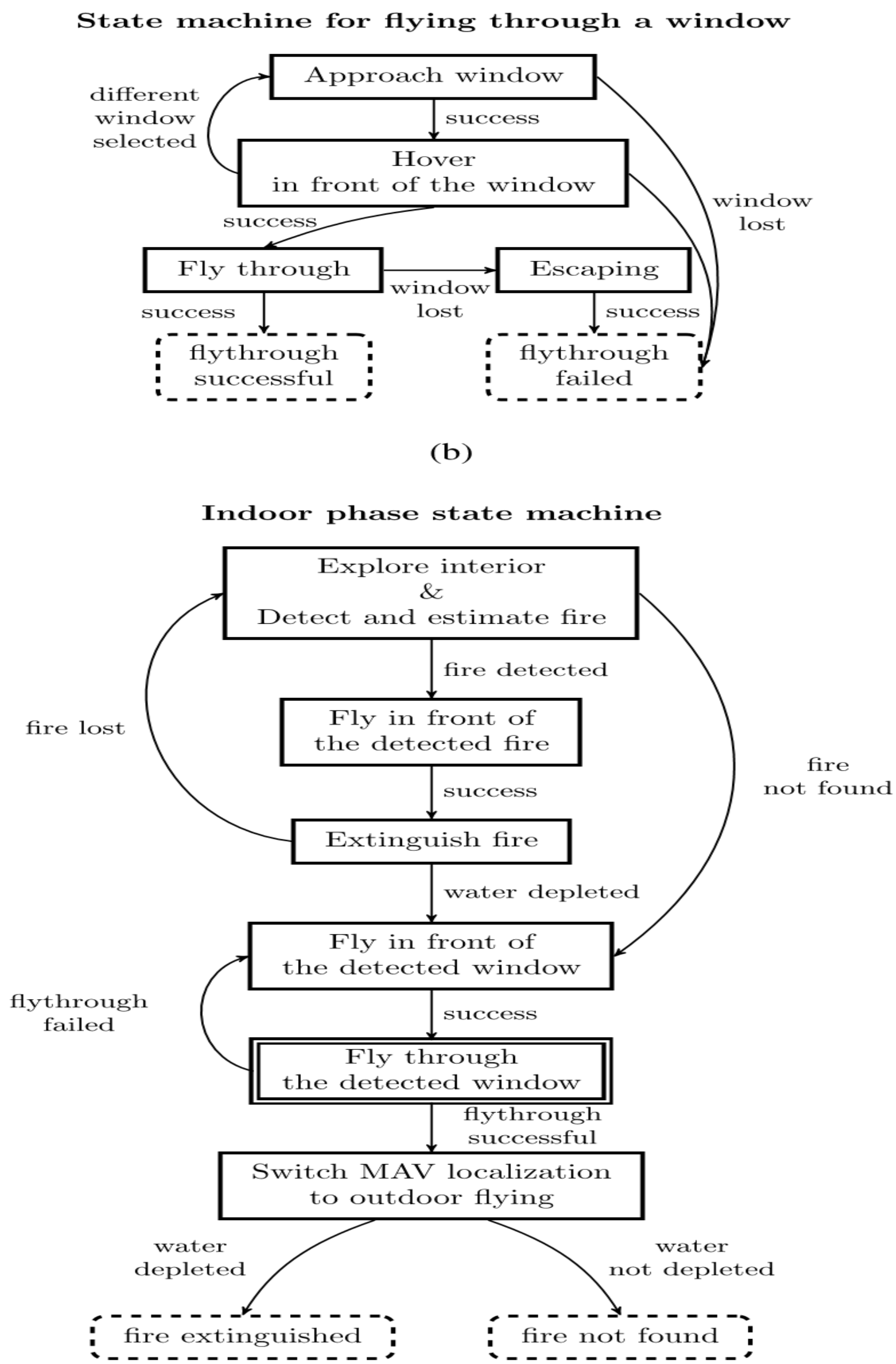

Fig.4 Work Flow of MAV[3]

2.4 Firefighting Robot Key Structure Design and Analysis

The research paper titled "Firefighting Robot Key Structure Design and Analysis" focuses on the development of an intelligent firefighting robot, presenting the overall structure and main technical parameters of the designed robot. The authors**, Ma Xiaolin, Sun Hao, Li Ran, Zhao Peifeng, Huang Xin, Fu Xiuzhuo, Wang Mingrui, Igor Skachkov, and Liu Yongcheng**, introduce the key components and structural considerations of the robot. They specifically analyze the relationships among critical parameters on the ramp, such as the position of the center of gravity, track grounding length, width, and slope angle. This comprehensive study provides valuable insights for optimizing the structural configuration of firefighting robots, ensuring their stability and effectiveness in real-world scenarios.In the subsequent part of the paper, the authors detail the implementation of their findings by adding a 50kg counterweight to the robot based on the structural analysis. They perform a multi-robot finite element analysis, revealing results that indicate the robot's structural integrity under various conditions. The maximum deformation of the bearing beam is reported as 3.35mm, and the maximum stress value is recorded at 92.2MPa, both within acceptable limits for practical use. This structural analysis demonstrates the suitability of the proposed design for firefighting applications, meeting necessary safety and performance criteria.

However, it's important to note that despite the success in structural design and analysis, the paper may have some limitations or disadvantages. For instance, the research might not extensively cover certain environmental or operational challenges that firefighting robots could face in complex and dynamic settings.[4] Additionally, the structural modifications, such as adding a counterweight, could potentially impact the robot's overall mobility or agility. Addressing these limitations and considering a broader range of scenarios in future research could enhance the applicability and robustness of the firefighting robot.

2.5 Monitoring and Controlling of Firefighting Robot using IoT

The research paper titled "Monitoring and Controlling of Firefighting Robot using IoT" presents an innovative approach to designing a versatile robot equipped for fire extinguishing purposes. Authored by **Kalathiripi Rambabu, Sanjay Siriki, D. Chupernechitha, and Ch. Pooja** the primary objective is to create a compact and powerful firefighting robot capable of autonomously detecting and extinguishing fires in disaster-prone areas. The authors employ the XLR8 board for the project, emphasizing its role in providing control and automation to the robot .In the first part of the paper, the authors outline the key features and capabilities of the proposed firefighting robot. The robot is designed to autonomously detect fires in disaster-prone areas, offering a compact and versatile solution to mitigate potential damage. Leveraging the XLR8 board and IoT technology, the robot operates in two modes: automatic and manual. The automatic mode enables the robot to detect and respond to fires independently, while the manual mode allows human operators to control the robot remotely. The integration of a camera provides real-time visual feedback, and the use of Raspberry Pi facilitates status monitoring of the robot.The second part of the paper delves into the operational aspects of the firefighting robot. The authors highlight the significance of overcoming obstacles in disaster-stricken environments. To address this, the robot is equipped with obstacle detection sensors, allowing it to navigate freely by sensing obstacles and choosing obstacle-free paths. The seamless integration of IoT technologies enhances both the autonomous and manual control modes, providing a comprehensive solution for firefighting in challenging scenarios[5]

Despite the innovative features presented in the paper, one notable disadvantage is not explicitly mentioned. However, the potential challenges or limitations could be related to the complexity of integrating IoT technologies and ensuring robust communication between the robot and the control system. Factors such as network connectivity issues, reliability, and real-time responsiveness may pose challenges in certain scenarios, and addressing these aspects is crucial for the successful deployment of such firefighting robots in practical applications.

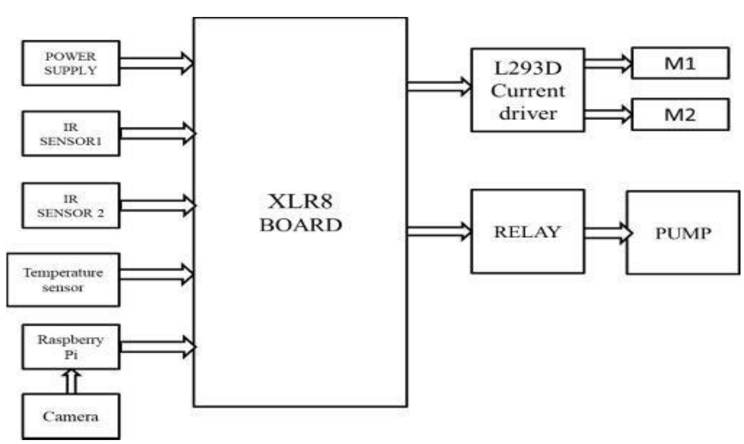

Fig.5 Block diagram of of Firefighting Robot using XLR8 Board[5]

2.6 FIRE FIGHTING ROBOT

The research paper titled "Fire Fighting Robot" by **K. Shamil Devi, K. Akhileswar, Ch. Vinayaka, M. Karthik, and Y. K. Viswanadham** introduces a robotic system designed for fire detection and extinguishing. The proposed model incorporates advanced sensors, including a flame sensor for fire detection and an ultrasonic sensor for calculating object distance. The inclusion of gear motors and a motor driver allows precise control over the robot's movements. The crucial element in the system is the integration of an Arduino MEGA microcontroller, which serves as the central processing unit, facilitating communication and coordination among the various components. In the operational phase, when the flame sensor detects the presence of fire, the robot's microcontroller receives the signal and initiates a response. The robot, equipped with gear motors, moves autonomously toward the location of the fire accident. To enhance the firefighting capabilities, a fire extinguisher is mounted on the robotic vehicle. This extinguishing mechanism is wirelessly controlled, allowing the robot to automatically deploy the fire suppressant and extinguish the fire. The integration of wireless communication enables remote and automated firefighting, reducing the need for human intervention in dangerous scenarios .However, despite the innovative approach to fire management, the research paper has certain limitations and disadvantages. One notable drawback could be the dependence on wireless communication for remote control. In situations with poor connectivity or interference, the effectiveness of the robot's response may be compromised. Additionally, challenges related to the limited capacity of the onboard fire extinguisher or the robot's ability to navigate complex environments may impact its overall performance. Acknowledging and addressing these limitations is crucial for the practical implementation and success of the proposed firefighting robot in real-world scenarios.[6]

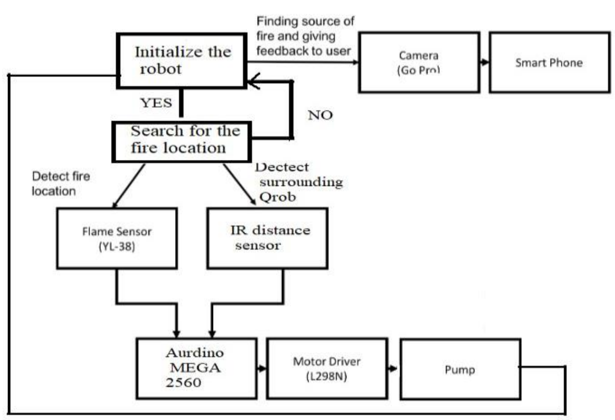

Fig.6 Block diagram of of Firefighting Robot using Arduino MEGA2560[6]

2.7 FIRE FIGHTING ROBOT

The research paper titled "Fire Fighting Robot" authored by **Sahil S. Shah, Vaibhav K. Shah, Prithvish Mamtora, and Mohit Hapani** presents a comprehensive exploration of a fire-fighting robot equipped with intelligent functionalities. The circuit implementation is divided into two main sub-circuits to address distinct aspects of the robot's operation. The first part involves the robot's ability to follow a black strip, achieved through a comparator circuit using Light Dependent Resistors (LDRs). The LDRs, responding to varying light intensity, enable the robot to detect the black strip and adjust its movement accordingly. The use of a Darlington pair and a source follower circuit amplifies the current to drive the motors effectively.

The second part of the circuit focuses on flame detection, utilizing both LDRs and Infrared (IR) receivers. The dual Op-Amp LM358 facilitates the implementation of comparator circuits for both LDR and IR receiver functionalities. The output of these components is ORed and directed to a monostable 555 timer with a time period of 4 seconds. This timer plays a crucial role when the robot detects a fire. It ensures that the motors remain stopped for a fixed duration, allowing the fan to start and address the fire. The timer generates a high pulse, independent of light intensity, to control the robot's behavior during the fire-extinguishing process. Once the fire is extinguished, the robot resumes its original motion.

While the presented research offers an innovative approach to fire-fighting robotics, it is essential to acknowledge potential limitations. One notable disadvantage is the reliance on the fixed 4-second duration for the monostable 555 timer. This fixed timing may not be adaptable to varying fire scenarios, potentially leading to inefficiencies in the extinguishing process. In dynamic fire situations, where the intensity or size of the fire may differ, a fixed timer might not optimize the response. Therefore, further refinements to the timing mechanism could enhance the adaptability and effectiveness of the fire-fighting robot in diverse real-world scenarios[7].

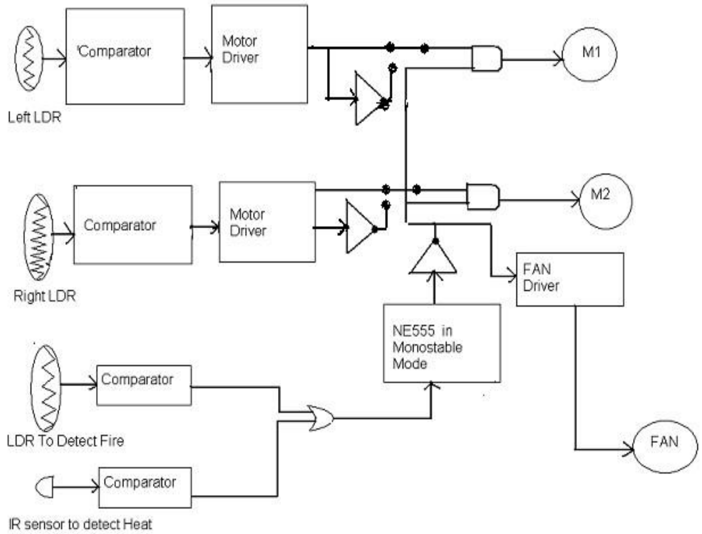

Fig.7 Block Diagram of Firefighting Robot using LDRs[7]

2.8 Remote Controlled Fire Fighting Robot

The research paper titled "Remote Controlled Fire Fighting Robot" **by Phyo Wai Aung and Wut Yi** Win presents an innovative approach to fire management using a remote-controlled robot. The primary focus of the study revolves around the design and functionality of the fire fighting robot, which is divided into two main parts: transmitting and receiving.

The authors employ two sets of RF modules to facilitate communication between the robot and the operator. The transmission module relays data to the motor drivers, while the receiving module provides information about the fire condition. The core of the fire fighting robot's operation lies in the microcontroller PIC16F887, which acts as the central processing unit. The motors of the robot are controlled by L298 and ULN2003 drivers, ensuring precise movement and navigation

. The operator exercises control over the robot with the assistance of a wireless camera mounted on the robotic vehicle. Upon detecting a fire, the robot is equipped to extinguish it using water stored in the attached tank. An interesting feature of the system is the incorporation of a temperature sensor, triggering an alarm if the fire site's temperature exceeds a certain threshold. This functionality allows the operator to take preventive measures and safeguard the robot from potential damage. While the paper provides valuable insights into the development of a remote-controlled fire fighting robot, it is essential to acknowledge some potential limitations or disadvantages.[8]

One possible drawback could be the reliance on wireless communication, which may face interference or signal loss in certain environments. Additionally, the effectiveness of the robot could be impacted by factors such as limited water capacity in the tank or challenges in navigating complex terrains. Addressing these potential issues could enhance the overall robustness and reliability of the proposed fire fighting robot system.

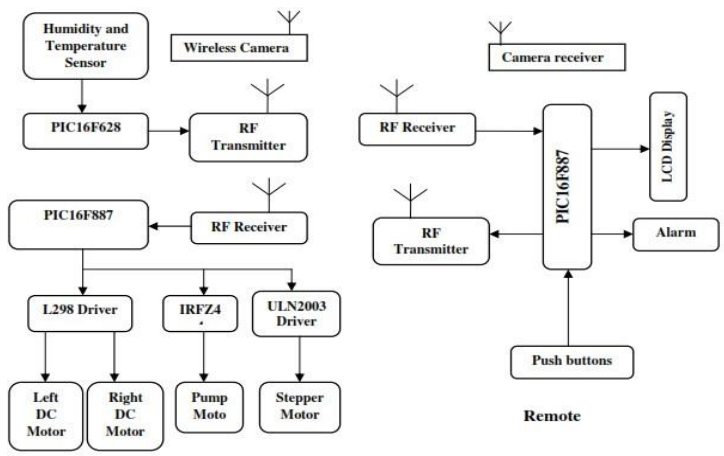

Fig.8 Block Diagram of Firefighting Robot using PIC16F628 Microcontroller[8]

2.9 Android Controlled Fire Fighting Robot

The research paper titled "Android Controlled Fire Fighting Robot" presents a comprehensive study on the development of a robotic vehicle designed for fire detection and extinguishing, with a particular focus on the integration of Arduino technology and Android-based control. Authored by **S. Sakthi Priyanka, R. Sangeetha, S. Suvedha, and guided by Ms. G. Vijayalakshmi**, the paper outlines the key components and functionalities of the robotic system.

The robot incorporates essential features such as a gas sensor for fire detection, gear motor and motor driver for movement, relay driver for pump control, and a Bluetooth module for remote control. The use of Arduino UNO R3 serves as the central processing unit, enabling seamless communication and coordination among the various components. In the described project, the robot operates at a consistent speed until the gas sensor detects the presence of fire. Upon detection, a signal is transmitted to the Arduino, initiating the extinguishing process[9].

The robot halts at the fire-affected location, activates the pump, and deploys a sprinkler to dispense water until the fire is extinguished. One notable feature is the integration of Android mobile control via a Bluetooth module, allowing operators to manage the robot's movements and firefighting actions remotely. This adds an element of flexibility and convenience to the firefighting process, enhancing the robot's usability in dynamic environments. Despite the project's innovative approach to firefighting automation, there are some inherent disadvantages.

One potential limitation could be the reliance on Bluetooth technology for remote control. Bluetooth has a limited range, which may impact the robot's operability in situations where long-distance control is required. Additionally, factors such as signal interference or obstacles between the Android mobile and the robot could affect the reliability of the communication link. Addressing these limitations and exploring alternative communication methods could further enhance the robustness and adaptability of the Android Controlled Fire Fighting Robot.

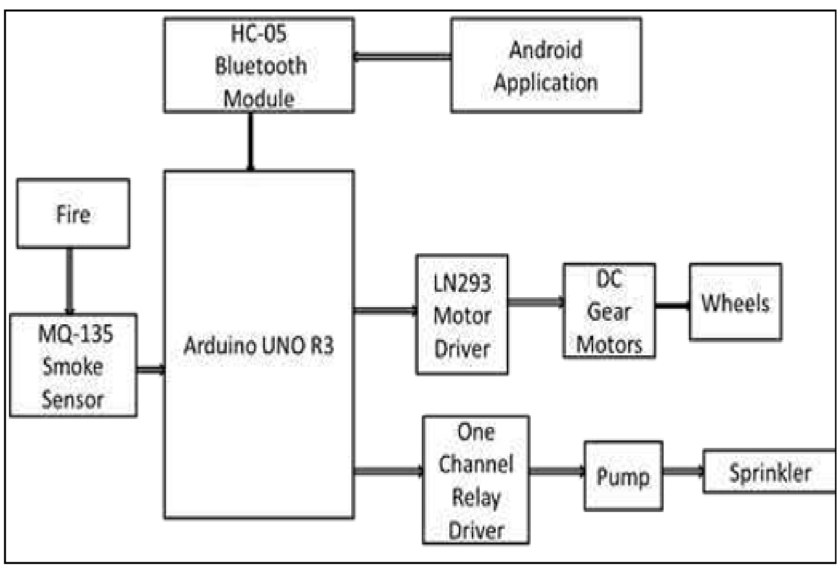

Fig.9 Arduino controlled Firefighting Robot [9]

2.10 Internet of Robotic Things Based Autonomous Fire Fighting Mobile Robot

The research paper titled "Internet of Robotic Things Based Autonomous Fire Fighting Mobile Robot" addresses the critical issue of fire accidents in industries and proposes a novel solution leveraging the Internet of Things (IoT) and robotics. Authored by **Anantha Raj P , BIT Sindri**, the paper highlights the importance of early fire detection and swift firefighting actions to mitigate losses and safeguard human lives. The primary focus is on integrating an autonomous firefighting mobile robot into the conventional fire safety IoT system to enhance the efficiency of firefighting procedures.

In the initial part of the paper, the author emphasizes the severity of fire accidents in industries and underscores the potential of early firefighting measures in minimizing damages. The proposed solution involves the integration of an autonomous firefighting mobile robot into the existing IoT-based fire safety system. The IoT system detects a fire, sends an alert to the fire safety department, and activates the mobile robot to take immediate action. The robot utilizes a path planning algorithm to navigate to the fire location, performs firefighting tasks, and streams video footage of the incident to the control room. This real-time information aids fire safety officers in making informed decisions and better planning to handle the situation effectively.

While the paper introduces an innovative approach to firefighting using IoT and robotics, there are potential disadvantages to consider. One drawback could be the reliance on technology, as any failure in the IoT system or the robotic components may compromise the effectiveness of the firefighting response. Additionally, the implementation of such advanced systems may pose challenges in terms of maintenance, cost, and compatibility with existing infrastructure. It is crucial to address these concerns to ensure the reliability and practicality of the proposed solution in real-world industrial settings.

In conclusion, the research paper presents a forward-thinking solution to industrial fire safety by combining IoT and robotic technologies. The integration of an autonomous firefighting mobile robot enhances the speed and efficiency of firefighting actions, potentially saving lives and minimizing losses. However, careful consideration of technological limitations and practical challenges is essential to ensure the successful implementation of such systems in industrial environments[10].

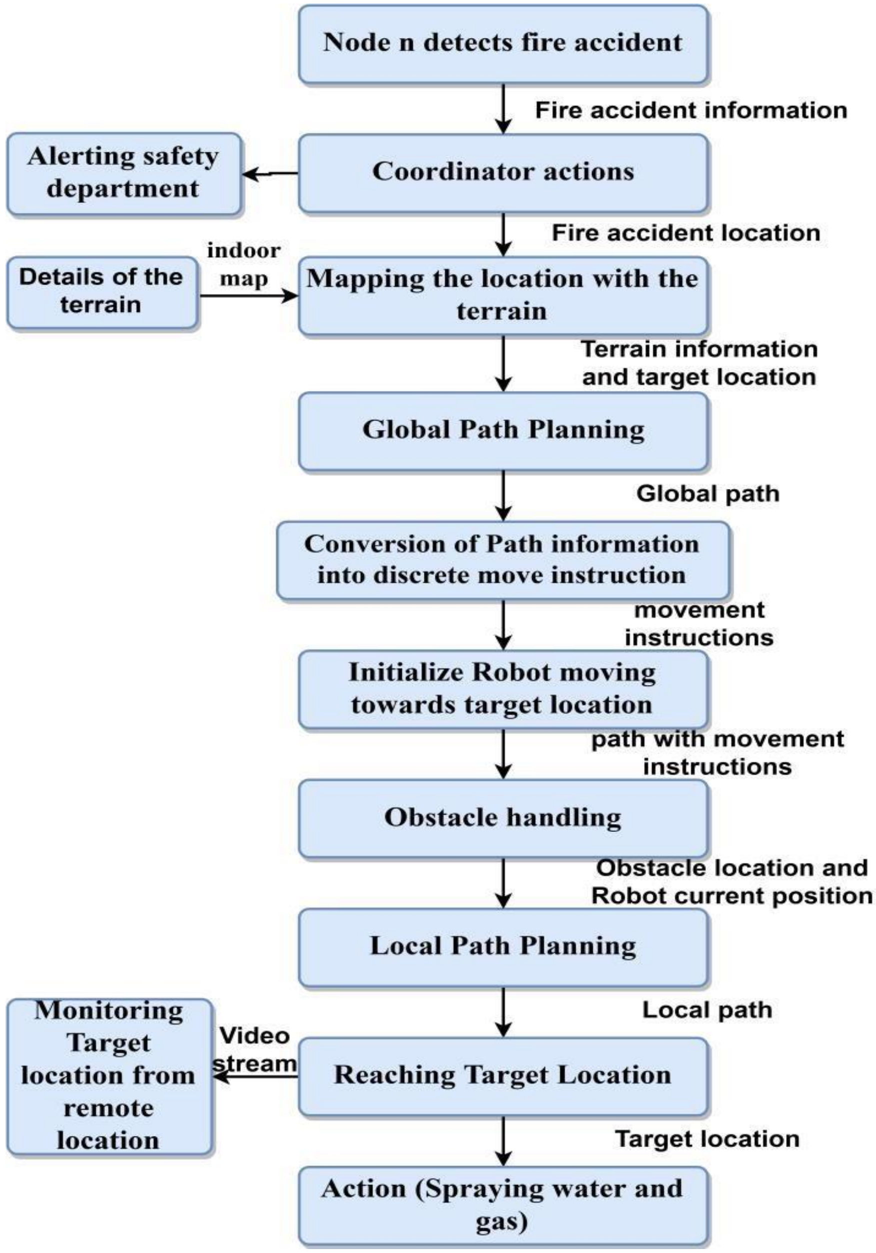

Fig.10 System Architecture of IoT based Firefighting Robot[10]

CHAPTER 3

EXISTING SYSTEM

3.1 EXISTING SYSTEM

Existing firefighting robots are primarily designed to detect and extinguish fires using sensors that identify temperature changes, smoke particles, and gas emissions. These robots are equipped with sophisticated technology that allows them to navigate through hazardous environments and assess the severity of fire outbreaks. However, one notable limitation of many existing firefighting robots is their inability to detect human presence. In emergency situations, the presence of humans in the vicinity of a fire can significantly impact the approach to firefighting and evacuation efforts. Therefore, the lack of human detection capabilities in current firefighting robots represents a critical gap in their functionality, highlighting the need for advancements in sensor technology to enhance safety measures during firefighting operations.

Furthermore, while automation is a common feature in many firefighting robots, the absence of manual control options through user-friendly interfaces like Android apps limits their versatility and adaptability in dynamic firefighting scenarios. Manual control functionalities would empower firefighters to intervene and make real-time decisions based on situational awareness and evolving conditions.

Additionally, the reliance on traditional flame sensors for fire detection, coupled with the deactivation of certain sensors after flame detection, underscores the need for continuous innovation in sensor technology to improve the accuracy and effectiveness of firefighting robots. Addressing these limitations and integrating advanced sensor technologies with intuitive control interfaces would pave the way for more efficient and responsive firefighting robotics systems, ultimately enhancing the safety of firefighters and the effectiveness of firefighting operations.

3.2 LIMITATIONS OF EXISTING SYSTEM

- Lack of Human Detection Capabilities: Existing firefighting robots without human detection capabilities pose a significant drawback as they cannot identify the presence of individuals in emergency situations. This limitation can hinder rescue efforts and compromise the safety of trapped or injured individuals, as the robot may not prioritize areas where human intervention is urgently needed.

- Low Accuracy in Fire Detection: Without advanced sensors specifically designed to detect fires accurately, firefighting robots may struggle to identify the precise location and intensity of fires. This lack of accuracy can result in delayed responses or ineffective firefighting strategies, ultimately prolonging the duration of the fire and increasing the risk of property damage or injury.

- High Cost and Expense: The absence of human detection capabilities and advanced sensors, coupled with reliance on traditional firefighting methods, can make existing firefighting robots without these features relatively expensive to develop, maintain, and deploy. This high cost can pose a barrier to widespread adoption, especially for organizations with limited budgets or resources for firefighting equipment.

- Absence of Gas Sensors for Harmful Gases: Firefighting robots without gas sensors to detect harmful gases present a significant drawback, as they cannot accurately assess the level of danger posed by toxic fumes or chemical emissions during firefighting operations. Without this crucial capability, firefighters may be exposed to hazardous environments, leading to health risks and potential fatalities.

- Reliance on Traditional Methods with Firefighters: Existing firefighting robots that adhere to traditional methods of firefighting, often involving direct intervention by firefighters to extinguish fires, may not fully leverage the potential of robotic technology to autonomously suppress fires. This reliance on human intervention can limit the efficiency and effectiveness of firefighting operations, especially in scenarios where conditions are too hazardous for direct firefighter involvement

CHAPTER 4

METHODOLOGY

4.1 PROPOSED SYSTEM

The proposed firefighting robot introduces an intelligent and responsive system designed to enhance the efficiency of firefighting operations in complex and dynamic scenarios. The robot is equipped with a cutting-edge camera utilizing the YOLOv8 object detection model, strategically placed to enable real-time fire and human detection. This advanced vision system empowers the robot to swiftly identify and locate fire outbreaks as well as individuals in distress, forming the cornerstone of an adaptive firefighting solution.

In tandem with fire and human detection capabilities, the robot incorporates gas sensors designed to detect harmful gases commonly associated with fires. This multifaceted approach not only equips the robot to combat flames but also enables it to monitor and communicate information about potentially hazardous gas concentrations to emergency responders. Real-time data on gas levels contributes to a more comprehensive understanding of the emergency environment, facilitating safer and more informed decision-making during firefighting operations.

The core firefighting mechanism of the robot relies on a mini water pump, automatically triggered upon fire detection to deliver a precisely targeted spray of water for rapid extinguishment. This autonomous firefighting capability is further enhanced by a manual control option, allowing operators to intervene remotely through an Android app. The flexibility of manual control ensures adaptability in diverse emergency scenarios, enabling operators to navigate the robot with precision based on real-time information received from the robot's sensors and vision system.

To navigate through potentially challenging environments, the robot integrates ultrasonic sensors strategically positioned to detect obstacles in its path. Upon sensing an obstacle, the microcontroller, serving as the central processing unit, orchestrates a deviation from the predefined path, ensuring the robot can maneuver around obstacles seamlessly. All sensors, including the camera, gas sensors, and ultrasonic sensors, are intricately connected to the microcontroller. In the event of a fire, the microcontroller not only detects the anomaly but also triggers the relay module, initiating the activation of the water pump. Additionally, when a human is detected, the microcontroller sends an alert message to the connected Android app, providing critical information to operators and emergency responders in real-time. This interconnected and intelligent system represents a holistic and effective approach to firefighting, leveraging cutting-edge technologies to maximize the robot's adaptability and responsiveness in emergency situations. Also an android app designed to accompany the firefighting robot serves as a user-friendly interface for remotely tracking and controlling the robot's operations. Through the app, users can access real-time data and visuals transmitted by the robot's onboard cameras and sensors, allowing them to monitor the firefighting situation from a safe distance.

The motor driver is critical to a firefighting robot's mobility and maneuverability. Firefighting robots are frequently outfitted with a variety of motors to enable movement across different terrains and navigation through difficult environments. The motor driver serves as an interface between the microcontroller, or the robot's main control system, and the motors. It takes commands or signals from the control system and converts them into specific actions that drive the motors accordingly. This enables the robot to move forward, backward, turn, and change speed as needed to reach fire-affected areas or access locations where humans may be trapped.

A relay module is an important component in firefighting robots because it controls high-power devices like motors and pumps. The relay module functions as a switch that can be electronically controlled, allowing the robot's control system to activate or deactivate various components in response to predefined conditions or commands. For example, in the case of firefighting robots, the relay module can be used to control the activation of a water pump. When a fire is detected, the control system can instruct the relay module to activate the pump, which will pump water from a reservoir or water source to the firefighting nozzle. This ensures that water resources are deployed efficiently in order to effectively extinguish the fire. Furthermore, the pump in a firefighting robot is critical in delivering water or firefighting agents to the target area at the appropriate pressure and flow rate. The pump generates the necessary hydraulic force, allowing the robot to deliver enough water to extinguish the fire, making it an essential tool for firefighting operations in a variety of environments and scenarios.

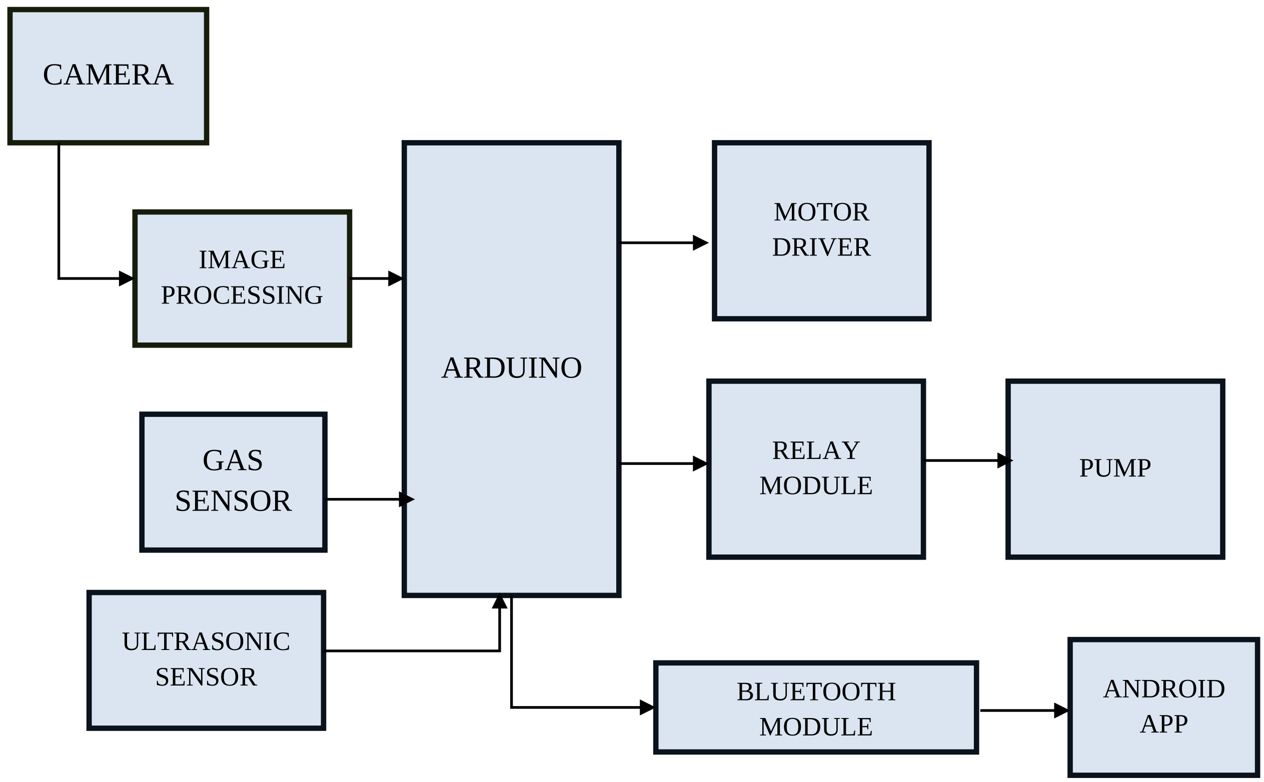

Fig 11 : Block Diagram of Proposed System

4.2 ADVANTAGES OF PROPOSED SYSTEM

- Fire and Human Detection Abilities: The integration of advanced sensors enables the robot to accurately detect both fires and human presence in emergency situations, enhancing safety measures and facilitating more efficient firefighting operations.

- Extinguishing Capability with Mini Water Pumps: Equipped with mini water pumps, the firefighting robot can effectively extinguish fires by delivering precise streams of water or fire-retardant agents to the source of the flames, minimizing property damage and reducing the risk of fire spread.

- Gas Sensors for Detecting Harmful Gases: Gas sensors incorporated into the robot's design enable it to detect and assess harmful gases emitted during fires, providing crucial information to firefighters and ensuring a safer working environment by alerting them to potential health hazards.

- Ultrasonic Sensors for Path Detection and Navigation: Ultrasonic sensors allow the robot to navigate through complex environments and obstacles by detecting pathways and obstacles in its vicinity. This capability enhances the robot's manoeuvrability and ensures efficient movement towards fire-affected areas, even in challenging terrain or confined spaces.

- High Accuracy in Fire and Human Detection: With advanced sensor technology, the firefighting robot achieves high accuracy in detecting both fires and human presence. This precision enables rapid and targeted response to emergencies, reducing response times and improving overall firefighting effectiveness.

CHAPTER 5

SYSTEM DESIGN

5.1 SYSTEM ARCHITECTURE

Fire detection and suppression systems play a crucial role in safeguarding lives and property against the devastating effects of fires. Within such systems, surveillance systems equipped with real-time video cameras or visual sensors continuously monitor the environment for signs of fire. These surveillance systems provide a constant stream of video feed, capturing the surroundings and any potential fire incidents. This video feed serves as the primary input for the system, feeding into the subsequent stages of fire detection and response.

In the realm of fire detection, advanced machine learning algorithms like YOLOv8 (You Only Look Once version 8) play a pivotal role. YOLOv8 is specifically designed for real-time object detection and localization within images or video frames. Trained on extensive datasets containing diverse fire scenarios, the YOLOv8 algorithm excels at identifying fire and other objects of interest. As the video feed is processed frame by frame, the YOLOv8 algorithm analyses each frame, generating predictions that include bounding boxes around detected objects and their corresponding class labels, such as "fire" or "non-fire."

Upon detecting a fire in the video stream, the system swiftly transitions into the fire extinguishing and control phase. This phase involves activating the fire suppression mechanism, often in the form of a water module or sprinkler system. The system may also initiate additional actions, such as sending alert messages to designated recipients or emergency services, ensuring prompt response to the fire incident. By integrating fire detection with automated suppression mechanisms, the system aims to minimize response times and mitigate the spread of fire, ultimately enhancing overall safety and protection.

Central to the effectiveness of the fire detection and suppression system is the quality and diversity of the training and testing data used to train and evaluate the YOLOv8 algorithm.

The training data comprises a vast collection of annotated images and videos depicting various fire scenarios, allowing the algorithm to learn and generalize patterns associated with fire detection accurately. Subsequently, the algorithm undergoes rigorous testing using separate datasets to evaluate its performance in real-world conditions, ensuring robustness and reliability in detecting fires while minimizing false positives and negatives.

In summary, the fire detection and suppression system outlined above represent a sophisticated integration of surveillance technology, machine learning algorithms, and automated response mechanisms. By leveraging real-time video feed, advanced object detection algorithms like YOLOv8, and proactive fire suppression measures, the system provides a comprehensive solution for early detection and effective containment of fires. With continuous monitoring, rapid detection, and prompt response capabilities, such systems play a vital role in enhancing fire safety and protecting lives and property against the destructive forces of fire.

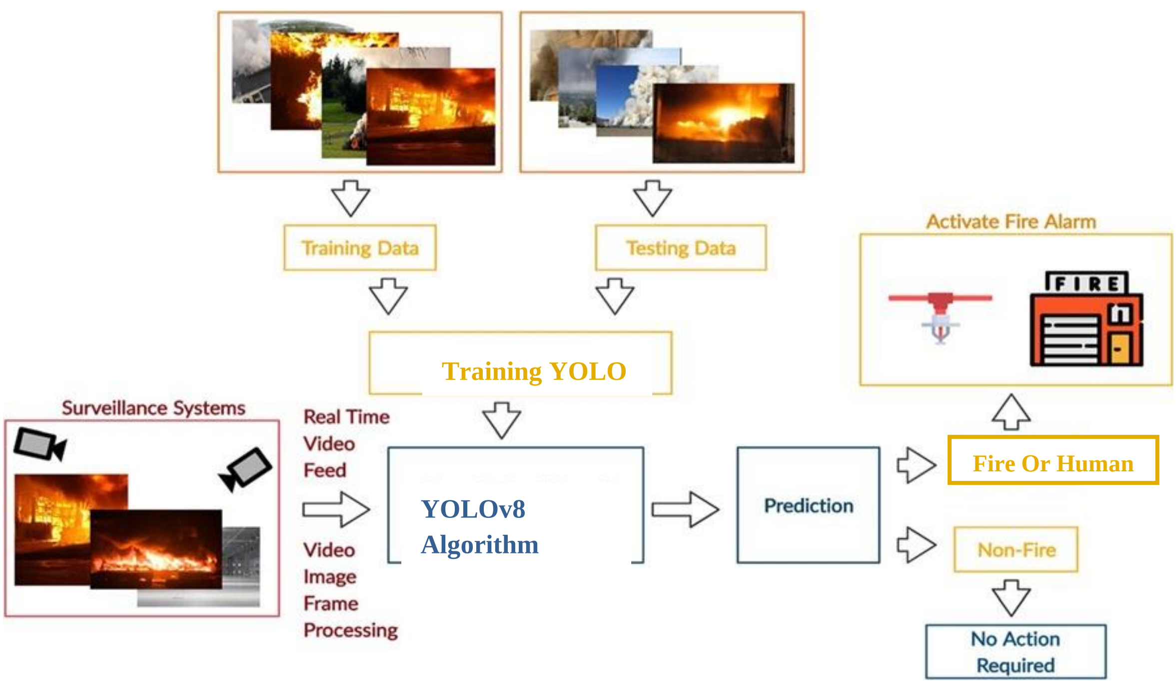

Fig 12: A basic architecture of YOLOv8 based fire and human detection and alarm systems

5.2 IMAGE PROCESSING STEPS

- Data Collection: This initial step involves gathering a diverse range of images and videos depicting fires from various sources, including security cameras, drones, and satellites. It's crucial to ensure that the collected data covers a wide spectrum of fire sizes, types (e.g., wood, oil), smoke intensities, and lighting conditions. This diverse dataset serves as the foundation for training a robust fire detection model.

- Data Preparation: Once the data is collected, it undergoes preprocessing to make it suitable for training the YOLOv8 model. This preprocessing stage may involve tasks such as resizing the images to a consistent resolution, normalizing pixel values to enhance model performance, and labelling the images with bounding boxes around the fires. Labelling is essential as it provides ground truth annotations that help the model learn to identify the location and size of fires in new images accurately.

- Splitting: After preprocessing and labelling, the dataset is divided into three subsets: a training set, a validation set, and a testing set. The training set is used to train the YOLOv8 model, while the validation set is utilized to monitor the model's performance during training and prevent overfitting. The testing set evaluates the model's performance on unseen data, ensuring its generalization ability.

- Model Selection: YOLOv8, a fast and accurate object detection algorithm, is chosen for fire detection due to its suitability for real-time applications. The decision to select YOLOv8 is based on its performance, speed, and ability to accurately detect objects, including fires, in images or video frames.

- Model Training: With the dataset prepared and the model selected, the training process commences. During training, the YOLOv8 model learns from the labelled images in the training set to recognize patterns that distinguish fires from other objects. Through iterative optimization algorithms like gradient descent, the model adjusts its parameters to minimize prediction errors and improve accuracy.

- Model Evaluation: After training, the model's performance is evaluated using the validation set. This evaluation helps assess the model's ability to generalize to new data and identify areas where it may need improvement. Metrics such as precision, recall, and F1-score are often used to quantify the model's performance.

- Model Deployment: Once the model demonstrates satisfactory performance, it can be deployed into a real-world application for fire detection. Deployment involves integrating the trained model into the target environment, whether it's a security system, firefighting robot, or surveillance network, enabling it to analyse incoming data in real-time.

- Integration: The fire detection model can be integrated with other systems, such as fire alarm systems or sprinkler systems, to facilitate automatic actions in response to detected fires. This integration enhances overall fire safety by enabling timely interventions and mitigating potential damages.

- Maintenance: Continuous monitoring and maintenance of the deployed system are essential to ensure its ongoing effectiveness. Regular performance checks, software updates, and data retraining may be necessary to adapt to evolving fire scenarios and maintain optimal performance over time.

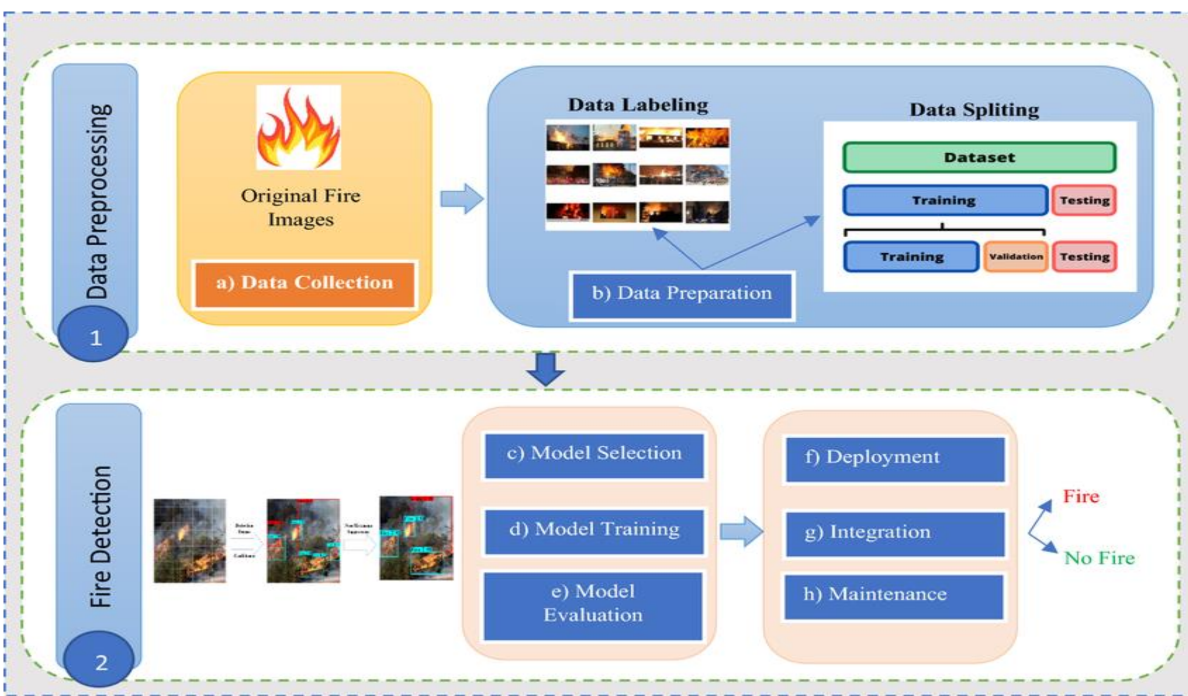

Fig 13 : Image Processing Steps

5.3 MODULE DESCRIPTION

1. Fire Detection Module

- Fire is detected by using a camera attached to the robot.
- This camera records pictures or videos of the area under observation.
- The images or video stream is sent to a computer for processing.
- The computer uses image processing algorithms to identify characteristic fire features, such as flames, smoke, or heat signature.
- YOLO –V8 algorithm is used to detect the presence of fire.
- If potential fire hazards are detected, the computer generates an alarm

2. Human Detection Module

- Human detection utilizes a camera-based approach.
- The YOLO-v8 algorithm is employed for efficient human detection.
- YOLO-v8 excels in real-time object detection, proving its effectiveness.
- Upon identifying a human, the system activates a response mechanism.
- Alert messages are sent to an Android app to notify relevant parties.
- Integration of YOLO-v8 enhances security and responsiveness.
- Suited for applications requiring real-time monitoring and alerting.

3. Fire Extinguishing Module

- Description: When the fire is detected, the data is passed to the microcontroller and the robot will move towards the fire manually with the help of android app and will extinguish it.
- Input: Command to initiate water pump from Arduino Output.
- Pumping water on the fire.

5.4 WORKFLOW DIAGRAM

The workflow diagram of a firefighting robot with a human detection system that utilizes a camera to detect fire and humans presents a comprehensive overview of the system's operational process. This diagram serves as a visual representation of the sequential steps involved in the functioning of the firefighting robot, from detecting potential threats to executing appropriate actions. Here's an introduction to the workflow diagram:

The workflow diagram outlines the systematic approach undertaken by the firefighting robot equipped with a sophisticated human detection system and a camera for fire detection. At its core, the diagram illustrates the sequential flow of operations, starting from the initial phase of environmental surveillance to the final stage of fire suppression and human rescue.

The process begins with environmental surveillance, where the camera system continuously monitors the surroundings for signs of fire or the presence of humans. Once potential threats are detected, the system proceeds to the next phase, where the captured video feed is processed using advanced algorithms for fire and human detection.

Upon identification of a fire or the presence of humans, the system triggers appropriate actions based on predefined protocols. If a fire is detected, the firefighting mechanism is activated, and the robot moves towards the location of the fire to extinguish it effectively. Simultaneously, if humans are detected within the vicinity of the fire, the system initiates measures for human rescue and evacuation, ensuring their safety.

Throughout the entire workflow, real-time communication and coordination play a crucial role. The system may incorporate mechanisms for data transmission and remote control, enabling operators to monitor the robot's activities and intervene if necessary. Additionally, feedback mechanisms are integrated to provide updates on the status of fire suppression and human rescue operations.

Overall, the workflow diagram encapsulates the intricate interplay between surveillance, detection, and response mechanisms employed by the firefighting robot. By delineating each step of the operational process, the diagram offers insights into the system's functionality and aids in optimizing its performance for enhanced efficiency and effectiveness in combating fire emergencies while ensuring human safety.

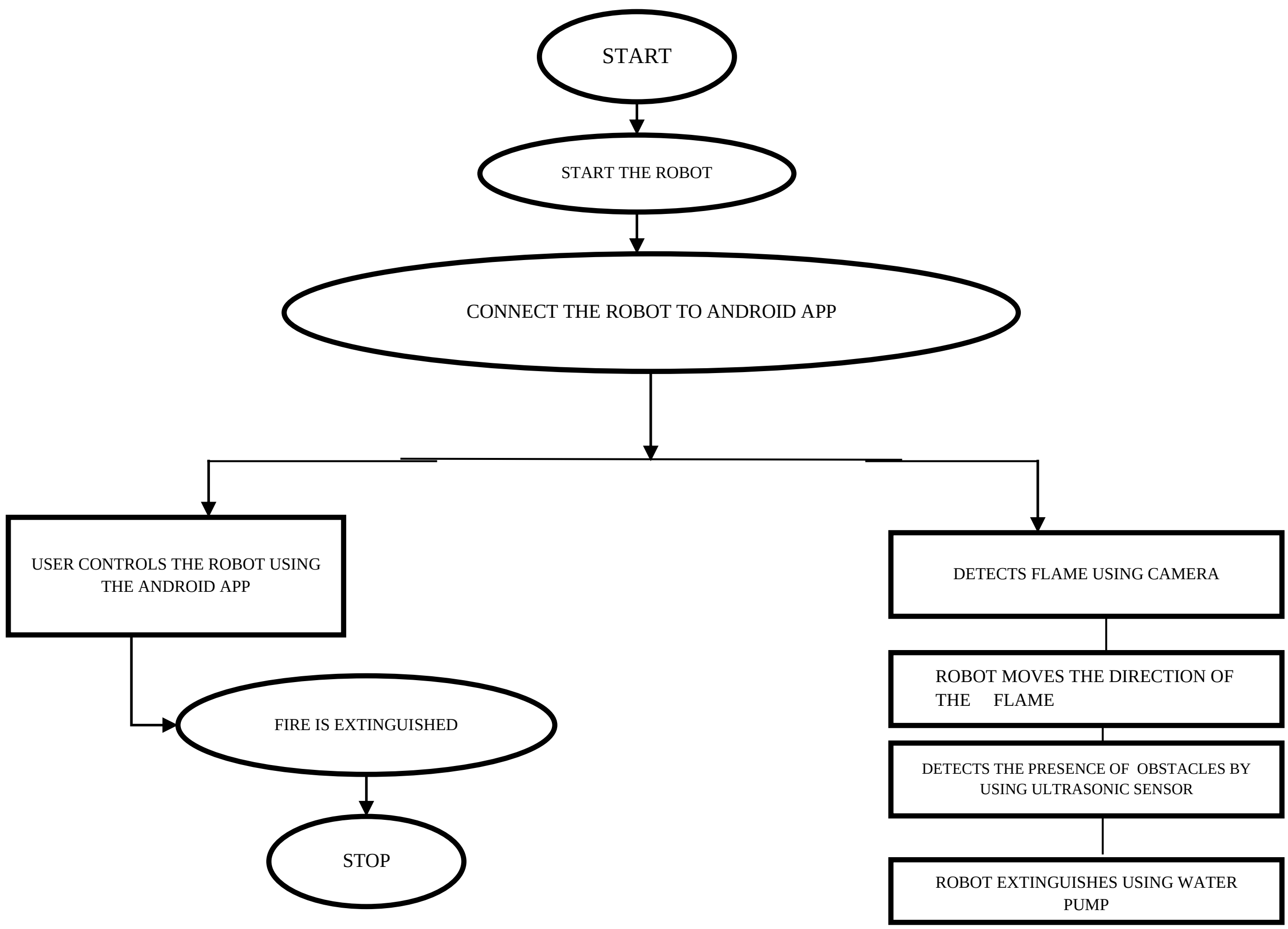

Fig 14 : Workflow Diagram

5.5 CIRCUIT DIAGRAM

The circuit diagram of a firefighting robot equipped with a human detection system and fire detection capabilities represents a sophisticated integration of hardware components and sensors aimed at providing autonomous firefighting capabilities while ensuring the safety of human lives. This advanced system harnesses modern technologies, including cameras, sensors, microcontrollers, and actuators, to detect and respond to fire incidents promptly and efficiently.

At its core, the circuit diagram illustrates the interconnectedness of various components, each serving a specific function in the firefighting robot's operation. Central to the system is a high-resolution camera strategically positioned to capture real-time video footage of the robot's surroundings. This camera serves as the primary sensor for detecting both fire and human presence within the robot's vicinity.

In tandem with the camera, the circuit incorporates specialized algorithms, such as YOLOv8 (You Only Look Once version 8), designed for real-time object detection. These algorithms analyse the video feed from the camera, enabling the robot to identify and differentiate between fires and other objects. Additionally, the human detection system leverages these algorithms to identify and locate individuals within the robot's operational area, ensuring their safety during firefighting operations.

Complementing the detection capabilities are actuators, including pumps and relay modules, essential for initiating firefighting actions upon detection of fire. The relay modules facilitate the control of various components, such as water pumps or fire suppression systems, enabling the robot to deploy extinguishing agents effectively. Furthermore, the circuit integrates communication modules for transmitting alerts or status updates to external monitoring systems or human operators, enhancing situational awareness and coordination during firefighting missions.

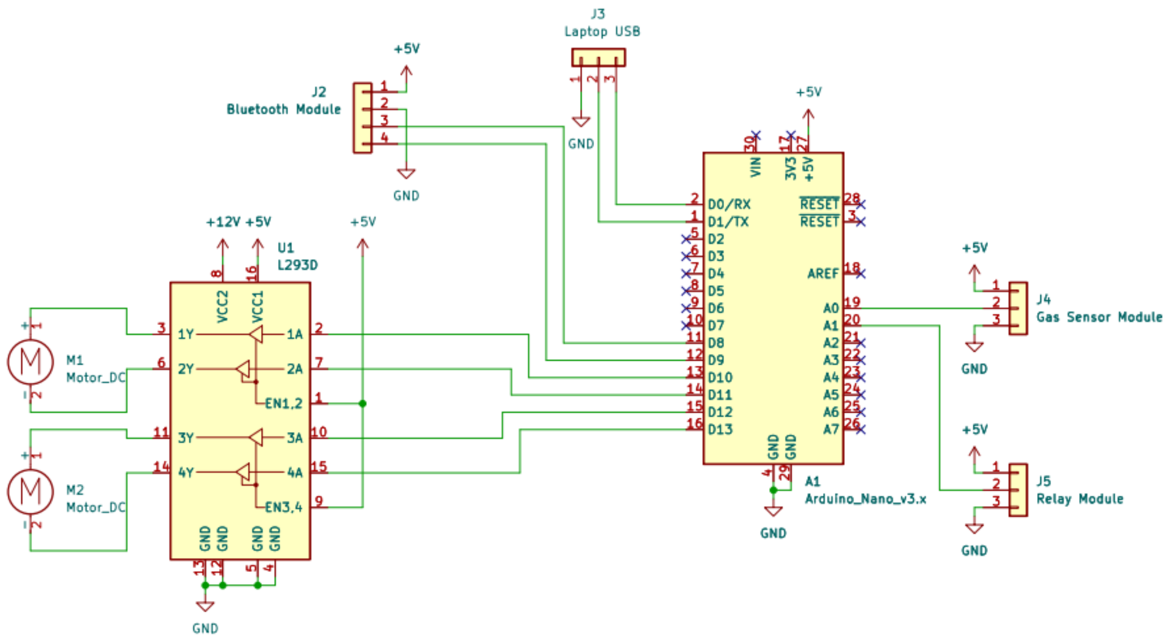

Fig 15 : Circuit Diagram

Overall, the circuit diagram of a firefighting robot with a human detection system embodies the convergence of cutting-edge technologies and engineering ingenuity to combat fire hazards while prioritizing human safety. By seamlessly integrating sensors, actuators, and intelligent algorithms, this system represents a proactive approach to firefighting, empowering autonomous robots to mitigate risks and respond swiftly to emergency situations in diverse environments.

CHAPTER 6

REQUIREMENT ANALYSIS AND SPECIFICATION

The first step in the system study includes analysis of the system. System analysis involves studying the way an organization currently receives and processes data to produce information with the goal of determining how to make it work better. System analysis includes both a preliminary and a detailed stage. During preliminary analysis the analysis takes a quick look at what is needed and whether it benefits the perceived want.

Detailed analysis includes an in depth look at what is wanted and contains more refined cost and benefits studies. The preliminary analysis begins when someone perceives a problem, modifications to existing, repairs to an existing system or demands an entirely new system. The analyst summarizes the gained modifications, including personal requirements and potential benefits of the new system in a formal report called the preliminary report. Detailed analysis expands the preliminary efforts to include the complete analysis of all possible alternative solutions to the problem and complete expansion of what appears to be the most practical solution.

The system study is the process of gathering and interpreting facts, using this information for further studies on the system. It does various feasibility studies. In these studies, a rough figure of the system activities can be obtained, from which the decisions about the strategies to be followed for effective system study and analysis can be taken. The system study also identifies the method collection to be followed. The system study conducted an initial picture about the system working. From the information got from the study, the data collection methods are identified. Even in the first investigation itself drawbacks of the existing system could be identified. Analysis involves the requirement determination and specifications. Basically, it involves establishing all the system elements and then mapping these requirements to the software form.

The analysis is intended to capture and describe all the requirements of the system and to make a model that defines a key domain class in the system. The purpose is to provide an understanding and to enable a communication about the system between the developers and the people establishing the requirements. Therefore, the analysis is typically terms of code or programs during this phase; it is the first step towards really understanding the requirements.

6.1 HARDWARE REQUIREMENTS

Minimum requirement of hardware is:

ARDUINO NANO	SERVES AS CPU
GAS SENSOR	DETECTS HARMFUL GASES
MOTOR DRIVER	CONTROL SPEED OF ROBOT
12V BATTERY	POWER SUPPLY
PUMP	EXTINGUISHING FIRE
ULTRA SONIC SENSOR	OBSTACLE DETECTION

Table 6.1

❖ ARDUINO NANO:-

- Microcontroller board using ATmega328 chip.
- Programmed via Arduino IDE
- Connects to computer via USB

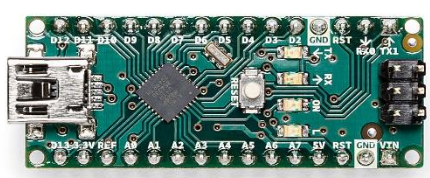

FIG 16 :- Arduino Nano

❖ GAS SENSOR:-

- The sensor detects harmful gases like smoke, iso-butane, propane, LNG, and related substances.
- It possesses high sensitivity and offers a fast response time.
- It possesses high sensitivity and offers a fast response time**.**

FIG 17 :- Gas Sensor

❖ Motor Driver L293D :-

- Motor driver controls motor speed and direction.
- L293D IC drives two DC motors simultaneously.
- Provides bidirectional control for movement and turning.

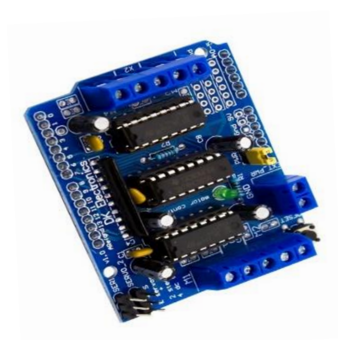

FIG 18 :- Motor Driver L293D

❖ 12V Battery:-

- 12-volt batteries power firefighting robot's electrical components.
- Multiple cells are connected in series for voltage.
- Maintains sufficient power for prolonged periods.

FIG 19:- 12V Battery

❖ Pump :-

- This is a powerful pump specifically designed to handle water.
- It draws water from the robot's internal tank and pressurizes it to send it out through the firefighting nozzle with enough force to extinguish flames

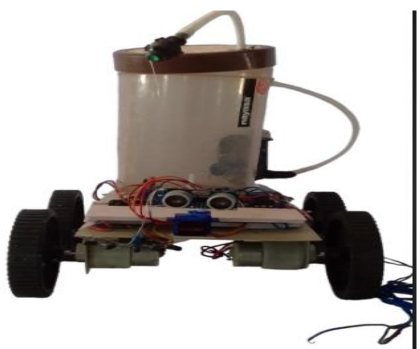

FIG 20 :- Pump

❖ ULTRASONIC SENSOR:-

- An ultrasonic sensor is a device that uses sound waves above the range of human hearing (typically above 20 kHz) to detect the presence, distance, or other characteristics of objects.

FIG 21 :- Ultrasonic Sensor

6.2 SOFTWARE REQUIREMENTS

The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware. A hardware requirement list is often accompanied by a hardware compatibility list (HCL), especially in case of operating systems. An HCL lists tested, compatible, and sometimes incompatible hardware devices for a particular operating system are application .Therefore the system require much different software to make the application which is in making to work efficiently. It is very important to select the appropriate software so that the software works properly.

PROGRAMMING LANGUAGE	PYTHON
DEVELOPMENT PLATFORM	ARDUINO IDE
MICROCONTROLLER CODING	EMBEDDED C

Table 6.2

CHAPTER 7

RESULT ANALYSIS

Result analysis is a pivotal component of any research or project report, providing insight into the outcomes, implications, and significance of the conducted work. This section serves as a critical juncture where the findings and observations obtained through experimentation, data collection, or analysis are thoroughly examined and interpreted. By delving into the results, researchers can discern patterns, draw conclusions, and derive meaningful insights that contribute to the broader understanding of the subject matter.

In this section, the system delve into a comprehensive analysis of the obtained results, scrutinizing them through various lenses to uncover underlying trends, correlations, and discrepancies. Through meticulous examination and interpretation, the system aim to elucidate the implications through findings, addressing key research questions, hypotheses, or objectives outlined in the study. Moreover, this analysis serves as a basis for drawing conclusions, formulating recommendations, and informing future research directions.

Key aspects addressed in the result analysis include the significance of observed trends or patterns, comparisons with existing literature or benchmarks, identification of factors influencing the outcomes, and potential limitations or sources of error. Additionally, the interpretation of results may entail discussions on unexpected findings, alternative explanations, or avenues for further investigation.

Ultimately, the result analysis section acts as a bridge between raw data and meaningful insights, offering stakeholders, readers, or peers a deeper understanding of the research outcomes and their broader implications. Through rigorous examination and interpretation, the system endeavour to extract valuable knowledge from the data, contributing to the advancement of knowledge in the field and informing decision-making processes.

7.1 CONFUSION MATRIX

A confusion matrix is a table that is often used to describe the performance of a classification model on a set of test data for which the true values are known. It allows us to visualize the performance of an algorithm by presenting a concise summary of prediction results compared to the actual ground truth.

$$\begin{bmatrix} 89 & 8 \\ 7 & 11 \end{bmatrix}$$

TP :- 89
FN :- 8
FP :- 7
TN :- 11

- True Positives (TP): 89
- False Positives (FP): 7
- True Negatives (TN): 11
- False Negatives (FN): 8

- True Positives (TP): These are the cases where the model correctly predicted the positive class. In this case, the model correctly identified 89 instances as positive.
- False Positives (FP): These are the cases where the model incorrectly predicted the positive class when it should have been negative. In this case, the model incorrectly identified 7 instances as positive.
- True Negatives (TN): These are the cases where the model correctly predicted the negative class. In this case, the model correctly identified 11 instances as negative.
- False Negatives (FN): These are the cases where the model incorrectly predicted the negative class when it should have been positive. In this case, the model incorrectly identified 8 instances as negative.

From this confusion matrix, system can calculate various performance metrics such as accuracy, precision, recall, and F1-score. These metrics provide valuable insights into how well the classification model is performing overall and for each class individually. Additionally, the confusion matrix helps in understanding where the model is making mistakes and can guide further improvements in the model or data preprocessing techniques.

7.2 PRECISION-CONFIDENCE CURVE

- 0.927
- Precision focuses on positive predictions.
- It tells that how accurate our model is when it predicts something as positive.
- Precision =(TP) / (TP + (FP))

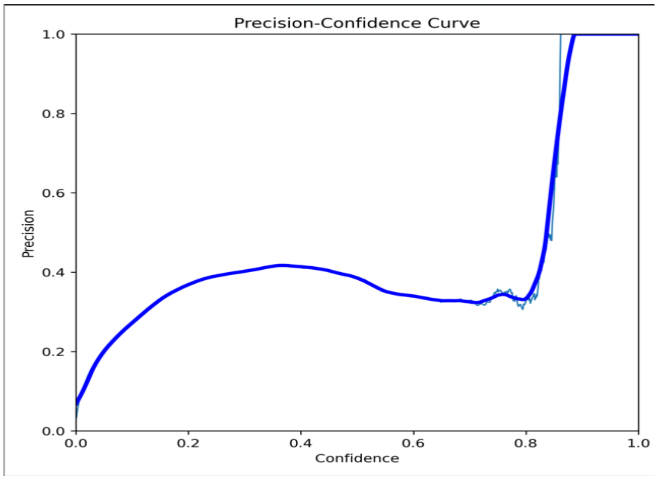

Fig 22:- Precision-Confidence Curve

7.3 RECALL-CONFIDENCE CURVE

- 0.9175
- Recall focuses on completeness for the positive class.
- It tells that how good our model is at finding all the actual positive cases.
- Recall = (TP) / (TP + (FN))

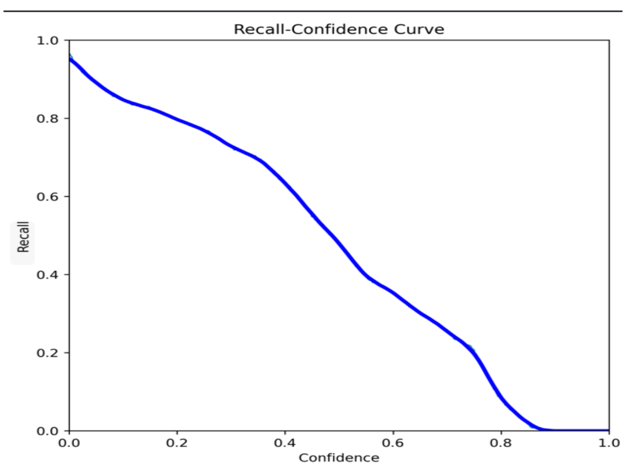

Fig 23:- Recall-Confidence Curve

7.4 F1-CONFIDENCE CURVE

- 0.922
- F1 score tries to find a balance between precision and recall.
- F1 Score=2 * (Precision * Recall) / (Precision + Recall)

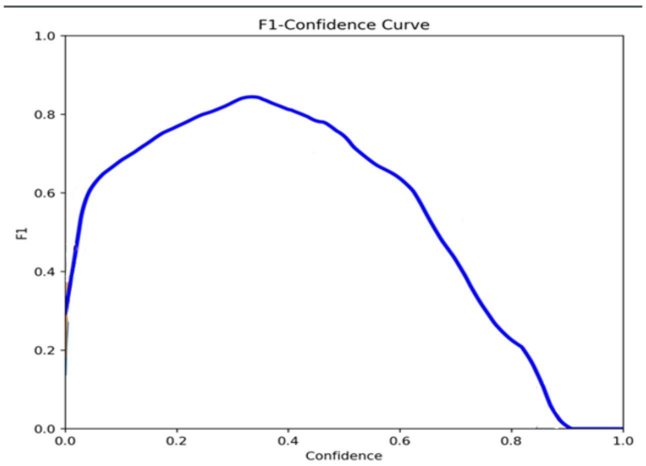

Fig 24:- F1-Confidence Curve

Accuracy :- (TP+TN)/(TP+FP+TN+FN)
:= 86.95%

7.5 HARDWARE SETUP

The designed system integrates a firefighting robot with an Android application to create an efficient and user-friendly solution for fire detection and suppression. The robot, equipped with a camera, serves as the primary means of fire detection and human identification. By utilizing image processing techniques, the camera can detect the presence of flames and individuals in its vicinity, ensuring swift and accurate responses to potential hazards. To navigate through indoor environments and circumvent obstacles, ultrasonic sensors are employed. These sensors enable the robot to move autonomously, scanning its surroundings for signs of fire or obstructions. In the event of a fire, a mini water pump mounted on the robot is activated to dispense water and suppress the flames effectively. The coordination between the camera, water pump, and microcontroller ensures timely and precise firefighting actions .The microcontroller serves as the central control unit, managing the operations of various components within the system. Upon detecting a fire through the camera feed, the microcontroller triggers the relay module to activate the water pump, initiating the firefighting process. Additionally, a gas sensor is incorporated to detect toxic fumes, providing an added layer of safety by alerting users to hazardous conditions. Human detection is another crucial aspect addressed by the system. Leveraging the camera's capabilities, the robot can identify individuals within its vicinity. Upon detecting a human presence, the system sends an alert message to the Android application, notifying users of potential dangers and facilitating prompt evacuation or rescue efforts. Overall, the system operates in real-time, continuously monitoring its surroundings for fire outbreaks and human presence. By leveraging advanced technologies such as image processing, sensor fusion, and wireless communication, it offers a comprehensive solution for fire detection, suppression, and human safety. The integration of hardware components and software applications ensures seamless operation and effective response to emergency situations, ultimately enhancing overall safety and security in both residential and commercial settings.

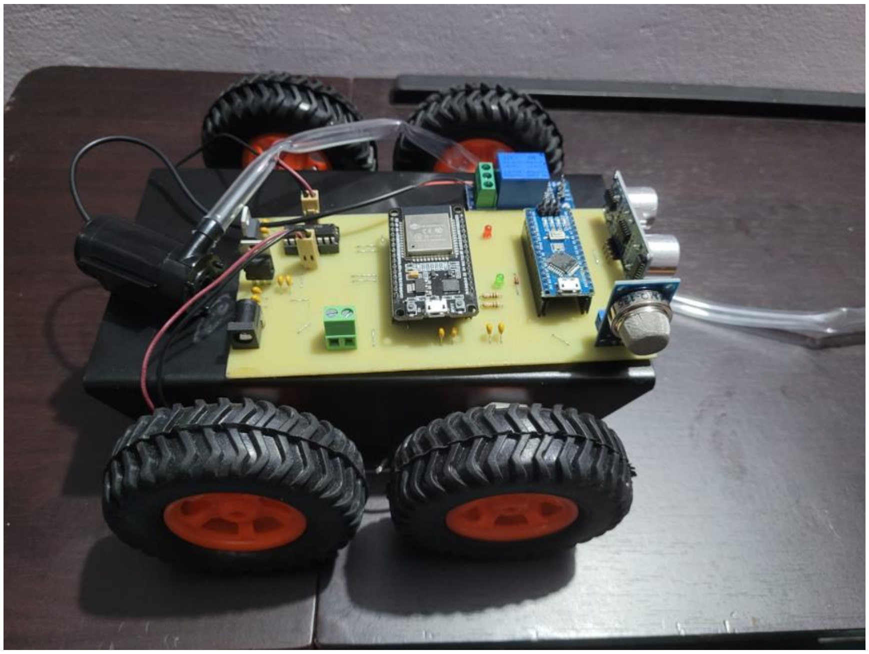

Fig 25:- Body of the Robot

7.6 FIRE DETECTION

Fire detection plays a pivotal role in safeguarding lives and property by enabling early identification and mitigation of fire hazards. Traditional fire detection systems often rely on sensors and alarms, but advancements in computer vision and artificial intelligence have paved the way for more sophisticated and efficient methods. One such approach involves the utilization of cameras coupled with state-of-the-art algorithms like YOLOv8 for real-time fire detection. In this proposed fire detection system, a camera is strategically positioned to capture live video footage of the monitored area.

The video feed is then processed using the YOLOv8 algorithm, renowned for its accuracy and speed in object detection tasks. Specifically trained to recognize fire patterns, YOLOv8 analyses each frame of the video stream, identifying instances of flames with remarkable precision. Upon detecting a fire within the video frames, the YOLOv8 algorithm generates bounding boxes around the flames, visually indicating their location and extent within the scene. This bounding box serves as a crucial visual cue for firefighters and building occupants, facilitating swift and targeted response efforts. Additionally, to ensure immediate awareness, the system triggers an alarm sound or visual alert, notifying relevant stakeholders of the fire's presence and urgency.

The adoption of YOLOv8 brings several advantages to the fire detection process. Firstly, its real-time capabilities enable rapid analysis of video footage, minimizing response times and enhancing overall effectiveness. Moreover, YOLOv8 exhibits robustness against varying environmental conditions, including changes in lighting, smoke, and occlusions, ensuring reliable performance in diverse scenarios. Furthermore, its ability to accurately delineate fire boundaries reduces false positives and enhances the system's reliability and trustworthiness.

Fig 25:- Fire detected using camera

The integration of camera-based fire detection with the YOLOv8 algorithm represents a significant advancement in fire safety technology. By harnessing the power of computer vision and deep learning, this approach offers unparalleled accuracy, speed, and reliability in identifying fire incidents. With its ability to produce precise bounding box annotations and trigger immediate alarms, the system empowers stakeholders with timely information and facilitates swift response actions, ultimately minimizing the potential impact of fires on lives and property.

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

The proposed approach to designing firefighting robots offers a promising solution to mitigate the destructive consequences of fire incidents, providing valuable assistance in critical situations where human intervention alone may be insufficient or hazardous. One notable aspect of this innovative robot design is its versatile mobility, capable of navigating in three directions: left, right, and front. This mobility feature enables the robot to traverse various terrains and access hard-to-reach areas within fire-affected environments, enhancing its effectiveness in firefighting operations.

Central to the functionality of the firefighting robot is its ability to autonomously detect and extinguish fires using an effective firefighting mechanism. Equipped with advanced sensors and detection algorithms, the robot can swiftly identify the presence of flames and deploy appropriate extinguishing agents to suppress the fire before it escalates further. This proactive approach not only helps contain the spread of fire but also minimizes property damage and reduces the risk to human lives.

Furthermore, the firefighting robot serves as a valuable asset in enhancing safety measures by detecting the presence of humans in hazardous environments. Leveraging sophisticated computer science techniques, such as object recognition and machine learning algorithms, the robot can accurately identify individuals within its vicinity, even in challenging conditions with limited visibility or obscured pathways. By promptly detecting and alerting firefighters to the location of trapped or injured individuals, the robot facilitates timely rescue operations, potentially saving lives in emergency scenarios.

In essence, the multifunctional capabilities of the proposed firefighting robot make it a valuable tool for fire response teams, offering efficient firefighting assistance and enhancing overall safety measures in the face of destructive burn situations. By combining mobility, fire detection, extinguishing capabilities, and human presence detection, this innovative robot exemplifies the potential of technology-driven solutions to address critical challenges in firefighting and emergency response efforts.

8.2 FUTURE SCOPE

The future scope of firefighting robots equipped with human detection capabilities and utilizing cameras for fire and human detection is vast and holds significant potential for revolutionizing firefighting and emergency response operations. Here's a detailed exploration of the future prospects for this technology:

- Enhanced Fire Detection Accuracy: Advancements in artificial intelligence (AI) and computer vision algorithms will continue to improve the accuracy and speed of fire detection in various environments. Future iterations of firefighting robots may leverage more sophisticated deep learning models trained on extensive datasets to recognize subtle signs of fire across different types of materials and environmental conditions.

- Multi-Sensory Integration: In addition to cameras, future firefighting robots may integrate a diverse range of sensors, including infrared, thermal imaging, and gas sensors, to enhance their ability to detect fires and assess the severity of the situation. Multi-sensory data fusion techniques can provide comprehensive situational awareness, enabling robots to make more informed decisions in dynamic and complex firefighting scenarios.

- Autonomous Navigation and Mapping: Future firefighting robots are likely to feature advanced autonomous navigation systems capable of generating detailed maps of indoor and outdoor environments in real-time. These robots can autonomously explore complex structures, such as buildings or industrial facilities, while simultaneously identifying fire hazards and mapping escape routes for both occupants and emergency responders.

- Integration with IoT and Cloud Computing: Integration with the Internet of Things (IoT) and cloud computing platforms will enable firefighting robots to access and leverage vast amounts of data for real-time decision-making and coordination. Cloud-connected robots can share information with centralized command centres, receive updates on changing environmental conditions, and collaborate with other robotic and human responders to optimize firefighting strategies.

- Human-Robot Collaboration: As robotics technology advances, future firefighting robots will increasingly collaborate with human firefighters as trusted partners rather than standalone entities. These robots can assist human responders by performing tasks such as reconnaissance, hazard assessment, and remote firefighting in hazardous or inaccessible areas, thereby enhancing overall operational efficiency and safety.

- Adaptability to Dynamic Environments: Firefighting robots of the future will be designed to adapt to rapidly changing and unpredictable environments. This adaptability may involve the ability to reconfigure their physical structures, adjust firefighting strategies on the fly, and collaborate with other robots and emergency responders to address evolving challenges in real-time.

- Enhanced Human Detection and Rescue Capabilities: Beyond detecting human presence, future firefighting robots may incorporate advanced capabilities for assessing the health status and needs of individuals trapped in hazardous environments. These robots could deploy medical sensors, communication devices, and life-saving equipment to provide immediate assistance and facilitate timely rescue operations.

- Global Deployment and Standardization: With the increasing prevalence of wildfires, industrial accidents, and urban disasters worldwide, there will be growing demand for standardized firefighting robot platforms that can be deployed across different regions and jurisdictions. Future efforts may focus on establishing international standards and protocols for the design, testing, and deployment of firefighting robots to ensure interoperability and compatibility across diverse operational contexts.

In conclusion, the future of firefighting robots with human detection capabilities and camera-based fire detection holds immense promise for transforming emergency response practices and mitigating the impact of fire-related disasters. By leveraging advanced technologies, collaborative approaches, and continuous innovation, these robots have the potential to revolutionize firefighting operations and save lives in the face of evolving fire challenges.

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