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Development of The Fire Fighting Robot

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Abstract*— *The Fire Fighting Robot is an autonomous system developed to efficiently detect and extinguish fires. It is capable of navigating its environment without human control. The core of the system is powered by an Arduino Uno microcontroller. Ultrasonic sensors are used to detect and avoid obstacles during movement. A dedicated fire sensor enables the robot to identify the presence of fire. Upon detection of fire, the robot immediately halts its motion. It then activates a buzzer to alert people nearby of the danger. At the same time, it turns on a water pump to extinguish the fire. The robot includes an ESP32 Camera module for video surveillance. This camera provides live video streaming to a connected mobile app. Through the app, users can remotely monitor the robot's real-time activity. The integration of these components makes the robot both responsive and efficient. It is especially useful in environments where human access is risky. The goal of the project is to reduce danger to firefighters. It also aims to improve the speed and effectiveness of fire response. The robot can access small or confined areas that humans may not reach. This increases the chances of early fire suppression. The entire system runs autonomously once powered on. It is suitable for use in homes, industries, and hazardous zones. Overall, this robot offers a smart, safe, and automated solution to firefighting challenges.

Keywords: *Firefighting robot; compact size robot; ultrasonic sensor; flame sensor; remote control*

Introduction

Fire-fighting robots are a groundbreaking advancement in modern safety technology. These intelligent machines are designed to operate autonomously during emergencies, requiring minimal human intervention. They are equipped with advanced sensors capable of detecting fire, smoke, and hazardous gases with high efficiency. These sensors allow the robots to assess danger quickly and respond appropriately. Artificial intelligence is at the core of their function, enabling them to make rapid and intelligent decisions in real time. This ability is crucial when dealing with unpredictable and life-threatening fire scenarios. One of their key tools is the thermal camera, which helps them accurately detect and locate heat sources, even in environments with dense smoke or poor visibility. These robots are built with heat-resistant materials, allowing them to function in extremely high temperatures without failure. They are capable of operating in dangerous and unstable environments where human firefighters face significant risks. Their design allows for efficient navigation through complex structures, debris, and narrow passageways. As a result, they can reach confined and hard-to-access spaces that are often too dangerous for humans. This capability greatly increases the effectiveness of fire suppression efforts. By minimizing the need for direct human involvement, these robots help reduce injury and save lives. They can work continuously and tirelessly, unaffected by fatigue or hazardous conditions. Robotics technology is continuously improving, making these machines more reliable and capable over time. Advancements in AI further enhance their decision-making accuracy and adaptability. Their usage is expanding across industries, including manufacturing plants, chemical facilities, and power stations. Public safety organizations are also beginning to adopt them to strengthen emergency response efforts. These robots are becoming an integral part of modern firefighting strategies. They not only support human teams but also perform tasks that would otherwise be too dangerous or impossible. Their ability to operate under extreme conditions and reach critical areas quickly contributes significantly to faster response times. Fire-fighting robots are reshaping how we handle fire emergencies. With each technological leap, they are becoming more essential in improving overall safety and effectiveness. As development continues, these robots are expected to become standard equipment in fire services around the world. They are no longer a futuristic concept but a real and impactful part of emergency response. The combination of robotics, AI,

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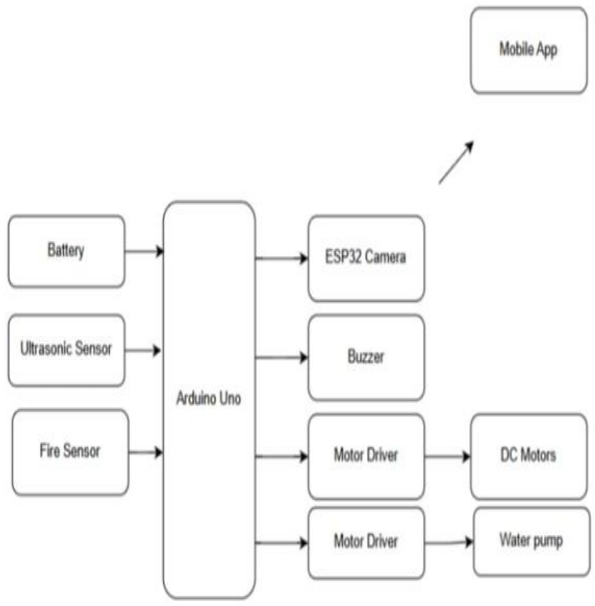
and fire safety technology is setting a new standard in protecting lives and property.

Existing Methods and Drawbacks

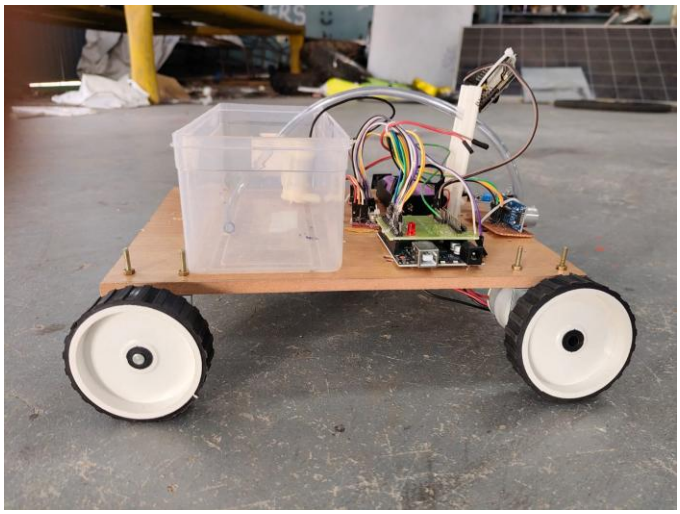
1. **Manual Fire-Fighting:**
   Human-operated fire extinguishers and hoses.
   Drawback: High risk to human life and slower response times.
2. **Fixed Fire Detection Systems:**
   Smoke detectors and sprinkler systems.
   Drawback: Limited mobility and coverage.
3. **Basic Fire Robots:**
   Robots with simple fire detection and extinguish capabilities.
   Drawback: Lack of obstacle avoidance and real-time monitoring.
   The Existing system of the Fire Fighting is by using Man Power that the Fire Fighters are Extinguish the fire using the Fire Fighting Vehicle that filled with Water. Existing system of the Fire Fighting is the Robot that are Equipped with Low Accuracy Flame Sensor and Infrared Ray Sensor that are mounted in the Arduino. Automation is done by these boards and the range is also a considerable one, because without range automation cannot be achieved.

Block Diagram



Result

The fire-fighting robot successfully demonstrated its ability to detect and extinguish small-scale fires. It was equipped with various sensors, including temperature sensors, smoke detectors, and flame sensors, which helped it locate fire sources accurately. Its movement was managed using motors and an integrated control system. This system allowed it to navigate around obstacles in different environments with ease. Upon detecting a fire, the robot stopped and activated its firefighting system. It typically used either water or a foam-based method to put out the flames. The robot's autonomous operation proved effective during testing. It consistently identified fire sources using sensor data. The extinguishing mechanism worked efficiently in controlling small fires. Navigation was smooth, allowing it to avoid and bypass obstacles. Some versions included real-time data transmission capabilities. This allowed environmental data to be sent to a control center during operation. Overall, the robot performed reliably in controlled testing conditions. Its success highlights the potential of automation in fire safety applications. Continued development could enhance its speed, accuracy, and adaptability in real-world environments.



Firefighters risk their lives to save vulnerable people in the event of a fire. Firefighting robot designs have been proposed to reduce the loss of life for firefighters and citizens. Furthermore, currently used firefighting methods are inadequate and inefficient. In real life, fire hazards are unpredictable. It is better to extinguish the fire while it is small. This firefighting robot uses an effective fire spray extinguishing mechanism to extinguish both electrical and normal fires. This

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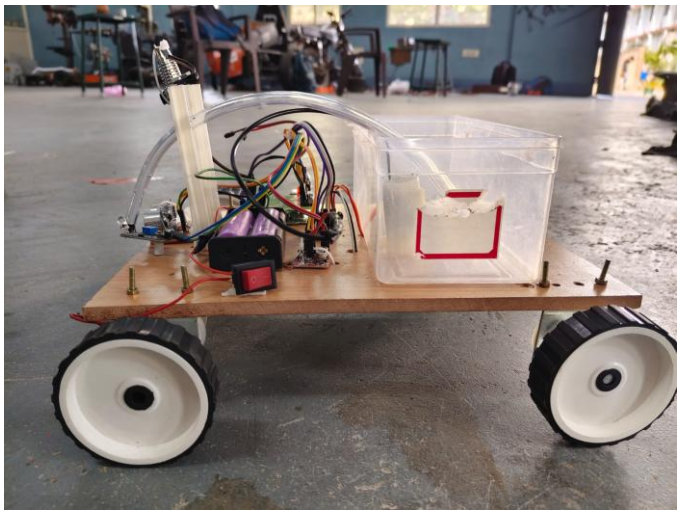
autonomous system is equipped with infrared flame sensors, microcontrollers, and ultrasonic sensors. The proposed system detects fire in all three directions, left, right, front. It has a special ability to detect and avoid obstacles. This robot reacts instantly, increasing the efficiency and success rate of firefighting. This advanced robotic fire extinguishing system detects and extinguishes fires automatically. Currently, the world has been gradually moving towards automation and self-driving cars, putting firefighters in constant mortal danger. Although many precautions are taken to prevent fires, the natural and man-made disasters do occur on occasion. At the time of fire accident, we are forced to use hazardous human resources to save lives and extinguish flames. With the advancement of technology, particularly in robotics, it is very likely to replace humans with robots in firefighting. This would increase the efficiency of firefighters while also preventing them from endangering human lives if the fire spreads quickly if not controlled. If there is a gas leak, there may even be an explosion. So, to overcome the problem and protect our hero's life, our system comes into play. Arduino Uno handles this firefighting, robotic system. It is equipped with an ultrasonic sensor mounted on a servo motor for the detection of obstacle and free path navigation, as well as a fire sensor or flame sensor for detection and approach fire. It also employs a water tank and a spray mechanism to ext.



The Existing system of the Fire Fighting is by using Man Power that the Fire Fighters are Extinguish the fire using the Fire Fighting Vehicle that filled with Water. Existing system of the Fire Fighting is the Robot that are Equipped with Low Accuracy Flame Sensor and Infrared Ray Sensor that are mounted in the Arduino. Automation is done by these boards and the range is also a considerable one, because without range automation cannot be achieved. Coding is also a major one, the functions that a car should be done is to be declared in the coding and send it to the microcontroller. The Range of the Fire Fighting Robot is very low accuracy. The existing systems for AI-based firefighting robots represent a significant leap in technology, blending Artificial Intelligence (AI) with robotics to enhance firefighting capabilities. These systems are designed to autonomously navigate through hazardous environments, detect and suppress fires, and assist human firefighters in mitigating emergencies. sensory Processing Perception begins with the reception of sensory stimuli by specialized sensory receptors, such as the eyes, ears, skin, nose, and tongue. These stimuli are then transmitted as electrical signals to the brain for processing. Sensory Integration The brain integrates and combines sensory inputs from different modalities (e.g., vision, audition, touch) to form a unified and coherent perceptual experience. This integration allows for the synthesis of complex multisensory information. AI-based firefighting robots leverage a range of sensors for comprehensive situational awareness. These include thermal cameras for fire detection, gas sensors to identify hazardous fumes, and LiDAR and ultrasonic sensors for navigation and obstacle avoidance. These sensors enable the robot to interpret its surroundings and make informed decisions The core of these systems lies in advanced AI algorithms. Machine learning models, particularly deep learning, are employed to analyze sensor data, recognize fire patterns, and make real-time decisions. These algorithms allow the robot to adapt to dynamic environments and respond effectively to evolving firefighting. AI algorithms process data from thermal cameras and other sensors to identify potential fire sources. Once a fire is detected, the system determines its location with precision. This information is crucial for the robot to approach the fire and apply firefighting measures effectively Firefighting robots are equipped with various mechanisms for suppressing fires. These may include water or foam dispensers, CO2 or other fire-extinguishing agents, and in some cases, robotic arms for precise application. The choice of suppression method depends on the type and intensity of the fire. While these robots are designed for autonomous operation, they often include features for human interaction and control. Firefighters can remotely monitor the robot's actions, adjust its mission parameters, and intervene if necessary. This

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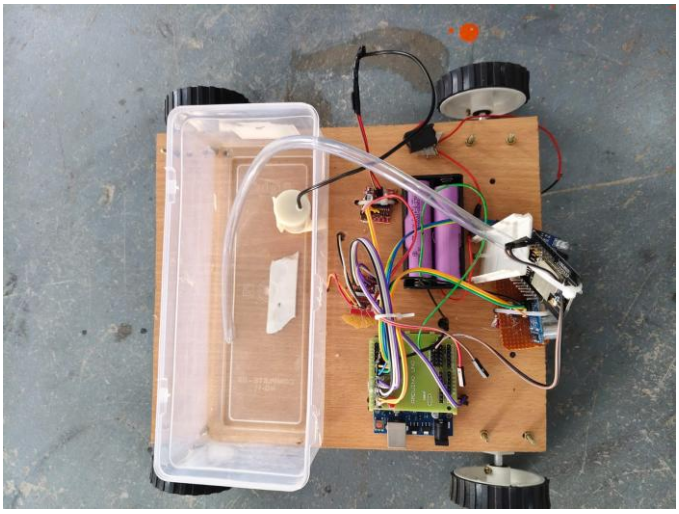
collaborative approach enhances the effectiveness of firefighting efforts. Reliable communication is vital for coordinating firefighting operations. AI-based firefighting robots are equipped with robust communication systems, ensuring seamless connectivity with command centers and other robots. This facilitates real-time data exchange and coordination during complex firefighting scenarios In situations where human intervention is required, these robots can be operated remotely. Remote control interfaces enable firefighters to steer the robot, operate its tools, and make critical decisions. To maximize their impact, these robots are often integrated into existing firefighting infrastructure. This includes compatibility with standard fire hoses, hydrants, and other firefighting tools. Integration ensures seamless collaboration between AI-based robots and human firefighters. In conclusion, the existing systems for AI-based firefighting robots represent a convergence of cutting-edge technologies. By combining AI, robotics, and advanced sensors, these systems offer enhanced firefighting capabilities, allowing for quicker response times, improved safety for human firefighters, and more effective suppression of fires. 8 Industrial Automation Remote operation and monitoring are extensively used in industrial settings to control machinery, processes, and production lines from centralized control centers. This allows for real-time adjustments, troubleshooting, and optimization of operations. Telemedicine In healthcare, remote operation enables physicians to perform medical procedures or surgeries using robotic systems from a remote location. Remote monitoring of patients' vital signs and health parameters allows healthcare providers to offer timely interventions and medical advice. Environmental Monitoring Remote sensors and monitoring stations are deployed in various environments to collect data on air quality, water quality, weather conditions, and other environmental parameters. This data helps scientists and policymakers make informed decisions and respond to environmental challenges. Infrastructure Management Remote operation and monitoring are essential for managing critical infrastructure such as bridges, dams, pipelines, and power plants. Continuous monitoring allows for early detection of issues, preventive maintenance, and rapid response to emergencies. Smart Grids and Energy Management In the energy sector, remote operation and monitoring enable the management of smart grids, renewable energy systems, and power distribute



An autonomous fire extinguisher robot is designed. The robot has fire sensors interfaced in its control circuitry which senses the presence and intensity of fire and take the responsive action accordingly. The robot is designed to detect intensity of fire and operate first at place where the intensity of fire is more. It is also an automatic robot as it does not need to be operated from any remote control. One only needs to deploy the robot in a fire prone zone and the robot will automatically initiate action once it detects a fire breakout. This Robot finds its applications in Rescue operations during fire accidents where the possibility for service men to enter the fire prone areas is very less. The control circuitry of the robot is built on Arduino UNO. There are three fire sensors interfaced in the control circuitry in the forward, left and right side of the robot. A motor fan is attached on the robot which will actually simulate the functioning of a water pump. This is a prototype model. In a production model, a motor pump should be attached in place of the fan. Apart from the component’s interfacing in the circuit, the main significance is of the Arduino sketch running on the controller circuit. It is the Arduino sketch which provides the software intelligence to sense fire intensity using fire sensors, move robot in the direction where fire intensity is more and increase or decrease speed of motor pump. The Arduino sketch is written and compiled using Arduino IDE. Power Supply in the circuit, Arduino board and fire sensors need a 5V regulated DC for their operation while the motor driver ICs needs 12V DC. A 12V NIMH battery is used as the primary source of power. The supply from the battery is regulated to 5V and 12V using 7805 and 7812 ICs. The pin 1 of both the voltage regulator ICs is connected to the anode of the battery and pin 2 of both ICs is

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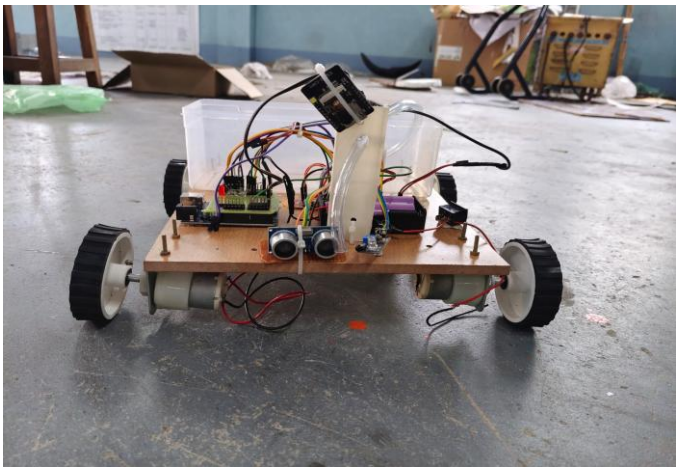
connected to ground. The respective voltage outputs are drawn from pin 3 of the respective voltage regulator ICs. An LED along with a 10K Ω pull-up resistor is also connected between common ground and output pin to get a visual hint of supply continuity. Despite using 12V battery, 7812 is used to provide a regulated and stable supply to the motor driver IC. Arduino UNO Arduino UNO is one of the most popular prototyping boards. It is used frequently in robotic applications as it is small in size and packed with rich features. The board comes with built-in Arduino boot loader. It is an at mega 328 based controller board which has 14 GPIO pins, 6 PWM pins, 6 Analog inputs and on board UART, SPI and TWI interfaces. In this project, three analog input pins of the board are utilized to connect fire sensors and 6 GPIO pins are used to 12 interface L293D motor driver ICs. L293D DC Motor Driver IC the L293D is a dual H-bridge motor driver integrated circuit (IC). The Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors. It has 16 pins with following pin configuration. The pin 4, 5, 13 and 12 of the L293D controlling DC motors for robot's navigation are grounded while pins 1, 16 and 9 are connected to 5V DC and pin 8 is connected to 12V DC. The pins 15, 2, 7 and 10 of this motor driver IC are connected to pins 8, 2, 3 and 7 of the Arduino board. The DC motor attached to right wheel is connected to pins 11 and 14 while motor attached to left wheel is connected to pins 3 and 6 of the motor driver IC. Another L293D IC is used to control a DC motor used for running a fan or pump. The pin 4, 5, 13 and 12 of this L293D IC are grounded while pins 1, 16 and 9 are connected to 5V DC and pin 8 is connected to 12V DC. The motor fan is connected between pins 3 and 6 of this IC and the pins 2 and 7 of this motor driver IC are connected to pins 13 and 12 of the Arduino board. Geared DC Motors in this robot, 12V geared DC motors are attached to the wheels. Geared DC motors are available with wide range of RPM and Torque, which allow a robot to move based on the control signal it receives from the motor driver IC. Fire Sensors a Fire Detection Sensor is sensitive to the flame but also can detect ordinary light. It is usually used as a fire alarm. It detects a flame or a light source of a wavelength in the range of 760 nm to 1100 nm. The detection point is about 60 degrees, particularly sensitive to the flame spectrum. It can detect the fire from a distance about 1 M to 2 M. IR receivers are used as fire detection sensors in the circuit. We have designed our own analog fire sensor where it makes use of the IR receiver. The IR sensors are connected in a voltage divider circuit and interfaced to the analog input pins of the Arduino. The output of the voltage divider circuits is connected to pins A0, A1 and A2 of the controller board. 13 The working of the circuit is simple and straightforward. The IR sensors used for fire detection are connected in voltage divider configuration with the analog input pins of the controller.



The resistance of the sensor changes when light from the flames falls on it. Due to change in resistance of the IR receiver, the analog voltage also varies between ground to VCC. The analog voltage is read from the analog input pin of the controller and converted to a digitized reading using inbuilt ADC channel. The Arduino UNO has 10-bit ADC channels, so the digitized reading ranges from 0 to 1023. The sensors are calibrated to detected fire from a distance of 1 meter. Appropriate reading corresponding to the calibration point is set as the threshold in the program code. The same calibration is done for all the three sensors. The controller is programmed to move the robot in forward direction when the front sensor detects fire and move in the left or right direction when the fire is detected by the left or right sensor respectively. As the robot moves towards the fire spot, the fan or water pump attached to the robot is also activated. The robot can be moved forward, backward, left or right by implementing the following input logic at the motor driver pins. As a responsive action, a fan is started which can blow carbon dioxide at the fire spot. For activating the fan mounted on the robot, the motor attached to fan can be either rotated clock-wise or anti-clockwise by sending Low and High logic or High and low logic at the pins 2 and 7 of the other motor driver IC. The fan can be rotated either way. In a production model, the fan will be actually used to

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blow carbon dioxide at the fire spot. Instead of the motor fan, even a water pump can be attached in the robot by interfacing it through an additional circuitry. The robot designed in this tutorial is a prototype. A production robot should have a fireproof body and should have control circuitry protected in a fireproof casing. A production robot may have specifically designed robotic body which can move around and enter any place with ease. It can have a larger battery pack and a powerful water pump or motor fan mounted on it.

Conclusion

A fire-fighting robot, named QR ob., has been successfully developed with several advantageous features. It can automatically detect fire locations, has a compact body, and is lightweight. Rob is designed to avoid obstacles with the help of an ultrasonic sensor. Its small size allows it to operate in tight spaces or areas with small entrances. The robot can be controlled remotely, allowing operators to extinguish fires from a distance. Operators can also monitor environmental conditions through a camera connected to a smartphone. Experimental results show that Rob can quickly and accurately sense smoke and fire. The robot's sensors ensure prompt response time in detecting hazards. The QR ob. project has met its objectives by developing a functional and efficient fire-fighting robot. The robot's design provides both practical usability and high performance in challenging environments. In conclusion, Rob has proven to be a successful development in fire-fighting technology, offering a reliable solution for emergency situations in confined or hard-to-reach areas.

For future enhancements to the current project, additional features can be integrated onto the system, namely the wireless communication module, so that it can communicate between the operator and the victims within the fire site; image processing technique to analyze for fire source instead of using the flame sensors; utilization of renewable source of energy such as solar power to drive the main circuitry on the AFFMP's platform; ability to navigate on uneven surfaces; and ability to climb staircases.

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