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DESIGN OF AUTOMATIC FIRE DETECTING AND FIRE FIGHTING ROBOT

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ABSTRACT
A fire incident is a calamity that may result in fatalities, property damage, and long-term disability for the victim. Chemical factories, gas tanks, nuclear power stations, petroleum refineries, and other large-scale fire industries do experience major fire mishaps, which can have very catastrophic repercussions. These accidents have claimed the lives of thousands of individuals. Consequently, this idea is improved to use a robotic vehicle to manage fire. Human intervention is decreasing daily due to advancements in robotics. For safety, robots are being used in large quantities. Fire incidents occur frequently in our daily lives, and occasionally it can be quite challenging for firefighters to preserve lives. A firefighting robot enters the picture in this situation

Keywords:
Firefighting robot; Arduino mega2560; DC motor; driver module; infrared distance sensor; flame sensor.

INTRODUCTION

One of the engineering specialties with the greatest rate of growth in the modern period is robotics. Robots are made to take the human element out of hazardous jobs and challenging environments. More people are using robots than ever before. Fire extinguishers are necessary. At its own risk, a robot is capable of detecting and putting out a fire. As engineers, our goal is to create a gadget that can detect and put out fires on its own. intends to lessen air pollution as well. Wireless control is how this robot is supposed to be operated. This technique can find a fire, navigate through a model structure, and use a water jet to extinguish it.
Robots are extremely clever devices that can be employed for any task. Keeping everything in mind, the robot may be controlled remotely by the Arduino Uno. In this case, I have used very basic ideas that are simple enough for both novices and robotics and engineering professionals to grasp.When no one is home or when everyone is sleeping there, a fire can start.
The purpose of this fire safety robot is to help people in the event of a destructive fire by employing an autonomous mechanism to quickly put out the fire. The Arduino Uno and other extra circuits will be programmed to create this self- sufficient system. Destructive scorched areas frequently occur in real life without our knowledge. Because of its benefits to both humans and the environment, this kind of robot will be in high demand in the market. It uses a flame detector module to automatically communicate fire. The project's goal is to create an electronic fire protection robot toolkit that can detect fires autonomously

LITERATURE SURVEY

Sushrut Khajuria et al., [1] suggested an Arduino-based firefighter robot that uses RF-based remote control to run robot and water pump. Within a 7-meter radius, the robot is controllable. Furthermore, it contains a wireless camera that lets people steer the robot in the appropriate ways.
Khaled Sailan et al., [2] proposed an obstacle-avoiding robot called the Amphibious Autonomous Vehicle. This robot uses a fuzzy controller to instantly avoid static obstacles. It seeks to steer the robot or vehicle down the path while avoiding every obstruction in the way.

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J Jalanil et al., [3] proposed a notification system for an automatic firefighting robot. Flame sensors are used by this robot to shoots in the left, right, and center directions. Additionally, ultrasonic sensors are used to identify and steer clear of obstructions. The robot uses a blue tooth module to send the user a warning notification when it senses a fire.

William Dubel et al., [4] created "The Rolly Firefighter Robot" to search for fire in a small house's floor plan, put out the fire (by covering the LEDs with a cup), and after which it returns to the building's front. The robot is guided through the house using data from ultrasonic transducers and a line tracker. To carry out the extinguishing device deployment, a servo-controlled custom arm is employed.

Viet Do et al., [5] created the "Fire Protection Robot", An autonomous vehicle that can navigate across an area and look for hot spots that could be signs of a fire. Once inside the room, the robot will look for a bright place using the colour camera once more. The heat sensor is triggered after the robot has approached the light source to ascertain whether a sizable amount of heat is being produced.

METHODOLOGY

This article's main goal is to automatically detect environmental fires and put them out without the need for human assistance. There are three sections to the methodology. The design structure is covered first, then the hardware description, and lastly the programming design. After putting all three of these components together, tests were conducted to create a system that could put out the fire.

1. DESIGN STRUCTURE

IR flame sensors, servo motors, a submersible water pump, a motor driver, a micro breadboard, BO motors, rubber wheels, and data exchange between the Arduino program and the firefighting robot are all incorporated into the robotic system prototype displayed in this section. Our firefighting robot's basic prototype is seen in Figure 2. The robot performs four primary tasks. It first initializes itself, meaning that when power is applied, its sensors initialize. Second, the robot recognizes the fireplace and senses its surroundings, including the temperature. Third, the robot transmits the navigational data and starts to navigate towards the fireplace. Lastly, employing servo motors and a submersible water pump, the robot finally begins putting out the flame.

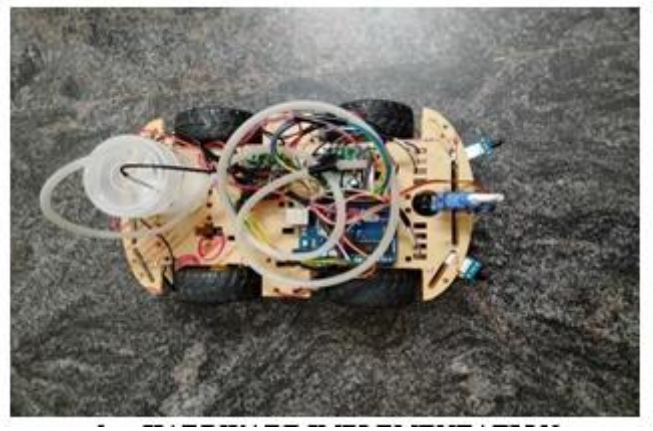

Fig-1: Fire Fighting Robot

2. HARDWARE IMPLEMENTATION

One of the most crucial components in the creation of a firefighting robot is the hardware. Rubber wheels, servo motors, a submersible water pump, a motor driver, a micro breadboard, an Arduino UNO, and infrared flame sensors are all included. The block diagram of a firefighting robot, which uses three infrared flame sensors as its input, is seen in Fig 3. A micro-controller called an Arduino UNO is employed to link additional parts. Two DC motors (the left and right) can be operated simultaneously by the L293D motor driver, which is used to drive motors.

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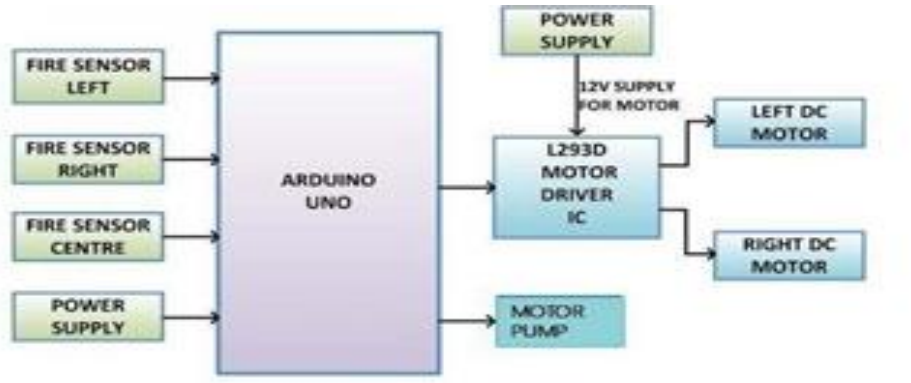

Fig-2: Robotic Firefighting Block Diagram

PROBLEM FORMULATION

A fire disaster is one of the dangerous situations that can result in both fatalities and large financial losses. High temperatures, smoke, and explosive materials can make it challenging for firefighters to reach a fire scene. Firefighters' lives are also at risk in such circumstances. Firefighting robots can be helpful in these kinds of settings. IOT technology is the foundation of this fire extinguishing robot. Our goal with Fire Extinguishing Robot is to create a system that can detect and move to a little flame and put it out. There are a lot of repercussions when firefighters arrive late. The fire extinguishing robot keeps an eye on the surroundings and puts out fires quickly.

1. EXISTING METHOD

Manual firefighting operations come with several disadvantages that can impact efficiency and effectiveness. Fire detection and extinguishing rely entirely on human intervention, which increases response time and can delay critical actions. Additionally, human judgment has a major impact in decision-making, making the process prone to errors that could lead to ineffective fire control. Another major drawback is the high manpower requirement, as a large workforce is needed to combat fires, leading to increased wages and operational costs. The dependence on human availability further results in slower response times, as firefighters may not always be immediately present at the scene. Furthermore, manual fire suppression methods may lack precision compared to automated systems, limiting their accuracy in controlling and extinguishing fires effectively.

2. PROPOSED METHOD

Another significant advantage is increased safety, as automation minimizes the need for face-to-face communication and lowers the risk of burns, smoke inhalation, and exposure to harmful gasses. Furthermore, automated methods eliminate human mistake, guaranteeing reliable and effective fire suppression independent of human judgment. Because these systems require less people, they eliminate the need for on-site firefighters, which lowers labour costs.

HARDWARE MODULES

a. ATmega328p Microcontroller

On the basis of the AVR architecture, the Atmel ATmega328P is a 32K 8-bit microcontroller. A throughput of nearly 20 MIPS at 20MHz is achieved by executing several instructions in a single clock cycle [9]. The ATMEGA328- PU is compatible with our 28-pin AVR Development Board and is available in a PDIP 28-pin package. On the one hand, a computer is made to do all general- purpose tasks on a single machine. As an illustration, you can utilize a computer to store multimedia files, run softwareto do calculations, or access the internet through a browser. However, contrary to, microcontrollers are made to do specific tasks, like turning the air conditioner off automatically when the room temperature falls below a certain threshold and when the temperature surpasses that threshold, it is turned back on.

b. L293DMotor

The Motor driver L293D which controls the direction and two dc motors' speed simultaneously. One well-liked IC for a 16-Pin Motor Driver is the L293D. Its primary use is to drive motors, as the name suggests. One L293D IC is capable of controlling two DC motors at the same time, and their directions can be separately regulated.

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Therefore, digital circuits like digital gates, 555 timers, Op-Amps, and even micron rollers like Arduino, PIC, and ARM, etc., are required to operate motors with operating voltages under 36V and currents under 600mA. It's quite easy to use this L293D motor driver. The IC operates on the Half H-Bridge principle.

c. Flame sensor module

The Flame Sensor Module uses infrared light generated by flames to detect the existence of fire or flame. By recognizing the infrared light that an open flame produces, the Flame Sensor Module can identify an open flame. It can identify infrared wavelengths in the spectrum that an open flame produces. The main function of this sensor module is to identify open flames. It accomplishes this by identifying infrared (IR) light, which is released by a flame. Usually, that spectrum falls between 700 and 1100nm.

d. 4-Wheel chassis

The 4wheel chassis is double layer 4-wheel smart car robot chassis DIY kit. It comes with the four pairs of Geared Motors and Wheels. All the products included in this car kit are quality products. The chassis used in this kit is transparent so as to create dynamic handling of the components mounted on your robotic vehicle.

e. DC servo motor

One kind of motor that can rotate extremely precisely is a servo motor. This kind of motor typically has a control circuit that gives feedback on the motor shaft's present location. This feedback enables the servo motors to rotate extremely precisely. A servo motor is used when you wish to rotate an object at a certain angle or distance. It consists solely of a basic motor that is driven by a servo mechanism. A DC servo motor is one that is powered by a DC power source; an AC servo motor is one that is powered by an AC power source. We will just be talking about the operation of the DC servo motor in this lesson.

There are numerous additional servo motor kinds based on the kind of gear arrangement and operating characteristics in addition to these main categories. The gear arrangement that servo motors typically come with enables us to acquire very high torque servo motors in compact, lightweight packaging. These characteristics have led to their employment in a variety of applications, including robotics, RC helicopters and airplanes, and toy cars. The majority of hobby servo motors have ratings of 3 kg/cm, 6 kg/cm, or 12 kg/cm. Servo motor ratings are expressed in kg/cm, or kilograms per centimetre. This kilograms per centimetre indicates the weight that your servo motor can raise at a given distance.

f. 18650 Battery

The lithium-ion battery, which measures 65 millimeters in length and 18 millimeters in diameter. They are made to produce high output voltage and can deliver high current. Li- ion batteries like the 18650 Cell are used in a variety of applications, including electric cars and vehicles like Tesla and portable gadgets like torch lights.

The main reason for this battery being successful is its properties compared to its competitors. These properties include current carrying capability, voltage, cycle life, storage life, safety, and operating temperature and much more. Below shows the comparison between popular batteries for key parameters.

g. Jumper cables

Simply wires with connection pins at both ends, jumper wires are used to join two places together without the requirement for soldering. Jumper wires are frequently used with prototype equipment such as breadboards to enable circuit adjustments as necessary.

SOFTWARE MODULE

a. Arduino IDE

Arduino boards can be programmed using a software package called the Arduino IDE (Integrated Development Environment). For creating, building, and uploading code to Arduino-compatible microcontroller boards, it offers an easy-to-use interface. Windows, macOS, and Linux are among the operating systems that support the Arduino IDE, which may be downloaded for free. The firefighting robot operates through a structured sequence of steps to detect and extinguish fires efficiently. The program begins by initializing the system and reading input values from fire sensors positioned on the left, front, and right sides

b. C++

The object-oriented paradigm was added to the C language to create C++, a general-purpose programming language. It is a compiled language and an imperative. System and application programming are the focus of C++, a high- level, general-purpose programming language. In 1983, Bjarne Stroustrup created it at Bell Laboratories as an addition to the C programming language. Procedural, functional, and generic programming paradigms are supported by the object-oriented, multi-paradigm language C++. The capacity of C++ to handle

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low-level, system- level programming is one of its primary characteristics, which makes it appropriate for creating operating systems, device drivers, and other system applications. C++ is a well-liked option for creating desktop programs, video games, and other sophisticated applications since it offers a wide range of libraries and tools for high-level application programming. There are many resources and tools available for learning and using C++, as well as a sizable and vibrant developer and user community. Because C++ allows object-oriented programming, programmers can specify methods and properties for classes and objects. C++ templates facilitate the creation of reusable and adaptable code by enabling developers to construct generic code that works with any kind of data. Writing effective and efficient code is made easier by the STL's extensive collection of data-working containers and algorithms.

PROGRAMMING

The Arduino software offers core libraries and an integrated development environment (Arduino IDE) for programming. A Java-based software application, the Arduino IDE is built on the Processing platform. AVR Liby is used to compile the Arduino IDE, which is essentially a framework built on top of C and C++. Writing code and uploading it to the Arduino Uno for execution is made simple by the open-source Arduino IDE.

MERITS, DEMERITS AND APPLICATION

a. Merits

With its many benefits, the firefighting robot is a dependable and effective fire suppression tool. Its ability to operate autonomously lowers the risk to firefighters by detecting and putting out fires without the need for human intervention. The technology promptly detects fire outbreaks and takes prompt action to stop their spread thanks to real-time fire detection and response. The robot can precisely move toward the fire and efficiently direct the extinguisher, guaranteeing optimal suppression, because of its great accuracy and effectiveness.

b. Demerits

Despite its advantages, the firefighting robot has certain limitations that impact its overall effectiveness. One of the primary drawbacks is its limited fire suppression capacity, as it can only extinguish small fires due to restricted water or extinguisher storage. Additionally, its restricted mobility may hinder its ability to navigate rough, uneven, or highly cluttered terrains, limiting its use in complex environments. The robot's performance is also heavily dependent on sensors, which may occasionally result in false positives due to heat sources other than fire, affecting accuracy. Another significant limitation is its power dependency, as the robot requires a continuous power supply, and battery life constraints may reduce its operational time. Lastly, the robot lacks human decision-making abilities, meaning it cannot assess complex fire scenarios or adapt strategies the way human firefighters can, which may be crucial in severe or unpredictable.

c. Applications

Applications for the firefighting robot are numerous and span many industries, improving fire safety and prevention. In industrial safety, it is used in factories, warehouses, and chemical plants to detect and suppress fires in hazardous environments, reducing potential damage and risks. In residential and commercial buildings, the robot aids in fire prevention in homes, offices, and shopping malls, minimizing fire-related accidents and improving safety. It is particularly valuable in data centers and server rooms, where it protects sensitive electronic equipment from fire damage, ensuring the security of critical IT infrastructure. The robot is also essential in labs and hospitals, where it maintains safety in areas with combustible materials and vital medical equipment.

In defense and military applications, firefighting robots are deployed in military bases and ammunition storage facilities to handle fire-related emergencies effectively. Additionally, they are employed in places that are prone to fire and forest fire detection, where they can be placed in isolated areas and forests to identify and put out little fires prior to them becoming major catastrophes.

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RESULT

Table 1: Result Comparison

Paper	Methodology	Proposed method
Sushrut Khajuria et al., [1]	Arduino-based firefighter robot controlled via RF remote with a water pump. Has a wireless camera for user monitoring.	This project enhances autonomy by eliminating remote control, making it a fully automated system with flame sensors detecting fire from different directions
W. Dubel et al., [4]	"Rolly Firefighter Robot" with ultrasonic and line-tracking sensors for navigation and a mechanical arm for fire extinguishing	Three flame sensors (left, right, front) for direct fire detection. Mini water pump system actively spraying water to extinguish fire.
Viet Do et al., [5]	A fire protection robot uses a color camera and heat sensor to gauge the degree of the fire before employing a fan to put it out.	Uses a mini water pump to spray water on the fire. Water spray direction controlled by servo motor.
Nik Md. Hafizul Hasmi et al., [6]	PIC16F84A microcontroller with RC circuit for autonomous control	Uses Arduino Uno microcontroller, fully autonomous operation

FUTURE SCOPE

The study has been motivated by the objective of developing a system that can detect flames and react suitably without requiring human aid. The maturity of robotics and the development of sensor networks allow us to use mobile agents for tasks that involve detecting external stimuli and reacting to them, even when doing so involves a lot of mechanical processes. This provides us with the opportunity to delegate tasks that were previously completed by humans but were inherently hazardous for robots. Firefighting is one evident application for this type of automation. The approach we foresee is begging to be adopted, considering the number of lives lost in firefighting on a regular basis. Additionally, we anticipate that the methods created in this work will be applicable to other domains where humans are to be replaced by automated mobile agents that sense and respond to stimuli. However, many of these parts have been examined in many scenarios, including cooperative mobile agents, obstacle detection and avoidance techniques, and real-time human-mobile agent communication. It will be fascinating and difficult to integrate all of this into a workable, self-sufficient firefighting service.

CONCLUSION

The fire-fighting robot using Arduino is an innovative and effective solution for detecting and extinguishing fires in hazardous environments. By integrating fire sensors, an Arduino Uno microcontroller, DC motors, and a water pump, the robot can autonomously navigate toward a fire source and suppress it efficiently. This automation reduces human intervention, minimizing the risk to firefighters and ensuring quick response in emergency situations. Despite its limitations, such as restricted mobility, limited fire suppression capacity, and dependency on sensors, the robot remains a cost-effective and customizable tool for fire safety. It can be deployed in various applications, including industrial plants, commercial buildings, data centers, and even forest fire monitoring. With further advancements in AI, IoT, and sensor technologies, the fire-fighting robot can be enhanced to improve accuracy, coverage, and efficiency. In conclusion, the Arduino-based fire-fighting robot is a promising step toward

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intelligent fire prevention systems, offering safety, automation, and efficiency. Its continued development and implementation can significantly contribute to fire safety, reducing property damage and saving lives.

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