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Development of Automated Fire Fighting Robot

Dr. P.R Rothe[1], Ashutosh Dharpure[2], Ashutosh Sirpure[3], Madhusudan Rao[4], Chetana Rahangdale[5]

[1]Project Guide, Department of Electronics and Telecommunication Engineering , Priyadarshini College of Engineering, Nagpur, Maharashtra.
[2345]Students, Department of Electronics and Telecommunication Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra.

Abstract-
Fire Fighter is a robot designed to be used in extreme conditions, where detecting and extinguishing fire poses significant risks to human life. The research and development in the field of Artificial Intelligence has given rise to Robotics. The robot can be operated and controlled remotely and has the ability to locate and extinguish fires. It is equipped with a monitoring system and operates through a wireless communication system. The fire detection system utilizes sensors mounted on the Fire Fighter Robot. The robot is controlled autonomously using an Android application. It can also transmit video to a remote location using a wireless camera mounted on it. This concept aims to generate interest and innovation in the field of robotics while working towards a practical and achievable solution to save lives and mitigate the risk of property damage. There are many fire accidents in which firefighters sacrifice their lives in the line of duty each year worldwide.

Keywords*: Arduino uno Controller, Dc pump, Temperature sensor, fire sensor, IR sensor, Automatic Fire detection, wireless surveillance etc.*

I. Introduction

Robotics is one of the fastest-growing engineering fields today, with robots designed to remove the human factor from labor-intensive or dangerous work and to operate in inaccessible environments. The use of robots is now more common than ever, extending beyond heavy production industries. The need for a Fire Extinguisher Robot capable of autonomously detecting and extinguishing fires is long overdue. With such a device, lives and property can be saved at a higher rate with minimal fire damage. Our task as engineers was to design and build a prototype system capable of autonomously detecting and extinguishing fires, while also aiming to minimize air pollution.

In this project, we designed a wireless-controlled robot, capable of moving through a model structure, locating a fire, and extinguishing it using a water jet. The project utilizes sensor based technology for controlling operation, with an Arduino Uno controller facilitating the desired operations. At the transmitting end, push buttons are used to send commands to the receiver, enabling control over the robot's movements—forward, backward, left, or right. At the receiving end, three motors are interfaced with the microcontroller, two for the vehicle's movement and one for positioning the robot's arm.

The transmitter serves as a sensor based control with a sufficient range of up to 5 meters, while the receiver decodes the commands and feeds them to another microcontroller, which drives the DC motors via a motor driver IC for the necessary tasks. The robot's water tank and pump, crucial for fire extinguishing, are controlled by appropriate signals from the microcontroller at the transmitting end. The entire operation is overseen by the Arduino Uno controller, which interfaces with the motor driver IC to control the motors. To further enhance the project, it can be integrated with a wireless camera, allowing the operator to remotely view the robot's operations on a screen.

II. Problem Definition

Fire disaster poses a significant threat, resulting in heavy financial loss and loss of lives. Accessing fire sites can be challenging due to factors like explosive materials, smoke, and high temperatures, endangering firefighters' lives. To address such challenges, fire-fighting robots are invaluable. This Fire Extinguishing Robot utilizes IoT technology. The objective of this project is to develop a system capable of autonomously detecting and extinguishing small flames. Delays in firefighters' arrival can have serious consequences. The Fire Extinguishing Robot continuously monitors its environment and promptly extinguishes fires as they occur.

Fig.1. Fire situation inside industries

III. Objective

- The major purpose of this project is to build a wireless technology-based fire fighting robotic vehicle with autonomous fire sense and wireless camera monitoring.
- Use of fire sensor to detect the exact fire situation and turn ON the pump automatically.
- Use of RF based wireless technology to control the robotic vehicles remotely using smartphone application.
- Use of wireless camera for monitoring the live situation.
- To test the model and find out results.

IV. Literature Survey

- *Swati Deshmukh, Karishma Matte and Rashmi Pandhare, March-2019.* In an unknown environment, obstacle avoidance in real-time is a crucial feature for a Vehicle. A fuzzy controller is implemented to regulate the Vehicle's obstacle avoidance. Its purpose is to steer the Vehicle along its designated path, ensuring avoidance of static obstacles present in its vicinity.

- *Muhamad Bukhari Al-Mukmin Bin Mohamad Zahar, 2017.* The human can control the robot using the GPS module, which operates in conjunction with an Android application. The GPS module communicates with the application through various components, including driving motor, Arduino Mega, voltage divider, tires, GPS, and motor driver.

- *Joe Davis, Ray Klundt and Paul Limpisathian., 2018.* There are four different types of system units utilized in this setup: 1. GPS system, 2. Fire detection system, 3. Extinguishing system, and 4. Communication system. The GPS system serves for obstacle detection, with four ultrasonic range finders employed to measure the distance between obstacles and the system. The fire detection system incorporates a gas sensor to detect fire. The extinguishing system is responsible for effectively extinguishing the fire.

- *William Dubel, Hector Gongora, Kevin Bechtold, Daisy Diaz, 2020.* A Pic microcontroller, sensor, motor driver, gear motor, relay driver, GPS module, pump, and sprinkler constitute the components used in this paper. Programming the Pic microcontroller necessitates the use of open-source software such as Pic controller IDE. The detection and extinguishing processes are facilitated by the Pic microcontroller, which interfaces with various components like sensors, gear motors, and relay drivers. The "solar-powered automatic fire-fighting robot" finds practical applications in everyday settings such as homes, laboratories, parking lots, supermarkets, and shops. A key function of the robot is patrolling. However, limitations include Bluetooth range and water capacity.

- Tawfiqur Rakib, M. A. Rashid Sarkar, A fire fighting robot model is proposed, featuring a base platform constructed from 'Kerosene wood', flame sensors for fire detection, an LM35 sensor to detect temperature, and a water container with a 1-liter capacity crafted from sturdy cardboard to ensure water resistance. Movement is facilitated by two wheels on the robot.

- Saravanan P. ,Soni Ishawarya, A model is proposed utilizing the Atmega2560 microcontroller, where the robot is categorized into three fundamental units based on their functions: locomotive unit, fire detecting unit, and extinguishing unit. Each unit operates independently to accomplish the objective of extinguishing fires. The locomotive unit facilitates the robot's movement and obstacle avoidance through the use of four IR and four ultrasonic sensors. The fire detecting unit identifies fires using LDR and a temperature sensor. The extinguishing unit utilizes a water container and BLDC motor to extinguish fires. Additionally, the robot is equipped with a Bluetooth module for smartphone connectivity, enabling navigation in the correct direction.

- S. Jakthi Priyanka,R. Sangeetha, A proposal is put forth for an Android-controlled fire-fighting robot utilizing the Arduino UNO R3. The robot comprises a gas sensor for fire detection, gear motor, and motor drive for movement, a Bluetooth module for connectivity with Android devices enabling smartphone control. Additionally, a water pump and sprinkler system are integrated. To program the Arduino UNO, Arduino IDE, an open-source software, is necessary for coding and implementing the code onto the Arduino UNO.

- Nagesh MS, Deepika T V , Stafford Michahial, Dr M Shivakumar, A fire extinguishing robot is proposed, utilizing DTMF (Dual Tone Multi-Frequency Tones) technology for navigation. The robot incorporates a flame sensor for fire detection, capable of sensing flames within the wavelength range of 760 to 1100 nm. Its sensitivity varies from 10cm to 1.5 feet.

- Sushrut Khajuria, Rakesh Johar, Varenyam Sharma, Abhideep Bhatti, An Arduino-based fire-fighter robot is proposed, featuring RF-based remote operation for controlling the robot and water pump. The user can control the robot within a range of 7 meters. Additionally, the robot incorporates a wireless camera to aid the user in directing the robot as needed.

- Khaled Sailan, Prof. Dr.-Ing. Klaus-Dieter Kuhnert, Simon Hardt, A proposal is made for an obstacle avoidance robot called the Amphibious Autonomous Vehicle. This robot employs a fuzzy controller to navigate around static obstacles in real-time, with the goal of guiding the vehicle along its path while avoiding any obstacles encountered along the way.

- J Jalani1 , D Misman1 , A S Sadun1 and L C Hong1, A proposal is made for an automatic fire-fighting robot with notification capabilities. This robot integrates three flame

sensors positioned for fire detection in the left, right, and center directions. Additionally, it incorporates three ultrasonic sensors for obstacle detection and avoidance. Upon detecting fire, the robot sends a warning notification to the user via a Bluetooth module.

V. Block Diagram

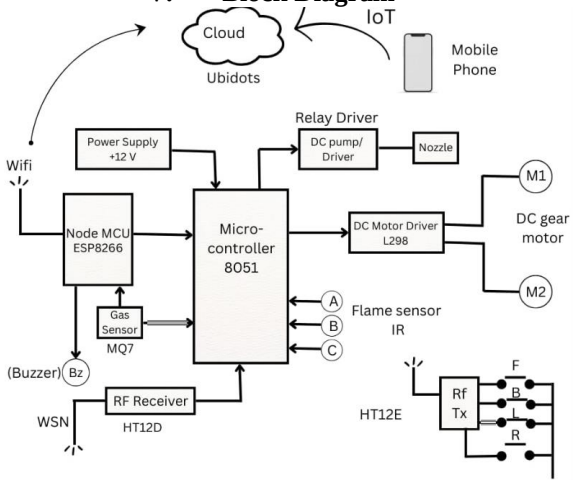

Fig.2.Block Diagram

VI. Working

The primary objective of this project is to design a solar-powered fire-fighting robot operated remotely. The robot is powered by solar energy and equipped with a water tanker and pump controlled wirelessly for sprinkling water, managed by an Arduino Uno controller.

Commands are transmitted from a RF remote to the receiver at the transmitter end, enabling control of the robot's movement—forward, backward, right, or left.

The remote control offers a range of up to 5 meters with the appropriate antenna, and a decoder processes the signals before passing them to another microcontroller to drive DC motors using a motor driver IC for necessary functions.

A water tank and pump mounted on the robot body automatically activate when the fire sensor detects a fire, with operation directed by the microcontroller's output signals.

Additionally, all operations can be displayed on an LCD display for monitoring.

First things first: make sure every part is connected and receiving power from an external source. After a while, the robot stops moving and begins to rotate in all directions in order to use a flame sensor to identify the presence of an object. It advances and rechecks for the presence of an object inside range if the object is out of range. One of the five channel flame sensors detects the signal, and if it matches the centre sensor, the robot moves precisely in the direction of the target. It advances a certain distance upon detecting the flame, then keeps testing its range until it gets close to the flame-producing item. It ignites the fire when it gets to the flame, it activates the fire extinguisher or water pump to extinguish the fire.

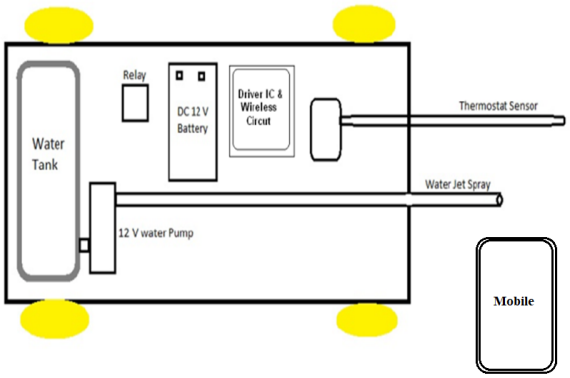

Fig.3.System Architecture

VII. Components Specification

1) Flame Sensor: The primary purpose of this sensor is to both identify and react to flames or fires. It uses five flame sensors placed in a 300-degree circle to detect fire. The range of detection is 700–1100 nm. A 60-degree detection angle is used.

2) Temperature sensor: The analogue output voltage of the temperature-measuring device LM35 is proportional to the heat. The input voltage ranges from 35V to -2V, minimum and maximum, respectively. Usually 5V.

3) 8051 microcontroller: In 1981, Intel created it. This microcontroller has eight bits. Two 16-bit timers, four kilobytes of RAM and one hundred and eighty pins of DIP (dual inline package) storage are included in its construction. It is made up of four parallel 8-bit ports that may be addressed and programmed to meet specific needs.

4) DC Motor: A DC motor is a kind of electric motor that transforms mechanical force from DC electrical power, or movement or rotation from a DC source. Motor operates smoothly from 4V to 12V and provides a wide range of RPM and torque, even if it only produces 500 RPM at 12V.

5) Driver Module: Each motor driving module has four HG7881 chips of its own. able to control two 4-wire, 2-phase stepping motors or four DC motors. Fit for the range of motors: 2.5V–12V is the motor operating voltage.

6) RF Transmitter: A tiny printed circuit board subassembly called an RF transmitter module is able to modulate and transmit radio waves in order to transport data. The transmission rate is between 1 and 10 Kbps.

7) RF receiver : Operates at the same frequency as the transmitter and receives the data that has been broadcast.

8) Gas sensors: Instruments that measure the concentration of gases by identifying the unique attribute of each gas, known as the ionisation potential or inimitable breakdown voltage. Gas molecules are detected using sensors based on breakdown voltage.

9) NodeMCU NodeMCU is an open-source development board that is based on the ESP8266 system-on-a-chip (SoC). It provides an easy way to prototype and develop IoT (Internet of Things) projects by offering built-in Wi-Fi connectivity and a programmable microcontroller. The NodeMCU board is widely used for various IoT applications due to its features and simplicity.

VIII. Scope of the study

- The goal of the project is to create a remote-operated firefighting robot that utilises RF technology.
- The robotic vehicles is equipped with a water truck and a wirelessly operated pump that shoots water.
- To control movement, orders are transferred to the receiver end RF module from the transmitter's mobile side using a keypad.
- The robot uses a pump motor attached to a water tank installed on its body to put out fires when it encounters one.
- Watering is done automatically and using two-way RF technology.
- With a sufficient range, the RF transmitter functions as a remote control.

IX. Advantages

- The robot will be used at places where it is dangerous for humans to enter.
- It can move automatically inside the room without any supervision.
- It as uninterrupted solar power supply unit
- The automatic water sprinkler will start where ever the fire is detected.
- The robot is fire resistance and can be used at situations where temperature is 120 degree Celsius.
- It can be controlled by android phone externally.

X. Results & Discussion

Locally obtainable components were used to construct the firefighting robot, and tests were conducted to evaluate its effectiveness in various scenarios. This performance test will assist us in creating a better model because a firefighter robot must be able to survive in a variety of circumstances. The following inferences can be formed based on the design and experimentation of the respective robot:

- Water cannot escape in this way since the water tank is made of fireproof aluminium alloy and the pipelines are made of waterproof white cardboard. The water velocity in the pump is greatly reduced by a water sprinkler at the end of the pipe, which also spreads the extinguishing water efficiently. They make extinguishing easier by delivering water to a precise and secure distance. The LM35 sensor, which transmits heat detection technology to the measured distance, is likewise carried by the other tube.
- Analogue output measurements are at their lowest during the day. The output reading difference between readings with and without the fire source, which is typically between 300 and 350, is provided by this, though. Thus, even in these circumstances and with the worst possible result reading, an effective algorithm can be created.
- When there is no source of light, readings are lowest at night and greatest during the day. Its detecting range is effective.
- The time period between 23:00 and 03:00 is excellent for identifying the fire's origin. This presents the best opportunity for device customization ever.
- The robot detects the fire and begins to move in its direction. The power of the LM35 fluctuates with temperature.

- The LM35's output change is not linear. Readings are acquired at various distances because the robot is calibrated to stop at a safe distance from the source.

Analysis

A. Sensitivity of flame sensor at day and night:

The results of testing the Arduino flame sensor's sensitivity during the day and at night, in the absence of a fire, and at a distance of three metres from the fire source are shown in Figures 4 and 5. Figure 4 demonstrates that the sensor output is larger at 7 o'clock with or without a fire source, but the reading falls over time. This is because sunlight contains infrared photons. Around 12 or 1 o'clock in the afternoon, when the sun is at its strongest for the day, a flame detector can pick up more infrared photons. Consequently, this is the time of day when the output reading is lowest, whether or not there is a fire source. However, after 3 o'clock the sun's intensity starts to wane, and as a result the initial reading starts to rise. When it sets at the end of the day, the sun is at its highest. Additionally, it was discovered that throughout the day, nearly identical patterns were seen and that the deviation of serial number profiles was fairly constant.

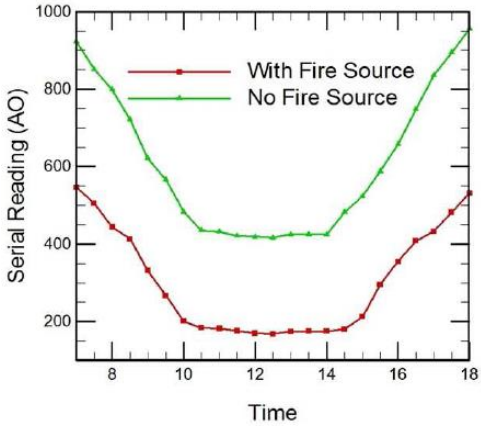

Figure 4: Effect of sensitivity of flame sensor at day

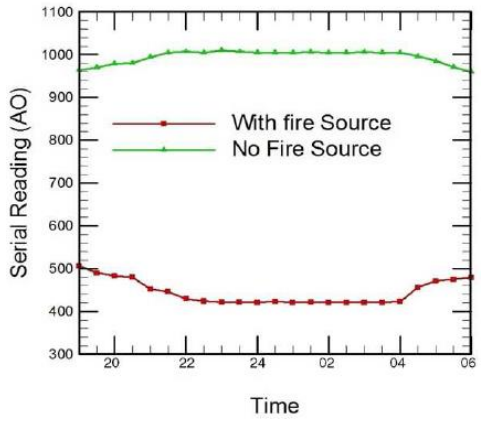

Figure 5: Effect of sensitivity of flame sensor at night

Figure 5 illustrates that the nighttime readings with and without the fire source are nearly equivalent. The initial reading is highest without the fire source and lowest with it at 23:03, when the sun's impact begins to wane. The discrepancy between the two readings is therefore highest at this hour of the night. The biggest distinction between a fire source and a typical circumstance can be made at this time. Therefore, at night, the flame detector will undoubtedly detect a fire.

B. Change of output of flame sensor when the robot moves towards *fire:*

Figure 6 depicts the difference in flame sensor power at 10 a.m. and 10 p.m. when the robot detects fire and begins to move towards the source. The analogue output reduces as you go closer to the source since the source's intensity has increased. Additionally, when you are farthest from the source, readings at 10 p.m. are higher than at 10 a.m. Because the analogue reading of the sensor is distorted by the sun's infrared radiation around 10:00 AM, the value decreases more dramatically at 10:00 PM than it does at 10:00 AM. However, if they are at a safe distance from the fire during the day, it can also be found because the readings are essentially the same at night and during the day. because as the source's intensity increases, more infrared photons are produced. Due to this, the output reading at 10 PM and 10 AM, respectively, both show a quick attenuation and a slight attenuation.

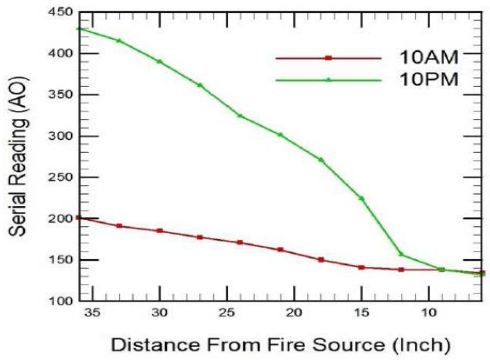

Figure 6: Change of output of flame sensor when the robot starts moving towards fire Source.

C. Change of output of LM35:

When the temperature begins to rise, the robot begins to move in the direction of the fire. A relatively small area can have heat detected by the LM35 sensor. It is frequently necessary to touch the source of fire in order to detect it, even with minor sources of fire. The LM35 sensor can detect heat at least 6 inches away from the source because of the intricate construction of the robot. Because it is mounted through a tube on the robot's front, the sensor is placed even closer to the source of the heat. The robot is able to keep a sufficient gap between itself and other people. As a result, when it notices a spike in temperature, the LM35 modifies the power. When the change reaches a certain threshold, the robot is trained to put out the fire predetermined threshold.

Table 1. Change of output readings of LM35

Temperature (°C)	Serial Reading(AO)
26	55
40	88
55	123

The fire robot's power allows it to extinguish minor flames. In regions with poor lighting, it is especially combustible. It was created to prevent bots. because it can put out fires before they spread and can identify them early. This multi-sensory robot can offer protection from all types of fire risks. Given enough funding and scope, this robot's design has more reserve power to put out larger fires, and its upgraded sensor can spot fire early in any situation.

Project Model:

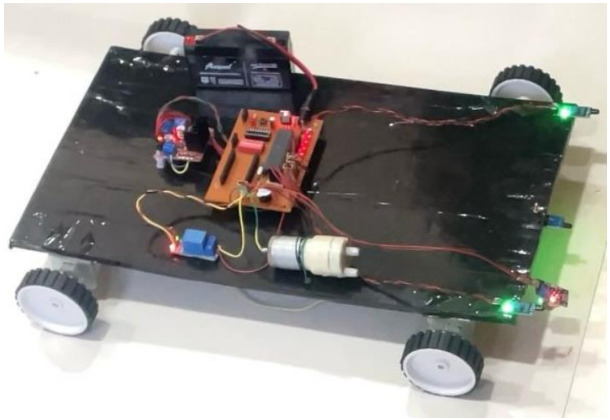

Figure 7: Prototype Model Image

XI. Conclusion

This project introduces a firefighting robot utilizing RF communication, designed and implemented with an Node and 8051 (MCU) within the embedded system domain. Careful experimental work has been conducted, demonstrating increased efficiency with the embedded system. The method proposed is confirmed to be highly advantageous for both security and industrial purposes. Currently, the robot can only dispense water at a high flow rate. In the future, enhancements will enable the robot to utilize controlled robotic arms for water deployment and object detection through integrated cameras. Further extensions of the project are envisioned to incorporate these additional features.

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