Towards Building Intelligent Robotic Systems to Enhance the Safety of Firefighters

Kirubakaran M N, Arun Kumar S, Sasikala S, Gohithmugilan S and Muralidhar M

Department of ECE, Kumaraguru College of Technology, Coimbatore- 641049

kirubakaran.17ec@kct.ac.in

Abstract. Firefighting robot is a human developed robot to safeguard human’s life. Nowadays, the accidents happening during the fire extinguishing is uncountable. The main role of the proposed robot is to detect the fire, to move towards the fire automatically, to move at any direction to extinguish the water and to send a notification to the nearest fire station. The automatic robot movement is fully controlled by a programmable ESP32. The automatic robot which is in a form of vehicle like will move right, left, front and back to detect and extinguish fire. The firefighting robot equipped with a camera is used to capture the live moment happening at a particular time. The live recording from the camera is sent to the nearest fire station which is already programmed. This recording helps the real fire fighters to know the intensity of the fire and they can plan accordingly to equip themselves. Cloud technology is used to send live recording to real fire fighters to identify the intense of the fire. The exact location of where the fire has happened is also sent to enable firefighters to arrive at the location very quickly.

1. Introduction

Naturally, fire is a threat to both human life, forests, and assets. According to the NFA (National Fire Administration) 39% of all fires are structural fires. These types of fire results in loss of lives, and damage of property worth millions of dollars. Many countries have spent huge amount to reduce forest fires and fire accidents by implementing advanced technology in fire station. Though, the fire service personnel are well equipped and trained, the sudden happening of fire accident is unpredictable and thereby damage the properties and result in casualties before the firefighters have arrived at the location. Further, the lives of firefighters are also under risk. This is undesired in this current technological space. Hence, Fire fighters must have better workspace to make their life safe and efficient. In the modern age, risky jobs to be given to machines and robots. Therefore, this work uses sensors and Internet of Things (IOT) based technology to prevent the spreading of fire until the firefighters arrive to the locality and the evacuation of people in the building/house. To mitigate this gap, the proposed work uses a robot that can lend a support in finding the source of fire from the building, alert the nearest firefighter with the location of the building, alert the nearby hospital to rush to the spot with a doctor supported ambulance and alert the people immediately to evacuate themselves the building.
2. Literature Review
Nowadays, firefighting is one of the big issues. The different techniques are proposed by many authors for firefighting. Many intelligent robot-based systems [1],[2] are developed for helping mankind in daily activities.

A new approach was introduced in [3] to extinguish fire. The robots are fully carried on without outside control. Environmental sensing and awareness, proportional motor control concepts are implemented in that robot. In robot the information’s are processed from its sensor and hardware elements. To detect any obstacle in the path, several light sensing techniques are used. The robots are designed and built to fight against the tunnel fire, industry fire and some military application. To detect fire, ultraviolet sensors are used. The robot sounds an alarm when the fire was detected. The robot sprinkles the water on the flame released by the electronic valve. In a short time, the robot detects fire and extinguishes with the help of sensors and microcontroller. These robots play a significant role when there is a danger to life.

In [4], a new intelligent firefighting tank robot was introduced to analyse the source of heat then extinguishing it for multiple flame position at high-risk areas. The authors in [5], introduced a robot for firefighting purpose in autonomous industries. This paper gives a brief of designing a moving robot. Two optically isolated D.C. motors are present in this system. It converts analog data to digital received from flame red sensors. Motion of the robot is controlled by two sensors and flame detection is controlled by three motors. The paper explains the detection and extinguishing the fire by using sensors and extinguish the fire using microcontroller.

In [6], a wireless robot is developed for fighting fire. It consists of machine that serves a purpose of extinguishing fire. All possible directions such as forward, backward, left and right can be done in firefighting robot. The robot can operate independently over some distance. Resistors depending on light detect the flame. The robot that authors in [7], developed explains the control of robot by making a phone call and the robot has sensors to detect things. When a button is held during the call, the respective tone can be heard on the other end mounted on the robot. Dual-Tone Multiple-Frequency (DTMF) signalling through a mobile placed on the robot is used. This system makes use of some advanced technologies and it also consumes less cost.

A phone controllable firefighting bot was developed in [8] using Bluetooth. Accelerometer helps in capturing the Gestures. The signals of the Bluetooth module are controlled by the microcontroller. Authors in [9] came up with a firefighting robot that is semi-autonomous. The autonomous navigation is controlled by Atmega2560 and it also controls the four D.C. motors. It uses several sensors and has a camera to take video and send it to base station. The fireplace is detected using sensors. The sensor detects fireplace, and it moves to the source to extinguish. The system used for extinguishing has motor and a tank. The system is operated by humans only during uncontrollable conditions and contains GUI to support the system.

A fusion algorithm was developed in [10] for detecting fire. The paper proposes an intelligent device System that uses sensors to extinguish fire. It can alert about the emergency situations and can mitigate the gap until help arrives. Intelligent buildings should be safer for living and these robots can take care of safety measures. When fire starts in a specific region, the system cuts off the electricity on that area and sprinkles water to reduce the flame.

The fire Fighting Robot developed in [11] is remote controlled and has transceiver and a pair of RF modules are used. One module is employed to send information to the driver and another module is employed to know the fire condition. The system uses microcontroller and drivers to control the...
operation. The robot is controlled by using cameras on the surface. Whenever the temperature goes beyond specific limit, the alarm starts ringing and we can use the robot to reduce fire flames.

An intelligent system is installed in [12], to detect fire accident and it works autonomously. So, the robot will find the exact place and moves on its own and quench the fire wherever detected without the controlling person. Once detected, simultaneously the alert message will be sent to authority. But in this scenario, it can be used only in short range like our home and personal space, and it cannot be installed in a big crowd gathering areas.

The fire robot in [13], is wireless device which can be controlled remotely from any parts of the places, it uses Bluetooth module connected with the microcontroller and on other side it can be controlled from a smart phone. Next flame sensor is used to detect in case of any fire accident. In this robot, LM35 is used to detect the flame. By using servo fitted to the water pump, whenever fire is detected automatically the water from pump will automatically quench the flame occurred. The system assisted with robot can assure safety to the fire brigade men. However, disadvantage is limited range owing to the usage of Bluetooth module.

The robot proposed in [14], works autonomously without the help of anyone to reduce human damage and it can be remotely accessed. By using servo fitted to the water pump, whenever fire is detected automatically the water from pump will automatically quench the flame occurred. Microcontroller controls all the sensors and actuators. Using ultrasonic sensor to detect the distance and flame sensor to detect the fire and a warning signal is sent to controllers if anything is being detected. Bluetooth module within the range of 100 meters is used, hence the remote access is only limited by 100 m. This operation will be connected through the Radio Frequency (RF) antennas used in the modules.

In [15], ultrasonic sensor and infrared sensor are used to find the obstacle. So, if there is any object ahead, by using these modules the obstacles will be detected and the signal will be sent to the microcontroller. After being detected the controller can decide to send the signal to which actuators, whether to stop vehicle or to spray water using servo motors. These sensors are very cheap in the market and compact, so it can be fit easily in the robot and makes light weight. The ultrasonic sensor will send the ultrasonic waves ahead and according to the echo coming back, it will calculate the distance and find where exactly the obstacle is ahead.

Though there are many firefighting robots in literature [1-15], the usage or robots is restricted owing to limited features. In existing literature, no notification alarm is sent to the nearest real fire fighters. Further, it does not help to reduce fire because the firefighting robot alone cannot control the entire robot. So, the fire fighters with additional features listed are included.

3. Proposed System
The significant contributions of proposed system are:

- A GSM module is used to alert the nearest hospital for the first aid.
- A night vision camera for accurate detection of the fire at night-time.
- Alerting the nearest fire station by sending the exact location through cloud technology. This helps the fire fighters arrive quickly to the desired location.
- A camera is used to monitor the live activity and the image is continuously captured and sent to the nearest fire station common mail. This helps the real fire fighters to guess the intensity of the fire.
- The intelligence of the robot helps in finding the fire automatically and extinguish fire.
- This advanced technology helps to low the risk of the real fire fighters
3.1 System Architecture

The block diagram of the proposed firefighting robot is shown in Figure 1.

![Block Diagram of Proposed System](image1)

**Figure 1.** Block Diagram of Proposed System.

This system architecture clearly explains how the actual system works. In this system it consists of flame sensor, microcontroller, ESP32 module, motor driver, water pump. The proposed work aims to control the robot manually using Transmission remote control. 8051 microcontrollers are used to transmit and receive signal. The block diagram for transmitter and receiver is shown in Figure 2 and 3.

![Block diagram of transmitter](image2)

**Figure 2.** Block diagram of transmitter.

Figure 2, presents the transmitter block diagram, it consists of encoder, RF transmitter connected with microcontroller. The main function of the encoder is to convert the parallel input from the microcontroller to serial. RF transmitter transmits the serial input to the receiver. 8051 microcontroller is used in the developed system. For communication, the system uses a RF receiver interfaced with the controller. A motor driver IC is used to interface the three motors to the controller. Two motors are used for varying the movements of the vehicle and third motor is used to control the water flow. Water is sprayed through the pump connected with the relay.
A water tanker is placed in the robotic vehicle and an RF transmitter remotely controls the pump. After the user establishes communication via an RF receiver, RF remote can be used to control all possible directions.

![Block diagram of receiver](image)

**Figure 3.** Block diagram of receiver.

Figure 3, shows the receiver block diagram which helps to receive the input signal from the transmitter. It consists of decoder, RF receiver, water pump, motor driver. The main function of the decoder is to convert the serial input to parallel output. This output is sent to microcontroller as parallel input. According to given input the motor driver and water pump works. This entire control is done manually. The transmitter and receiver come under the Transmission remote control. Here, ESP 32 module is used to capture the live activity and send images to the nearest fire station.

### 3.2 Workflow of The Algorithm in Fire Fighting Robot

The algorithm used in proposed Fire Fighting Robot is discussed in this section and presented in Figure 4.

1. **STEP 1:** Start
2. **STEP 2:** Flame sensor in the robot detects fire and this sensor acts as the main source in detecting the fire.
3. **STEP 3:** The input and output pins are setup.
4. **STEP 4:** If the fire is detected the input from the flame sensor, microcontroller starts sending parallel input to the ESP module which helps in recording the intense of the fire.
5. **STEP 5:** Motor starts moving near the fire and stops.
6. **STEP 6:** Microcontroller attached to the robot gives input to the camera which is inbuilt in ESP32 module starts recording the intense of the fire.
7. **STEP 7:** The captured image is sent to the respective mail id (nearest fire station common mail). No need of extra camera module, as ESP 32 itself has inbuilt camera and the remote accessing of robot makes this robot more advanced.
8. **STEP 8:** The fire extinguish is done manually using Transmission remote control. It consists of AT89C51 microcontroller, push buttons for the water pump, encoder, buttons (back, forward, right, left), capacitors and resistors. This circuit helps to transmit signal. The transmitter is controlled manually.
4. Result and Discussions

The hardware setup which consists of ESP 32 module, flame sensor, camera and servomotor is shown in Figure 5. Once the fire is detected by the flame sensor, the controller executes the process. Servomotor starts extinguishing the water in all 360 degrees. The camera captures the live activity and sends a notification alarm to the desired mobile number or through mail. The original model consists of four wheels and driver motor which allows the robot to move to the accurate angle.

![Flow chart of the workflow of a firefighting robot.](image)

**Figure 4.** Flow chart of the workflow of a firefighting robot.

The operation of the developed prototype model of proposed fire fighter robot is explained in Figure 6, 7, 8 and 9. In Figure 6, transmitter remote is shown. In Figure 7, the location where the fire occurred, and the live picture of that location captured by ESP 32 camera is shown. Figure 8 and 9 shows the complete firefighting robot setup.

![Hardware Connection Setup.](image)

**Figure 5.** Hardware Connection Setup.
5. Conclusion and Future Work

Fire accidents are increasing day by day because of human error, electronic and electrical systems failure, or mechanical problems. Therefore, humans undergo material and personal losses. At same time, fire brigade men also cannot be at risk all time because some property might have explosive or cylinders may get exploded. To avoid the above limitation, the proposed robot with intelligent computing capability is developed. The robot shall be accessed remotely so that fire service personnel face minimal risk in case of any mishappenings. The proposed system identifies the fire accident place, quenches wherever the fire. Further, the system continuously monitors, and alert messages and images will also be sent to the authorities so that necessary actions can be taken. At the same time, the fire accident is automatically detected and extinguished and the live recording sent to the nearest fire station helps to equip themselves. Notifying the exact location of fire happening to the fire station helps the personnel to arrive to the location as soon as possible.

As the technologies are advancing rapidly, the proposed work can be developed as a product with more precision and accuracy using artificial intelligence techniques and long distance / high sensitivity range modules. The future work includes implementing carbon-dioxide gas cylinders, high resolution camera and increasing the range of remote accessing through phone for improved accuracy.
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