Section A -Research paper

REFES - Robot Engineering Based Fire Evacuation System

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Abstract
This paper presents a comprehensive review of research papers focused on fire evacuation and rescue robots. The objective of this project report is to gather valuable information and insights from related studies to enhance the development of a system for rescuing individuals in hazardous fire situations. The proposed robot aims to safely evacuate people from fire-confined areas and transport them to a secure location. The project involves path-planning techniques to determine the shortest route from the trapped individual's position to the nearest exit or a designated safe spot. With advancements in mechanical technology, robots are increasingly replacing human intervention and serving various purposes for the well-being of individuals. In emergency scenarios, firefighters can utilize firefighting robots in addition to their own efforts. These robots should possess the capability to search designated areas, locate the source of the fire, and extinguish it effectively. To achieve these objectives, an appropriately designed controller is crucial for the robot's successful completion of tasks. The work done & presented in this paper is the result of the final year one year project work that has been done by the final year engineering students of the college and as such there is little novelty in it and the references are being taken from various sources from the internet, the paper is being written by the students to test their writing skills in the final stages of their engineering career and also to test the presentation skills during their final year project presentation and the work done & presented in this paper is the report of the undergraduate project work done by the students. The work done & presented in this paper is the result of the final year one year project work that has been done by the final year engineering students of the college and as such there is little novelty in it and the references are being taken from various sources from the internet, the paper is being written by the students to test their writing skills in the final stages of their engineering career and also to test the presentation skills during their final year project presentation and the work done & presented in this paper is the report of the undergraduate project work done by the students.

Keywords Robot, IoT, Mechanical, Rescue, Fire.

1. Introduction

Video-based fire detection relies on intelligent video processing techniques. Path generation algorithms can incorporate multi-sensor fusion technology to handle static obstacles. Emerging bionic intelligent algorithms such as particle swarm optimization, ant colony optimization, and immune algorithms show promise in this domain [1]. Despite various challenges, the adoption of intelligent firefighting robots has been limited. Rapid urbanization has led to the construction of basement buildings and petrochemical facilities, putting firefighters' lives at risk in some firefighting operations [2]. Robots, equipped with ultrasonic and compass sensors, are employed for high-risk tasks like firefighting. Algorithms play a crucial role in locating and extinguishing flames [3]. A wireless sensor positioning system, integrating real-time fire alarms, disaster relief notifications, and building databases, has been developed. Path optimization analysis provides firefighters with suitable rescue routes [4]. Innovative methods for extinguishing fires in industries and workplaces involving hazardous substances are being explored. One such method under study is the use of flying drones, which are expected to

have high demand due to their effectiveness [5]. The ALPHA I (Fire Fighting Robot) was designed by Anand Mohan Misra (2008) and employs an RF module to detect and extinguish fires remotely. A fire alarm and monitoring system designed by S. Bhosale uses GSM for data upload but lacks a control system. Swati Deshmukh et al. have developed a wireless firefighting robot capable of fire recognition and extinguishing [6-7]. A proposed robot designed for fire detection and extinguishing can operate autonomously in small and narrow spaces that are difficult for humans to access [8]. In 2016, Bangladesh witnessed 16,858 fire incidents, resulting in 152 deaths and significant financial losses. A fire-detection robot has been developed for our project, incorporating flame sensors and water-pumping capabilities [9]. Surveillance plays a critical role in minimizing the impact of disasters and timely response. Blob-level flame detection methods outperform pixel-level or patch-level approaches. Convolutional neural networks have been studied for early-stage flame detection in CCTV surveillance videos [10]. Building fires pose a significant threat to safety. This paper presents a long-distance transmission mode of fire information within buildings using ZigBee-Wi-Fi, enabling real-time monitoring of fire-prone areas [11]. Analyses of high-rise buildings indicate lower fatality rates compared to similar low-rise buildings. Understanding building use is crucial for predicting occupant behavior and designing effective fire safety measures. Detailed investigation of individual variables is necessary to provide specific recommendations for evacuation processes [12]. The Grenfell Tower fire in London resulted in numerous casualties due to delayed evacuation. Incident commanders may lack sufficient information to assess the need for altering evacuation tactics [13]. Wireless sensor networks offer solutions for communication bandwidth, data transmission, real-time detection, and other key challenges. Sensors monitoring humidity, temperature, and visibility provide valuable weather reports, aiding in timely rescues of buried and injured individuals [14].Artificial Intelligence (AI) is used to generate intelligent behaviors primarily in computer games. Pathfinding is a technique used to find the shortest path between two locations for a computer-controlled player. Dijkstra's algorithm has been the foundation on which various pathfinding algorithms have been developed [15].

2. Literature Reviews / Surveys

Numerous researchers have conducted extensive work in the chosen field, and this paper provides a comprehensive review of the existing studies. One approach combines an RGB camera and an infrared thermal imager to detect the source of fire. The infrared thermal camera is used for initial temperature assessment, while the RGB camera analyzes the color characteristics of high-temperature objects in the image, thereby improving the accuracy of identification. The improved ACO algorithm is analyzed using MATLAB and ROS [1]. The control board utilizes STM32, and remote-control handles enable firefighters to operate the robot from a safe distance, reducing their risk of entering the fire scene. A Wi-Fi camera monitors the scene and collects data. The sprinkler system automatically expands, rotates, and extinguishes fires over a wide area while occupying minimal space and maintaining high stability. A protective cover safeguards the equipment from damage, and a camera mounted on the pan tilt enables 360° rotation for complete fire environment observation [2]. The robot is equipped with ultrasonic, flame, thermal array, micro switch, and compass sensors for navigation and maneuvering in specific areas. Sound activation circuitry, including a DTMF transmitter and receiver, is incorporated for robot activation. A flame detector and thermal array sensor are used to detect and locate flames. The robot consists of two servo motors for each wheel, and two DC motors power fans to extinguish the flame [3]. Floor nodes in a building can include smoke detectors, magnetic sensors, and Bluetooth sensors to identify ignition points, trapped occupants, and firefighters. The fire rescue path-planning algorithm is developed using C# programming language in Microsoft Visual Studio. Notable algorithms such as Dijkstra's algorithm, Bellman-Ford algorithm, and A* algorithm are employed for solving the shortest path problem [11]. Metaheuristic pathfinding algorithms like genetic algorithm (GA) and particle swarm optimization (PSO) algorithm are frequently used in optimal path planning [4]. The firefighting robot incorporates smoke, fire, and temperature sensors for flame detection. The system consists of a transmitter and receiver with two sets of RF modules. One RF module transmits data to the motor driver, while the other provides real-time fire condition information [12]. The entire firefighting robot system is operated by a PIC16F887 microcontroller. L298 and ULN2003 drivers control the motors. A wireless camera mounted on the robot enables remote operator control. An alarm sounds if the fire temperature exceeds 40 degrees Celsius, allowing the operator to control the firefighting robot and prevent heat damage [6].

3. Picture Analysis

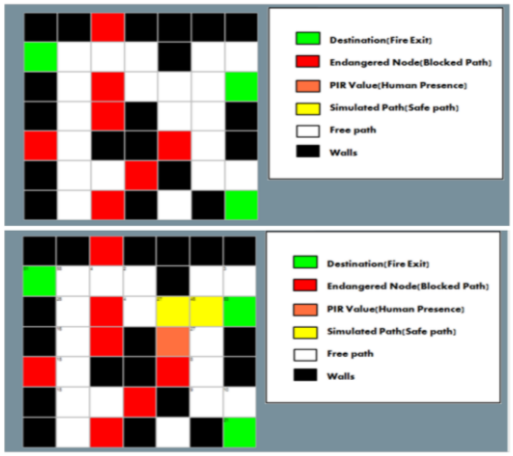

Fig. 1 : Detecting Optimal path using Floor Plan

4. Coding Technology

The Coding Technology used are Python, Arduino. The Python code is used to Find optimal path using Dijkstra Algorithm whereas Arduino code is used to move the Robot and detect the fire inside building as shown in the Fig. 4 [13].

- Implementation of Dijkstra's algorithm
- Dijkstra's algorithm is a well-known greedy algorithm.
- It is specifically designed to solve the single source shortest path problem.
- The algorithm calculates the shortest path from a source node to all other nodes in the graph.
- Dijkstra's algorithm is applicable only to connected graphs.
- Dijkstra's algorithm is effective only for graphs without any negative-weight edges.
- The original Dijkstra's algorithm does not provide the actual shortest paths.
- Instead, it outputs the cost or value of the shortest paths.
- By making slight adjustments to the original algorithm, obtaining the actual shortest paths becomes feasible.
- Dijkstra's algorithm is suitable for both directed and undirected graphs.
- Simulation of optimal path using Dijkstra's algorithm.

Fig. 2 : Before Simulation Result

Fig. 3 : After Simulation Result

The total matrix consists of 570 buttons in each row it has 30 buttons and each column it as 90 buttons. As Blue denotes source, green denotes destination and black buttons denotes walls or obstacles. For input first reset the matrix and specify source, destination and constructed the required wall and click on start button and observe the optimal path between source and destination over a wall and obstacles as shown in the Fig. 5 [14].

5. Flow Chart

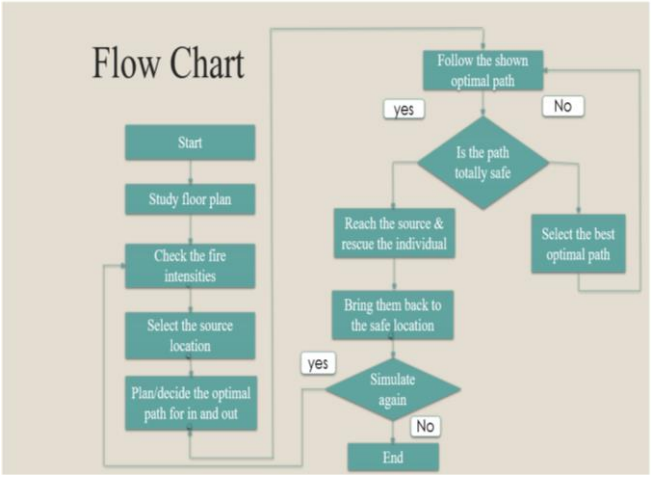

Fig. 4 : Development of the flow-chart

The system is demonstrated through a software-based simulation utilizing a floor plan that has been specifically designed for practical implementation. The designed floor plan includes rooms, walls, free paths, and fire exits, which are represented as a graph using a grid system. Each grid represents a node, and each node is assigned a cost generated by the cost function. In this context, the node where human presence is detected serves as the source, while the fire exits serve as the goals. The objective is to determine the shortest safe path from the source to the fire exit, thus necessitating the use of Dijkstra's algorithm. Whenever a node in danger is identified, the algorithm guides the path towards the shortest safe route to the exit. Additionally, the algorithm is designed to optimize crowd movement. If a path becomes congested, the algorithm redirects towards an alternative safe path to the exit. Users have the flexibility to use customized floor plans for simulation based on their specific requirements. Before connecting to the hardware, the floor plan needs to be selected. Figure 1 illustrates the grid view of a floor in the software, as depicted in Fig. 6 [15].

6. Proposed Methodology

The methodology can be divided into parts where first the physical / mechanical structure is considered to help evacuate a human. The hardware part where the robot is atomized to perform certain tasks when certain parts or buttons are triggered. In the third part the robot is programmed to follow the location according to the path fed by the algorithm as shown in the Fig. 7 [16].

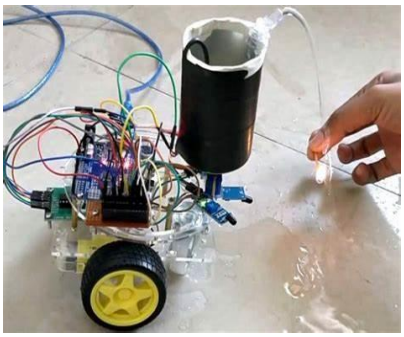

Fig. 5 : Prototype of the robot developed

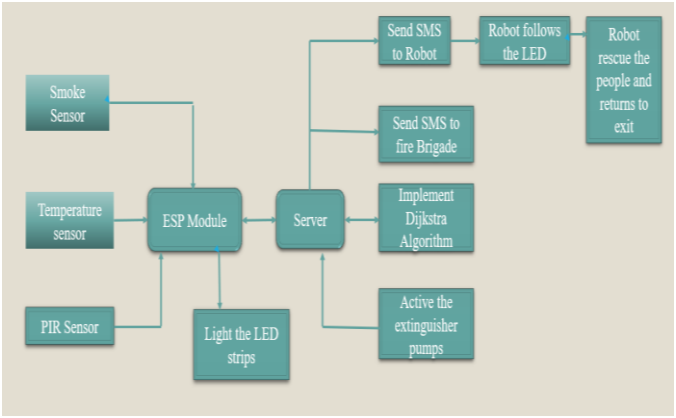

Fig. 6 : Overall block-diagram of the process - 1

7. Block Diagram-1 shows information Optimal Path

Arduino Mega: The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital The microcontroller board features various input/output pins, with 15 of them capable of being utilized as PWM outputs. It also includes 16 analog inputs, 4 UARTs for hardware serial ports, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

The Passive Infrared Sensor (PIR) is employed for detecting infrared radiation emitted by objects with temperatures above absolute zero within its field of view. This sensor is commonly used for human motion detection.

The Smoke Sensor (MQ-2) is designed to detect smoke as well as flammable gases like LPG, Methane, and Hydrogen.

The Heat Sensor (LM35) is a precision integrated-circuit device that provides an output voltage proportional to the temperature in degrees Celsius.

The ESP Module 8266 is a Wi-Fi module that can serve as an application host or handle all Wi-Fi networking functions for another application processor.

LED Lights are semiconductor devices that convert electricity into light, serving various purposes.

The 5V Buzzer is an audio signaling device commonly used as an alarm for detecting fire hazards.

The methodology can be divided into parts where first the physical/mechanical structure is considered to help evacuate a human. The hardware part where the robot is atomized to perform certain tasks when certain parts or buttons are triggered. In the third part the robot is programmed to follow the location according to the path fed by the algorithm. This optimal path is sent to the firefighters and the robot. According to the optimal path of the server, the LED lights will turn on and the robot will follow the LED and sprinkles the water on the fire and bring the person back from the fire accident as shown in the Fig. 8 [17].

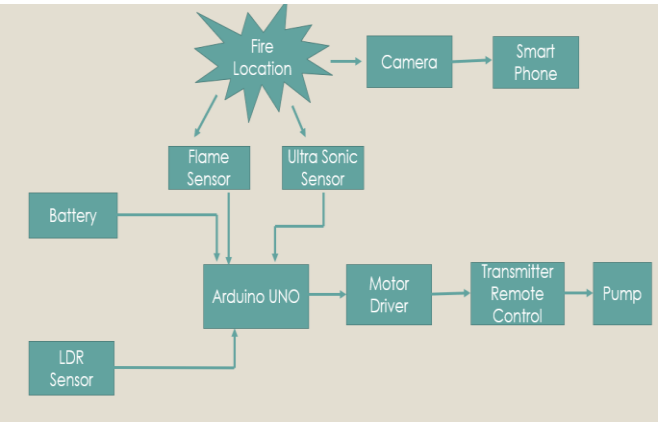

Fig. 7 : Overall block-diagram of the process - 1

8. Block Diagram-2 shows the information about the robot

The Flame Sensor is an integral component in firefighting robots as it serves as their "eyes" to detect fire sources. It operates by identifying fire based on the wavelength of light within the range of 760 nm to 1100 nm. It has a detection angle of approximately 60 degrees and a distance range of 20 cm (4.8V) to 100 cm (1V) [18].

For barrier and obstacle avoidance in autonomous target detection robots, the Ultrasonic Sensor plays a critical role. It meets the requirements of being compact, cost-effective, easy to produce, and suitable for large-scale applications. The HCSR04 ultrasonic sensor is used in this project to measure distances ranging from 2 cm to 400 cm, with an angle of 15 degrees. It emits waves into the air and detects the reflected waves from objects. It features four output pins: reference voltage (VCC) operating around 5V, ground pin (GND), digital output (DO), and analog output (AO) [19].

The DC Geared Motor with Rubber Wheel is selected as a suitable material for this project. It is compatible with 2WD and 4WD car chassis replacements. The working voltage for the DC motor ranges from 5V to 10V DC, with a gear ratio of 48:1. The appropriate current for this motor is 73.2 mA. It is used to propel the robot towards the fire location [20].

The Water Pump is a crucial component responsible for pumping water or soap to extinguish fires, depending on the fire class. A small-sized and lightweight water pump with low noise, high efficiency, and minimal power consumption is chosen for this project. The optimal voltage for the water pump is 6V, with a working voltage range of 4V to 12V and a working current of 0.8A [21].

A wireless remote-control transmitter and receiver with four control modes (S4C-AC110) are utilized in this study. The remote operates at AC 100-120V, while the relay's working voltage range is AC 110-240V or DC 0-28V. The transmitter model is C-4, and the remote control has a range of 100m or 300ft. The transmitter is powered by 12V, and the transmitting frequency is 315 MHz / 433 MHz. Using this remote control system, the robot can be operated from a safe distance while entering a hazardous fire area [22].

The Light-Dependent Resistor (LDR) is a component with a variable resistance that changes according to the intensity of light falling upon it. The 18650 battery is a rechargeable lithium battery model with a voltage of 3.7 volts [23].

9. Conclusions

The expected outcome of this project would be to get the shortest path to the escapee and launch the robot to the location which has detected life and bring back the person back to safety. through the path planning process an optimal path is designed by referring the floor plan of the building on fire. Then the same data is fed to the robot to follow and bring the rescue back to a safe location in less time-frame. The objective is to determine the shortest path from the source node to the destination node, taking into account the presence of walls and obstacles. This task is accomplished by employing Dijkstra's algorithm, as illustrated in the above figure, which depicts the resulting outcomes.

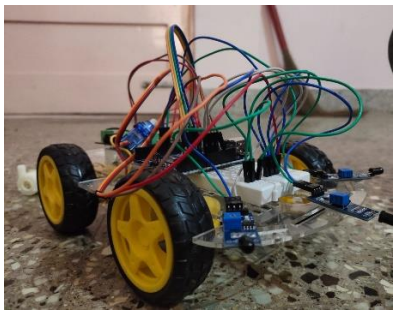

Fig. 8 : Fabricated robot

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