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Research Article

Arduino Based Fire Extinguisher Vehicle Design and Application

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Abstract – In this study, a low-cost and autonomous fire extinguishing vehicle is proposed. Thanks to this vehicle, there will be no need for direct human intervention in the fire, thus increasing life safety. The information received from the flame sensor block is read by the analog input of the Arduino card. The Arduino card moves the vehicle to the flame position by controlling the wheels and motor driver circuits. When the flame point is reached, the water pump is started, the water spray tip is moved angularly by the servo motor, allowing the water to spread over the area. The extinguishing process continues until the flame is not detected, then it stops. The tests of the proposed system were carried out in a laboratory environment. It was observed that the tasks of flame detection, going to the location of the flame and extinguishing the fire were completed successfully. It is seen that the proposed system will be usable in the fields after some improvements are made (flame sensors with greater detection distance, etc.).

Keywords – Arduino, Fire Extinguisher, Remote Control, DC Motor, Flame Sensor.

I. INTRODUCTION

In recent years, technological advances in embedded systems have enabled the creation of highly efficient and cost-effective solutions for various applications. Platforms such as Arduino and Raspberry Pi have become widely used due to their flexibility, affordability, and ease of use. The versatility of these platforms has led to their use in numerous applications, including robotics [1], home automation [2], environmental monitoring [3] and more. For example, Arduino and Raspberry Pi have been successfully implemented in temperature and humidity monitoring systems, various types of automated machines and more sophisticated projects [4,5].

Arduino, an open-source microcontroller platform, is known for its simplicity in both hardware and software. It is ideal for beginners and professionals alike, making it a popular choice for a wide range of projects, from basic hobby experiments to more complex industrial applications. The platform offers a variety of models, including the Arduino Uno, Mega and Nano, each suitable for various levels of processing power and input/output needs [6].

Firefighting robots and autonomous vehicles have the potential to save lives and reduce property damage by reaching hazardous areas that can be too dangerous for human responders. The use of Arduino allows real-time sensor integration, control and automation of the vehicle's movements and extinguishing mechanisms [7]. This work explores the combination of fire detection, motion control and extinguishing system integration, aiming to improve the safety and efficiency of fire emergency responses.

The increasing frequency of fire-related incidents, particularly in urban and industrial environments, has necessitated the development of innovative fire detection and extinguishing systems. Among the emerging technologies, Arduino-based systems have shown significant promise in automating fire safety mechanisms.

Several studies have demonstrated the capabilities of Arduino in fire detection and extinguishing systems. For instance, a robotic platform utilizing an Arduino UNO board was developed to autonomously detect and extinguish fires, showcasing the system's ability to operate in hazardous environments [8]. Another study described a fire detection and control system that employs Arduino with integrated sensors to extinguish fires effectively in vehicles, emphasizing its adaptability for automotive safety [9]. The integration of IoT technologies with Arduino has also been explored, leading to the development of systems capable of detecting fires and transmitting warnings in real-time. Imteaj et al. [10] presented an IoT-based fire alarming system utilizing Raspberry Pi, which could be adapted for Arduino applications. This suggests a potential pathway for enhancing the situational awareness of fire safety systems through connectivity and remote monitoring. The literature highlights various robotic implementations designed to reduce the risks faced by human firefighters. Cheong et al. [11] and Sowah et al. [12] both described remote-controlled fire-fighting robots designed to operate in hazardous environments, further supported by fuzzy logic control systems to optimize response actions. Such developments illustrate the potential of Arduino-based platforms in creating semi-autonomous systems that can be controlled remotely, thereby enhancing firefighter safety through reduced exposure to danger. In addition, semi-autonomous UAVs equipped with fire extinguishing capabilities have been proposed. Zhang et al. [13] reviewed UAV applications in fire detection and monitoring, indicating a growing interest in aerial solutions that can complement ground-based firefighting efforts. Innovative approaches have also been explored, such as the use of fire-extinguishing microcapsules embedded within lithium-ion batteries. Although this study by Yim et al. [14] does not focus on Arduino systems, it highlights the potential for integrating advanced materials into fire safety technologies. This suggests a future direction where materials science and Arduino-based technologies could converge to create smarter, more effective fire extinguishing devices. Moreover, Taryudi et al. [15] introduced an IoT-based integrated home security and monitoring system, which could be adapted to monitor fire safety conditions in residential settings. The potential for Arduino-based fire systems to integrate with existing home automation technologies presents another avenue for enhancing public safety.

Despite the advancements in Arduino-based fire extinguisher vehicles, several knowledge gaps persist. Most studies focus on theoretical applications or small-scale implementations, lacking extensive field testing and validation in real-world scenarios. Moreover, the scalability of these systems for larger environments, such as industrial sites or urban areas, remains underexplored.

The paper is organized as follows. In Section 2, fire extinguisher vehicle system and its components are explained. Experimental results are presented in Section 3. Finally, conclusion is given in Section 4.

II. MATERIALS AND METHOD

The block diagram of the proposed fire extinguisher system is presented in Fig 1. The system includes one flame sensor block, one water pump, one water pump driver, one servomotor-controlled nozzle, four DC motors and driver circuits for the wheels, two RF module, one remote control module with Arduino Uno board, and an Arduino Mega board that controls the entire system.

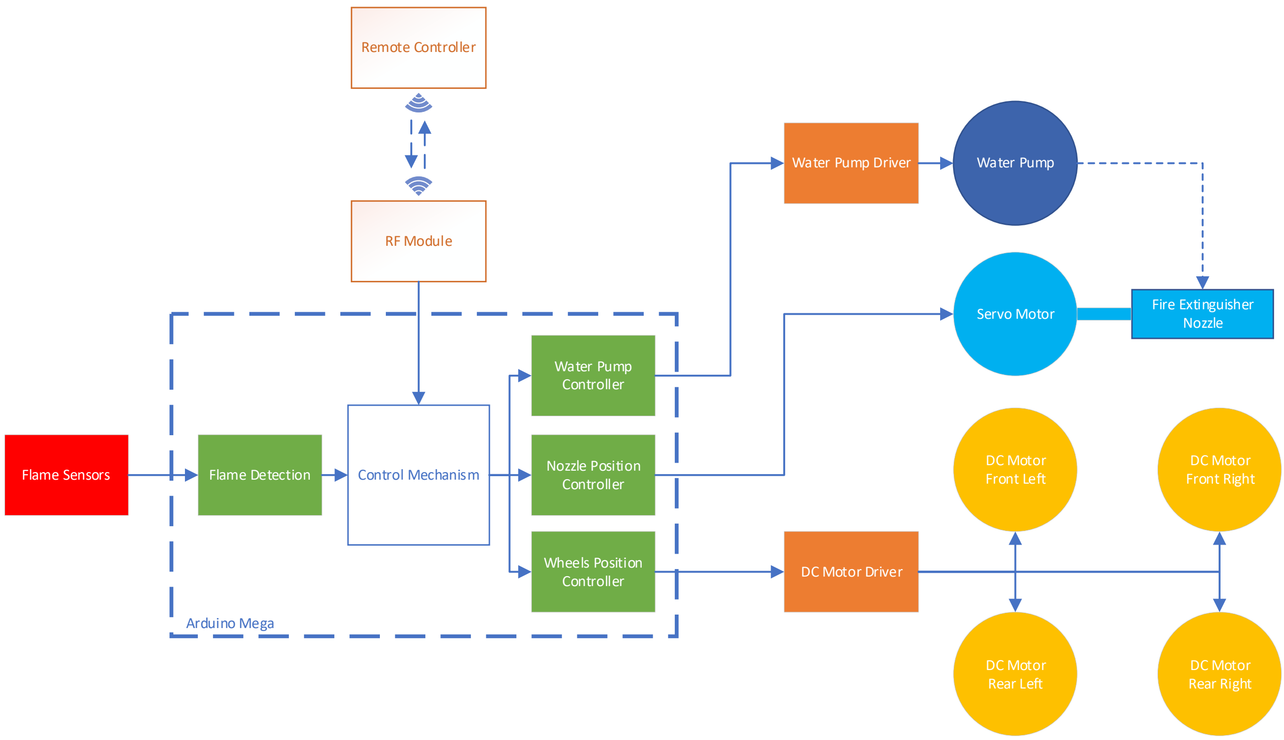

Fig. 1 Block diagram of the system.

Detailed descriptions of all components of the proposed fire extinguishing system are given in the following order:

Arduino MEGA board: The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 chip. It serves as an extended version of the popular Arduino Uno board, offering additional features and expanded capabilities. The Mega 2560 is designed for larger projects that require more input/output pins, increased memory, and additional serial communication options. Here are the main specifications:

- The board operates at 5V and features 54 digital I/O pins, of which 15 can be used as PWM outputs. It also provides 16 analog input pins and 4 UARTs (hardware serial ports). The clock speed is 16 MHz, and it includes a USB connection, a power jack, and an ICSP header. Like the Uno, it is compatible with shields designed for previous Arduino boards.

The Arduino Mega 2560 is commonly used in robotics, automation, and other applications. It is shown in Fig 2.

Fig. 2 Arduino Mega 2560.

Flame sensor block: A flame sensor for Arduino is a device capable of detecting and measuring infrared light emitted from flames. It is commonly used to detect fire. This sensor is also known as an infrared flame sensor or fire sensor. The flame sensor provides two types of outputs:

- Digital Output (LOW/HIGH): The digital output pin is LOW when the flame is detected and HIGH when no flame is present. You can adjust the threshold value for flame detection using a built-in potentiometer.
- Analog Output: The analog output pin provides an analog signal that decreases as the infrared level decreases (i.e., as the flame intensity decreases) and increases as the infrared level increases.

The infrared flame sensor is designed to be selective in detecting specific wavelengths of infrared radiation associated with flames.

The flame sensor block is high accuracy flame detector module. It is used for detecting direct fire (as it detects fire radiation). The module uses five flame sensors. It can output both analog and digital signals. The sensitivity of the sensor can be adjusted using the on-board potentiometer. The sensor has a wide detection angle (more than 120 degree) and five LED indicators (one for each sensor). It is shown in Fig 3 and the specifications of the sensor are given in Table 1.

Fig. 3 Flame sensor block.

Table 1. Specifications of flame sensor block.

Input Voltage	3.3V~9V
Detection Range	~ 1.5 meter
Detecting Angle	>120 degree
Wavelength Detection Range	700:1100

DC motors: The DC BO motor 12V dual shaft is a geared DC motor designed for use in smart car and robot projects, especially those based on Arduino. The motor operates within a voltage range of 3V to 12V DC. It has a reduction ratio of 1:48, meaning the output shaft rotates 48 times slower than the input shaft. The motor comes with dual plastic shafts, making it suitable for attaching wheels or other components. The no-load speed of the motor varies based on the voltage: At 3V, the no-load speed is approximately 90 RPM. At 6V, the no-load speed is approximately 200 RPM. The motor draws a current of around 40mA to 180mA (no-load). The rated torque is approximately 0.35 kg-cm. This motor is commonly used in small robotic car chassis, line-following robots, and other Arduino-based projects. Its lightweight design, dual shafts, and compatibility with various wheels make it ideal for creating mobile robot cars. It is presented in Fig 4.

Fig. 4 DC BO motor.

Water pump: Water pumps for Arduino projects are commonly used in applications such as automatic plant watering systems. These pumps operate at the same voltage as Arduino boards, simplifying the electrical design. These pumps are affordable, and specifications are given in Table 2. It is also shown in Fig 5.

Table 2. Specifications of water pump.

Voltage	3-5 V
Operating current	100-200 mA
Maximum lift height	40-110 cm
Flow rate	80-120 L/hour

Fig. 5 Water pump.

L298N Motor Driver: The L298N Motor Driver is a versatile module commonly used with Arduino to control DC motors and stepper motors. The L298N can control the speed and spinning direction of two DC motors.

- It achieves this by combining two techniques: PWM (Pulse Width Modulation): Adjusts the average input voltage by sending a series of ON-OFF pulses. The duty cycle (width of pulses) determines the motor speed.
- H-Bridge Configuration: An H-bridge circuit, consisting of four switches arranged in an “H” shape, allows reversing the polarity of the voltage applied to the motor. This changes the motor’s spinning direction.

L298N motor driver module is presented in Fig 6 and its technical specifications are listed in Table 3.

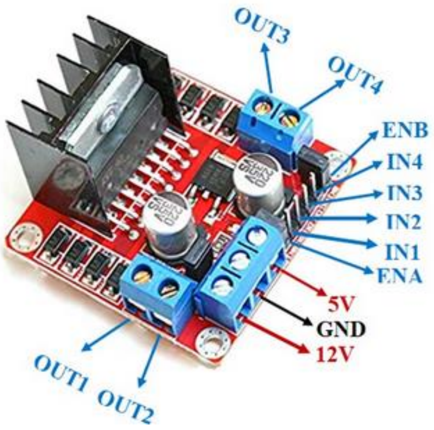

Fig. 6 L298N motor driver module pinout.

Table 3. Specifications of water pump.

Motor output voltage	5V to 35V
Recommended motor output voltage	5V to 7V
Logic input voltage	5V to 7V
Continuous current per channel	2A
Max power dissipation	25W

Servo motor: The SG90 Micro Servo Motor 9G is a compact and lightweight servo motor commonly used in various radio-controlled applications. Operating within a voltage range of 3V to 6V DC, this motor features a reduction ratio of 1:48, meaning the output shaft rotates 48 times slower than the input shaft. It comes with a dual plastic shaft, making it easy to attach wheels or other components. The no-load speed varies based on voltage, with approximately 90 RPM at 3V and 200 RPM at 6V. With low energy consumption and compatibility with microcontrollers like Arduino and Raspberry Pi, the SG90 servo motor is ideal for embedded systems, hobby projects, and small-scale robotics. It is presented in Fig 7.

Fig. 7 SG90 micro servo motor.

RF module (nRF24L01): The nRF24L01 is a widely used wireless transceiver module in Arduino projects. It operates in the 2.4 GHz worldwide ISM frequency band and employs Gaussian Frequency Shift Keying (GFSK) modulation for data transmission. The module's data transfer rate is configurable, allowing you to choose between 250 kbps, 1 Mbps, or 2 Mbps.

Key specifications include an operating voltage of 3.3V, nominal current of 50 mA, and maximum operating current of 250 mA. Communication with the module is via the SPI protocol. The range typically spans 50 to 200 feet, depending on external factors. In terms of cost, the nRF24L01+ is affordable (around $2). Some versions come with an external antenna for extended range or a built-in antenna for shorter distances.

Applications for the nRF24L01+ include wireless control in hobby projects, robotics, and industrial systems. It can be interfaced with any microcontroller (MCU), making it versatile. To use it with Arduino, you will need two nRF24L01+ modules and two Arduino boards. It is shown in Fig 8.

Fig. 8 RF module (nRF24L01).

Remote controller shield: Joystick shield expansion board is an accessory designed for Arduino boards. When placed on top of an Arduino Uno or compatible board, it transforms it into a simple game console or robotic controller. The shield features a two-axis thumb joystick (X and Y axes) and seven momentary push buttons. The buttons include four large buttons (typically used for up/down/left/right functions), two smaller buttons (for less common functions like 'select' or 'start'), and a joystick select button. All buttons have pull-up resistors and pull to ground when pressed. nRF24L01 connector allows you to plug in an nRF24L01 RF transceiver module. (see Fig 9). This expansion board offers a neat user interface suitable for gaming and menu navigation. Its onboard headers for display and radio modules simplify communication and readout tasks.

Fig. 9 Remote controller shield.

III. EXPERIMENTAL RESULTS

The experimental setup of the system is demonstrated in Fig 10. The experimental setup consists of 1 Arduino Mega 2560 board, 4 12V DC motors, 2 L298N motor driver circuits, 1 Li-Po battery block, 2 9V batteries, 1 flame sensor block, 1 water pump, 1 water tank, 1 nozzle, 1 water hose, 1 micro servo motor, 2 RF modules, 1 Arduino Uno, 1 remote controller shield, 4 wheels, connection cables and plexiglass chassis.

Results should be clear and concise. The most important features and trends in the results should be described but should not interpreted in detail.

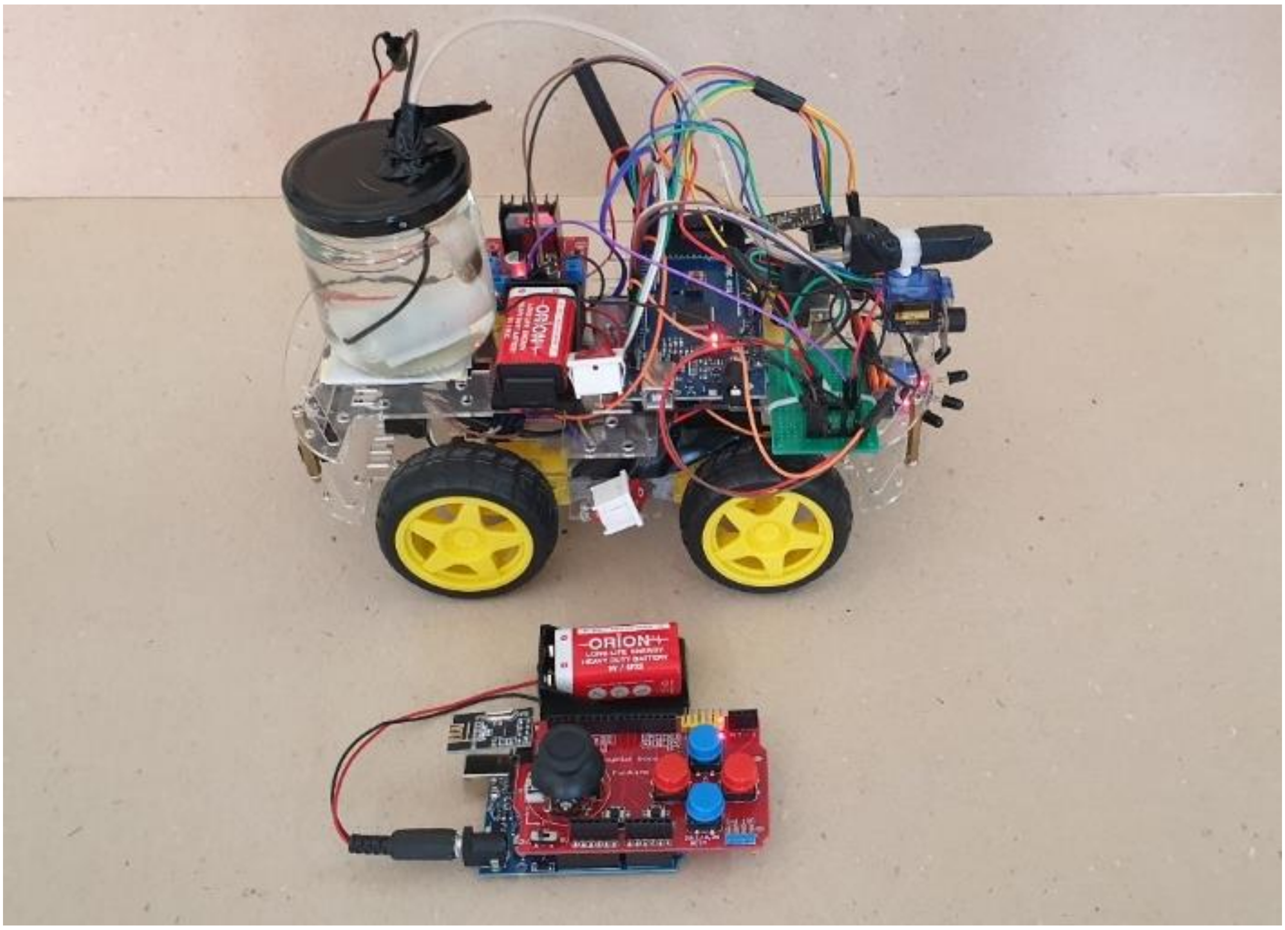

Fig. 10 The experimental setup.

In remote operation mode, data communication is provided between the vehicle and the remote control by means of two RF modules, one on the vehicle and one on the remote control. In this mode, the vehicle stops flame detection, movement and water spraying operations from being automatic. The vehicle can be moved in the desired direction with the 4-position joystick on the remote control. In addition, water spraying and servo motor-based angular movement mechanism can be operated with the buttons on the remote control.

An algorithm has been prepared for autonomous operation. The flow chart of this algorithm is presented in Fig 11. In autonomous operation mode, the system initially scans the environment for flames via flame sensors. Scanning continues until a flame is detected. When a flame is detected, the motion control mechanism is activated, the vehicle wheels are activated and the vehicle is taken to the flame position. When the flame point is reached, the vehicle stops and the water spray system is activated. Thanks to the servo motor controlling the spray system, the nozzle part is moved angularly, and the water is spread over the flame. This process continues until no flame is detected by the flame sensors. When no flame is detected, the water spray and servo motor mechanism are stopped.

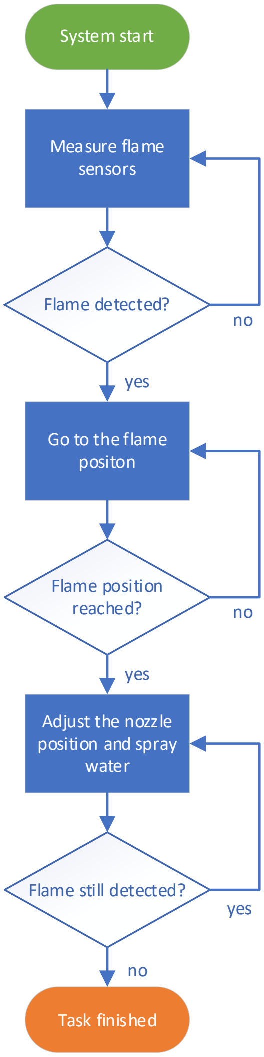

Fig. 11 Flow chart of the system.

Fig 12 shows the results of the system's test conducted in a laboratory environment. The vehicle autonomously reached the flame location detected by the flame sensors. It extinguished the fire by spraying water and successfully completed the task.

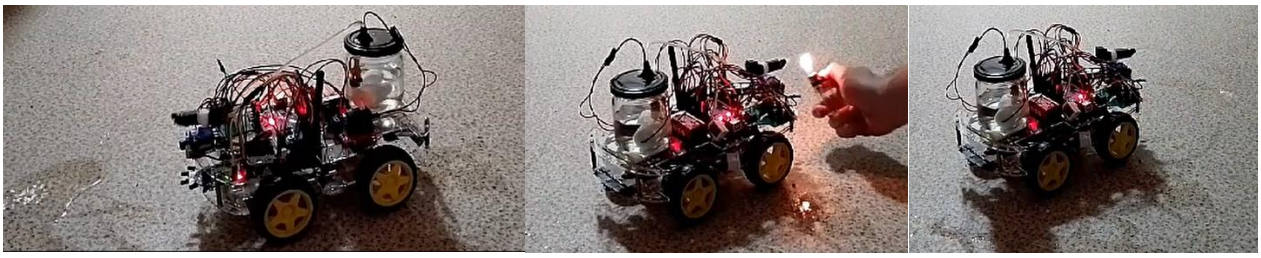

Fig. 12 Laboratory test result: Vehicle spraying water in manual mode (left), vehicle detecting flame (center), vehicle spraying water on flame (right).

IV. CONCLUSION

This study is about the design of an Arduino Mega based fire extinguisher vehicle. The vehicle is designed to operate autonomously or manually. An Arduino Uno card and remote controller shield are used for manual operation mode. In autonomous operation, the written algorithm is activated. First, the flame is detected with flame sensors. Then the vehicle wheels take the vehicle to the flame position. The water spraying process on the flame is conducted angularly by the servo motor. When the fire extinguishing process is completed, the vehicle stops until another flame is detected. The system tests were successfully conducted with the produced prototype in the laboratory environment. It is planned to be used in the fields after the developments are made on the prototype.

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