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Designing and Prototyping of an Autonomous Fire Fighting Vehicle

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Abstract

This abstract presents the conceptualization and development of an Arduino-based Autonomous Firefighting Vehicle (AFFV). The vehicle is equipped with a suite of sensors, including Flame, Ultrasonic, PIR, and Temperature/Humidity sensors, to autonomously detect and respond to fire incidents. The integration of these sensors enables the vehicle to navigate through obstacles, monitor environmental conditions, and ensure the safety of human presence during emergency situations. The Arduino Uno Rev3 serves as the central control unit, orchestrating the vehicle's actions based on inputs from the sensors. In the event of a fire, the Flame Sensor triggers the vehicle to enter firefighting mode. The Ultrasonic Sensor ensures obstacle avoidance, enabling the vehicle to navigate through complex environments. The PIR sensor detects human presence, ensuring the safety of both responders and the public. Additionally, the Temperature and Humidity Sensor continuously monitors environmental conditions, optimizing firefighting strategies based on real-time data. The vehicle operates through a decision-making algorithm that processes sensor inputs and dictates actions, allowing it to efficiently suppress flames, avoid obstacles, and adapt its behavior over time. The implementation of machine learning algorithms contributes to the vehicle's adaptive capabilities, enhancing its performance with each firefighting mission. This Arduino-based AFFV also explores optional features such as remote monitoring through IoT technologies. It enables operators to remotely control the vehicle, receive realtime sensor data, and make informed decisions during firefighting operations. The advantages of this autonomous firefighting vehicle lie in its swift response to fire incidents, safe navigation through obstacles, and real-time environmental monitoring. The proposed AFFV finds applications in diverse settings, including residential areas, industrial complexes, and public spaces, where it can augment emergency response capabilities, enhance safety, and optimize firefighting strategies.

Keywords: Arduino UNO, NodeMCU, Autonomous, Fire fighting

Introduction

Life, property, and the environment are all seriously threatened by fire accidents. There is a need for safer and more effective fire suppression techniques because traditional firefighting methods frequently expose firefighters to dangerous situations. The goal of this project is to create an automated fire engine that can independently identify, locate, and put out flames. By using such a vehicle, fire suppression effectiveness can be increased and the risks to human firefighters can be decreased.

PROBLEM DEFINITION

Fires may be extremely harmful, particularly in locations that are difficult to access or too dangerous for people to go. Firefighters now face difficulties and potential dangers while responding promptly to a fire. We require an improved approach to handle fires in a safer and more efficient manner. Hard to Reach Places: Fires can occasionally occur in areas that are challenging for people to reach, such as damaged structures or locations that contain dangerous objects. Something that can manage the fire and enter these dangerous locations is what we need. Rapid Action Required: In order to prevent a fire from spreading, quick action is required as soon as it starts. Humans require time to arrive, thus in order to extinguish the fire more rapidly, we need something that can operate autonomously. Firefighters' Safety Concerns: Firefighters put their lives in jeopardy as they respond to emergencies. People will be safer if fewer of these jobs necessitate human interaction, such as when a robot completes them. Poor Visibility and Tricky Paths: Smoke and other obstructions can occasionally make it difficult for firefighters to see and maneuver. In these circumstances, a car equipped with certain sensors can function well and not be impacted. Using Cutting-Edge Technology: While robots and smart sensors are great tools, firefighters don't use them to their full potential. Building a vehicle that can utilize these technologies can make it far more adaptable and useful in a variety of scenarios, especially with Arduino controls that are simple to build. Increasing Efficiency: It might take a lot of time and resources to battle fires using traditional methods. A car can respond to fires faster and more efficiently, which makes it a better tool for fighting fires. Our goal is to improve the safety, efficiency, and speed of firefighting in difficult circumstances by utilizing an Arduino-powered firetruck to solve these difficulties. The goal here is to come up with a cleverer and contemporary method of defending people and property against the perils of wildfires.

HARDWARE USED

A. Arduino Uno Rev3

Figure 1 illustrates the Arduino Uno, a company-produced microcontroller board that is based on the ATmega328P. Six analog inputs, fourteen digital input/output pins (six of which may be used as PWM outputs), a reset button, an ICSP header, a power connector, a USB port, and a 16 MHz quartz crystal are all included. Everything needed to support the microcontroller is included; all you have to do to get it rolling is power it with a battery or an AC to DC converter, or connect it via USB to a computer [1].

Fig.1. Arduino Uno Rev3

B. NodeMCU

The NodeMCU-Board is a low-cost, cutting-edge wireless technology as shown in figure 2. High-end, sophisticated LUA-based technology nowadays. With all of the resources at its disposal, it functions as a cohesive unit. It is very easy to integrate with any development board that has accessible I/O pins or with already-existing Arduino projects [2].

Fig.2. NodeMCU

C. PIR sensor

This sensor is able to detect motion thanks to the PIR Motion Sensor Detector Module as shown in figure 3. Within the sensor's range, it is nearly usually utilized to detect the motion of a human body. "PIR," "Pyroelectric," "Passive Infrared," and "IR Motion" sensors are frequently used to describe it [3].

Fig.3. PIR Sensor

D. Servo Motor

An actuator that rotates and provides accurate angular position control is called a servo motor as shown in figure 4. It is made comprised of a motor and a feedback system that continually checks and modifies the motor shaft's position. Servo motors can move to precise angles or precisely retain a specified position thanks to this feedback loop. Because servo motors can provide precise and regulated motion, they are frequently utilized in a wide range of applications, including robotics, automation, aircraft, and manufacturing [4].

Fig.4. Servo Motor

E. Human Detection Sensor

A device that detects moving objects, particularly people, is called a human detection sensor as shown in figure 5. A portion of a system that periodically performs an assignment or could notify a client of movement in the region is linked to a motion sensor. An essential component of energy efficiency, home automation, security, automatic light detection, and other adapting systems is built around these sensors [5].

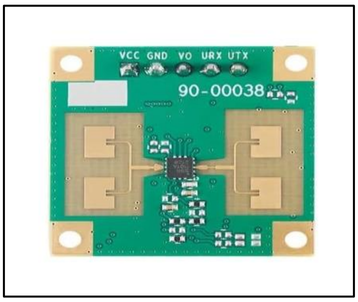

Fig.5. Human Detection Sensor

F. Flame Sensor

A kind of detector that is primarily intended for identifying and reacting to the presence of a fire or flame is a flame sensor as shown in figure 6. The fit of the flame detector may affect the reaction. It has a fire suppression system, a propane line, an alarm system, and a natural gas line [6].

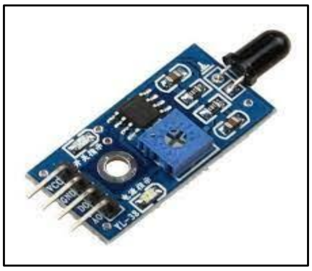

Fig.6. Flame Sensor

G. Ultrasonic Sensor

An ultrasonic sensor is a type of electronic device that uses ultrasonic sound waves to detect an object's distance and then transforms the reflected sound into an electrical signal as shown in figure 7. The speed of ultrasonic waves surpasses that of audible sound, which is sound that is perceptible to humans. The transmitter, which uses piezoelectric crystals to produce sound, and the receiver, which detects sound after it has travelled to and from the target, are the two primary parts of ultrasonic sensors [7].

Fig.7. Ultrasonic Sensor

H. Og555 Dc Motor

This OG555 12V 100RPM DC motor is primarily helpful. The motor has a 90K gear reduction and a rated torque of 173.6N-cm as shown in figure 8. This motor's primary characteristic is its 27 mm-long, 6 mm-diameter shaft. A wheel or any other kind of connection on the shaft is far too simple [8].

Fig.8. DC Motor

I. Monoblock Water Pump

A particular kind of liquid pump known as a self-priming pump is made to contain the liquid inside the cavity or pump body in order to initiate the pumping operation as shown in figure 9. In process facilities where pumps are utilized for a range of repetitive yet sporadic processes, this presents the possibility of improved operational efficiency [9].

Fig.9. Monoblock Water Pump

J. DC Motor Drive

An electrical device that regulates a DC motor's speed, direction, and torque is called a DC motor drive as shown in figure 10. It controls how the motor works, just like the brain does. In order to accomplish the intended performance, the drive essentially receives input signals—typically from a controller or user commands—and modifies the voltage and current provided to the motor appropriately [10].

Fig.10. DC Motor Drive

K. Servo Motor Drive

A servo motor drive is a device that manages the function of a servo motor as shown in figure 11. It is sometimes referred to as a servo amplifier or servo drive. It serves as the motor's brain, controlling its torque, position, and speed in response to orders sent into the device [11].

Fig.11. Servo Motor Drive

L. Temperature Sensor

Sensor for humidity and temperature Humidity: 0~100%; Temperature: 40~+80°CRH as shown in figure 12 has an upgraded MEMS semiconductor capacitive humidity sensor component, a standard on-chip temperature sensor component, and a newly built ASIC dedicated chip [12].

Fig.12. Temperature Sensor

SOFTWARE USED

The Arduino IDE is the software that the Arduino uses as shown in figure 13. The Processing programming language and the Wiring project served as the model for the development of the cross-platform Java application known as the Arduino IDE. It is intended to introduce programming to novices who are not experienced with software development, such as painters. It can compile and upload programs to the board with a single click, and it has a code editor with features like syntax highlighting, brace matching, and automatic indentation. Usually, using a command line interface to launch applications or modify build files is not necessary. Nevertheless, if necessary, construction may be done via the command line using some third-party programs like Ino. "Wiring" is a C/C++ library included with the Arduino IDE. The Arduino Integrated Development Environment is another name for the Arduino Software (IDE). It has several menus, a message box, a text terminal, a toolbar with buttons for commonly performed operations, and a text editor for writing code. It connects to the Arduino hardware in order to upload and communicate with programs. Programs made with the Arduino software are called sketches. These illustrations are kept on file with the. are made with a text editor and have no extension. In addition to cutting and copying, the editor has features for text replacement and search. The message box not only shows errors but also offers feedback when exporting and storing. The console displays more text output from the Arduino software as well as complete error notifications. In the lower right corner of the window, you can see the configured board and serial port. The toolbar buttons allow you to create, open, save, and validate applications. Additionally, drawings may be created, opened, and validated by opening the serial monitor. Automatic Formatting This beautifully arranges your code by indenting it such that the statements within curly braces are more indented and the opening and closing curly braces line up. Archive Sketch: A compressed.zip file containing a copy of the most recent sketch. The drawing and the archive are saved in the same directory. Correct Encoding and Reload addresses any differences in char map encoding between the editor and various operating systems. Monitor in Serial begins data exchange with any connected board on the presently specified Port and opens the serial monitor window. If the board allows Reset over serial port opening, this often resets the board. Board Choose the board you are utilizing.

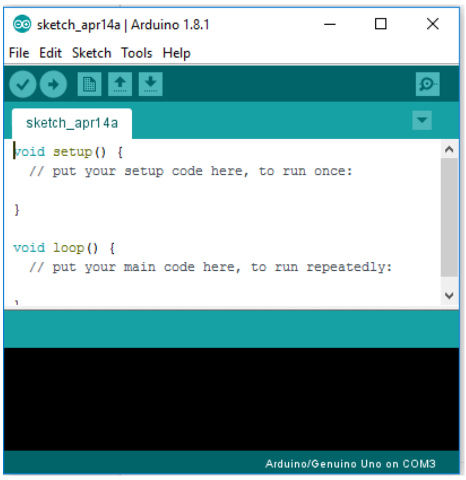

Fig. 13. Arduino IDE

DESIGNING

An autonomous firefighting vehicle has to incorporate several various components, such as sensors, actuators, controllers, and communication systems, in order for it to be able to detect, move, and extinguish fires on its own. A high-level overview of the components and design factors is provided below:

M.Sensors

Fire detection: To find out whether there are any fires, use sensors like thermal cameras or infrared (IR) cameras.

Environmental Sensors: To precisely analyze fire conditions, include temperature, humidity, and smoke sensors.

Obstacle detection: To identify and avoid obstacles, use LiDAR or ultrasonic sensors.

N. Actuators

Water Pump: To put out fires, provide a high-pressure water pump.

Water Cannon: For focused firefighting, use a controllable water cannon or nozzle.

Vehicle Control: Use steering and motor systems to move and navigate a vehicle.

O. Control System

Microcontroller or Single Board Computer: To control sensors, actuators, and algorithms for making decisions, use platforms such as Arduino, Raspberry Pi, or comparable ones. Create algorithms for fire suppression that will evaluate sensor data, pinpoint the position extent of the fire, and adjust firefighting tactics accordingly.

Navigation and Mapping: To plan routes and avoid obstacles, use navigation algorithms.

Safety protocols: Incorporate failsafe measures, including emergency stop buttons and obstacle avoidance techniques, to guarantee safe operation.

P. Communication System

Wireless Connectivity: Using Wi-Fi, Bluetooth, or comparable protocols, enable communication between the fire truck and other firefighting units or a central control center.

Data Transmission: Real-time commands, sensor data, and status updates are sent between the vehicle and control station.

Provide a dependable power source, such as a battery, so that the car and its parts can be operated for lengthy periods of time.

Charging System: Provide a means of recharging the battery while it is not in use.

Q. Features for Safety

Fire-Resistant Materials: To safeguard internal components, use fire-resistant materials while building vehicles.

Automated Shutdown: Put automated shutdown procedures in place for emergencies or system breakdowns.

Remote Control Override: If human involvement is required, provide a manual control alternative.

R. Valication and Testing

Simulation: Before deploying algorithms and control techniques, test them with software simulation tools.

Field Testing: To confirm the vehicle's functionality in actual firefighting situations, carry out extensive field testing.

METHODOLOGY

Start Application

S. Initial variables

Set up serial communication Calibrate and initialize sensors and actuators Activate stepper motor (go to 0°) Obstacle Detection

T. Read Ultrrasonic Sensor Distance

Check if any obstacle is detected within the specified range If an obstacle is detected, follow the Obstacle Handling function If no obstacle is detected, proceed to Flame Detection Flame Detection

U. Read Value from Flame Sensor

Check if any flame is detected above the threshold If a flame is detected, follow the Flame Handling function If no flame is detected, go back to Obstacle Detection Obstacle Handling Function

V. Rotate the robot away from the Obstacle

Retry to move forward If the obstacle is still present, send a command to the slave device for assistance Flame Handling Function

W. Determine the direction of the Flame

Rotate the robot to align water spray with the flame Activate the water pump and sprayer until the flame is extinguished Communication with Slave

X. Send Command to slave Device

Receive responses from the slave device End Application

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SCHEMATICS

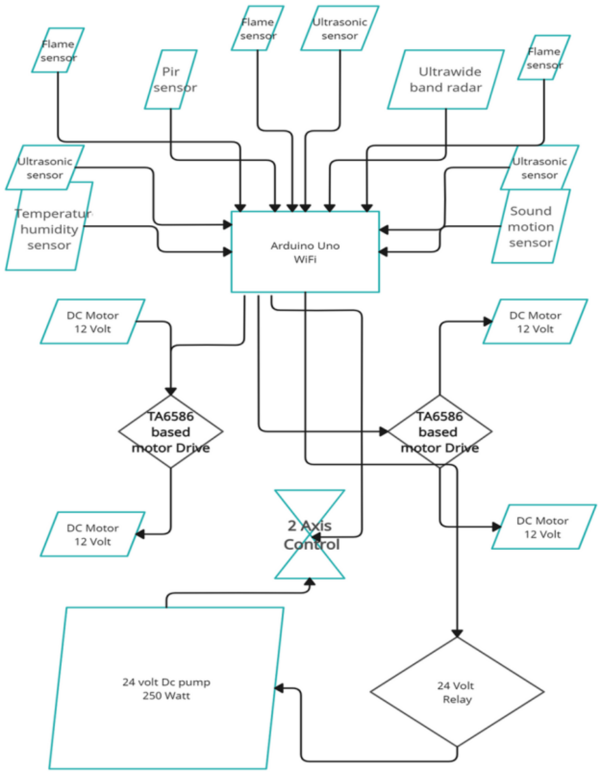

Fig.14. Schematics of Prototype

RESULT

Realtime testing shows that the vehicle can quickly and reliably identify fires and react to them within the range of 2 to 3 meters. Its efficiency in overcoming obstacles and putting out fires has been verified by field testing. Performance indicators, including suppression success rate and detection range, show that the vehicle satisfies design goals and outperforms other available solutions

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