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Advanced Fire Fighter Robot Using Image Processing

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Abstract: ***Fire accidents in industrial areas, residential buildings, laboratories, and server rooms can cause serious damage to life and property. Traditional firefighting methods often involve high risk to human firefighters, especially in hazardous environments where toxic gases, smoke, and high temperatures are present. This paper presents the design and implementation of an Advanced Fire Fighter Robot using Image Processing based on Raspberry Pi Zero 2W. The robot is designed to autonomously detect fire, move toward the flame source, and extinguish it without human intervention.***

The system uses a flame sensor module for fire detection and a Raspberry Pi Camera Module V2 integrated with OpenCV for basic visual alignment of the flame source. A 4WD smart car chassis provides mobility, while the L298N motor driver controls the DC motors for movement. A 5V DC submersible water pump is used for fire suppression. The robot continuously scans the surroundings, detects fire, aligns itself using camera feedback, moves toward the flame, and activates the water pump automatically until the fire is extinguished.

The proposed system is cost-effective, compact, self-powered, and fully standalone without requiring IoT, cloud connectivity, or external control systems. This project demonstrates an efficient embedded systems solution for small-scale autonomous fire suppression.

Keywords: Fire Fighting Robot, Raspberry Pi, OpenCV, Flame Sensor, Autonomous Robot, Embedded Systems, Fire Detection

I. INTRODUCTION

Fire hazards are one of the major threats to human life and infrastructure. In industries, laboratories, homes, and offices, early fire detection and rapid suppression are essential to prevent major losses. Traditional fire suppression systems such as sprinklers and extinguishers are either fixed in location or require human operation, which may be dangerous during emergencies.

Robotic fire-fighting systems provide a safer and more efficient solution by allowing autonomous movement toward the fire source and controlled extinguishing actions. Such robots can operate in dangerous environments where human intervention is risky or delayed. The Advanced Fire Fighter Robot proposed in this project is a self-contained autonomous system designed for indoor fire detection and suppression. The robot uses Raspberry Pi Zero 2W as the main controller, a flame sensor for primary fire detection, and a camera module with OpenCV for flame alignment. The system moves autonomously using a 4WD chassis and extinguishes fire using an onboard water pump. The project focuses on simplicity, reliability, and cost-effectiveness by avoiding unnecessary complexity such as IoT dependency, cloud computing, or advanced AI systems. It demonstrates practical implementation of embedded systems and robotics for real-world fire safety applications.

II. LITERATURE SURVEY

A. Literature survey for problem identification and specification

Several researchers have developed fire-fighting robots using flame sensors, gas sensors, and obstacle detection systems [1][2]. Traditional fire-fighting robots mainly depend on basic flame detection and manual remote control, which limits their efficiency in dangerous environments [3]. These robots are useful for reducing human risk, but their operational capability is often restricted by simple sensing mechanisms and lack of autonomous decisionmaking [4].

Some systems use ultrasonic sensors for obstacle avoidance and Arduino-based controllers for simple movement [2]. More advanced systems integrate thermal cameras and machine learning for fire classification and victim detection [5].

These intelligent systems improve fire detection accuracy and rescue efficiency, especially in smoke-filled environments. However, they often increase system complexity, maintenance requirements, and overall project cost significantly [6]. Many existing projects also rely heavily on IoT connectivity for remote monitoring and control [7]. While IoT improves remote accessibility and real-time monitoring, it may fail during emergencies due to network instability, power failure, or signal interruption. This creates reliability issues during critical rescue operations where uninterrupted performance is essential [8]. The proposed system improves practicality by focusing on autonomous operation using a Raspberry Pi-based standalone architecture [3]. The combination of flame detection and basic image processing provides accurate alignment without requiring expensive AI systems. Raspberry Pi offers sufficient processing power for real-time control, sensor integration, and camera-based monitoring while maintaining low system cost [9]. Additionally, the use of a motor driver module with obstacle detection sensors helps the robot navigate safely in indoor environments and reach the fire source efficiently [10]. The integration of a water pumping mechanism ensures immediate fire suppression after flame detection, improving response time and minimizing fire damage. This standalone architecture reduces dependency on internet-based systems and increases reliability during emergency situations [11]. This approach ensures low cost, reliability, and efficient performance for small-scale indoor fire suppression applications. It is especially suitable for industries, laboratories, offices, and residential buildings where quick autonomous response can prevent major accidents and protect human lives [12].

B. Problem Identification

Traditional firefighting operations are dangerous, time-consuming, and highly dependent on human intervention. Fixed fire suppression systems cannot move toward the exact fire source, and manual fire extinguishing exposes humans to hazardous environments.

Existing low-cost fire-fighting robots often suffer from poor flame alignment, inaccurate suppression, and limited autonomous operation.

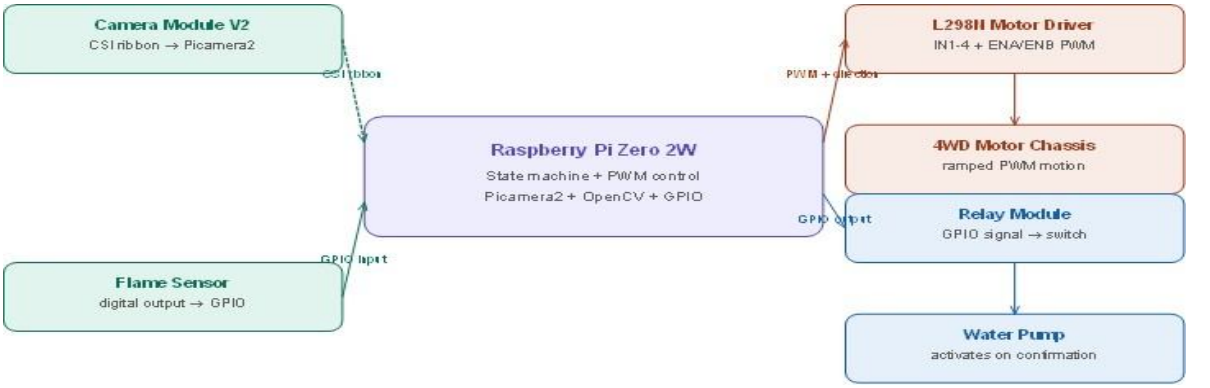
There is a need for a compact, intelligent, and self-powered robotic system capable of detecting fire accurately, aligning itself toward the flame source, moving autonomously toward the fire, activating fire suppression automatically, and operating without external control systems.

The proposed project addresses these challenges using Raspberry Pi-based embedded control and image processing.

C. Project Objectives

1) To design and develop an autonomous fire-fighting robot using Raspberry Pi Zero 2W for indoor fire detection and suppression.
2) To detect fire using a flame sensor module and implement image processing using OpenCV for accurate flame alignment.
3) To enable autonomous navigation toward the fire source with obstacle avoidance for safe operation.
4) To activate the water pump automatically for quick and efficient fire suppression without human intervention.

III.BLOCK DIAGRAM



IV. WORKING

The robot works in six phases:

1) Scanning
2) Detection
3) Alignment
4) Approach
5) Suppression
6) Verification

The robot rotates continuously, detects fire, aligns itself using OpenCV camera processing, approaches the flame, activates the pump, verifies fire extinguishing, and resumes scanning.

V. EXPECTED RESULT

The expected result of the proposed system is the successful development of an autonomous fire-fighting robot capable of detecting and extinguishing small-scale indoor fires without human intervention. The robot should accurately detect the presence of fire using a flame sensor, align itself toward the flame source using image processing with OpenCV, and navigate efficiently using a 4WD chassis.

Once the fire is detected, the system is expected to automatically activate the water pump and suppress the flame within a short response time. The robot should operate reliably without the need for internet connectivity or external control, ensuring continuous performance even in emergency conditions. Overall, the system is expected to provide a cost-effective, compact, and efficient solution for indoor fire safety applications.

VI. CONCLUSION

The Advanced Fire Fighter Robot using Image Processing successfully demonstrates a practical and cost-effective autonomous fire suppression system using embedded systems and robotics. The integration of Raspberry Pi Zero 2W, flame sensor, camera module, OpenCV, motor driver, and water pump creates a fully functional robot capable of detecting and extinguishing fire without human assistance. The system achieves all the project objectives while maintaining simplicity, affordability, and reliability. It provides a strong foundation for future improvements and large-scale deployment in industrial and residential safety applications.

This project proves that intelligent robotic systems can significantly improve fire response efficiency while reducing risk to human life. This project highlights the importance of embedded systems and robotics in enhancing safety and reducing human risk in hazardous environments. It also provides a strong foundation for future improvements such as AI-based detection, IoT monitoring, and large-scale deployment in industrial and residential applications.

VII. PROJECT SNAPSHOT

VIII. ACKNOWLEDGMENT

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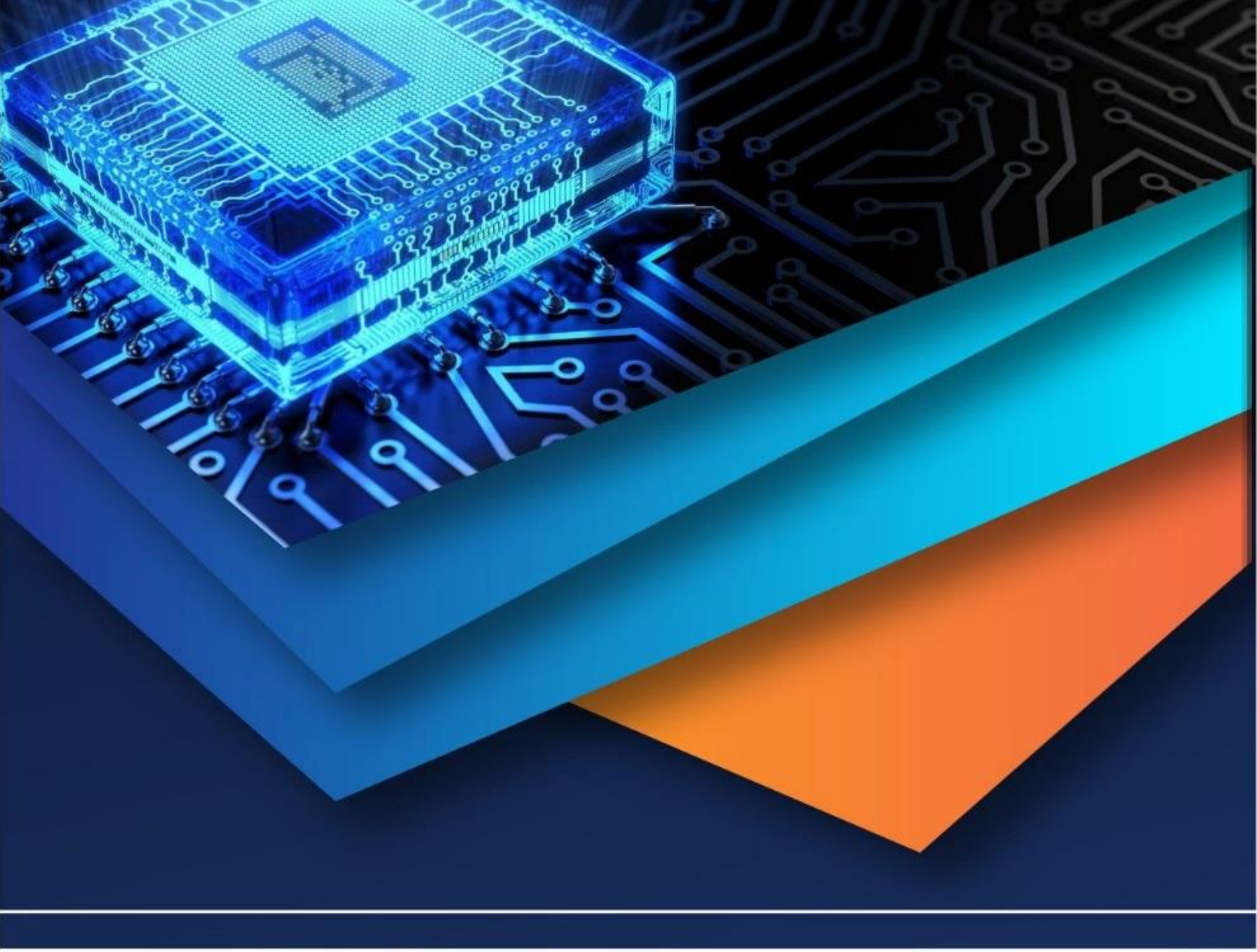

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