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Automated Fire Monitoring And Electrical Control System Using Raspberry Pi And Image Processing

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Abstract: An Automated Fire Monitoring and Electrical Control System using Raspberry Pi and Image Processing is presented to enhance safety in fire-prone environments. A USB camera captures images of the surroundings, which are processed by the Raspberry Pi to detect fire using image analysis techniques. Once fire is detected, a relay-based electrical actuation system is triggered to operate a fan, providing an immediate suppression mechanism. An LCD display is employed to present system status and fire alerts, ensuring effective user interaction. The integration of Raspberry Pi with relay control and electrical actuation enables rapid response, reduces the need for manual intervention, and improves system reliability. By combining vision-based detection with automated electrical control, the system offers an efficient and practical solution for fire monitoring and safety applications. This approach is suitable for residential, commercial, and industrial environments where early detection and automatic intervention are essential to minimize risks and prevent severe damage.

Index Terms **–** Fire Detection, Raspberry Pi, Image Processing, Electrical Control System

I. INTRODUCTION

Fire accidents are one of the major causes of damage in residential, commercial, and industrial environments, often leading to severe loss of life and property. The consequences of such incidents extend beyond financial loss, including injuries, environmental hazards, and disruption of normal activities. Therefore, early detection of fire is a crucial aspect of safety management, as it enables timely intervention and reduces the risk of further damage.

Conventional fire detection systems primarily rely on smoke, heat, or gas sensors. Although these systems are widely used, they may exhibit limitations under varying environmental conditions. Factors such as airflow variations, dust accumulation, and sudden temperature changes can delay detection. These challenges highlight the need for more reliable and efficient fire detection techniques capable of operating accurately in diverse environments.

Advancements in image processing and computer vision have led to the development of intelligent fire detection systems that overcome many limitations of traditional approaches. Vision-based methods analyze visual characteristics of flames, including color, intensity, shape, and motion patterns, enabling faster and more accurate detection. By directly observing the presence of fire, these systems provide early warnings and improve overall system responsiveness.

The proposed system titled "Automated Fire Monitoring and Electrical Control System using Raspberry Pi and Image Processing" utilizes a camera-based approach for real-time fire detection. A USB camera continuously monitors the surrounding environment, and the Raspberry Pi processes the visual data using image analysis algorithms. These algorithms detect fire based on predefined color thresholds and motion features, ensuring reliable performance under varying conditions.

Upon detection of fire, the system activates an audible buzzer to alert nearby individuals and simultaneously operates a relay module to control an electrical device, providing an initial suppression response. An LCD display is incorporated to present real-time status updates and alert messages, thereby enhancing user awareness and system interaction.

The system is designed to support remote monitoring, where the Raspberry Pi connects to a local network and can be accessed using Virtual Network Computing (VNC) Viewer on a mobile device. This enables users to execute the program, monitor system operation, and observe real-time outputs without the need for a dedicated display. By integrating real-time image processing with automated alert and control mechanisms, the system provides an efficient and reliable solution for fire monitoring and safety applications.

II. BLOCK DIAGRAM

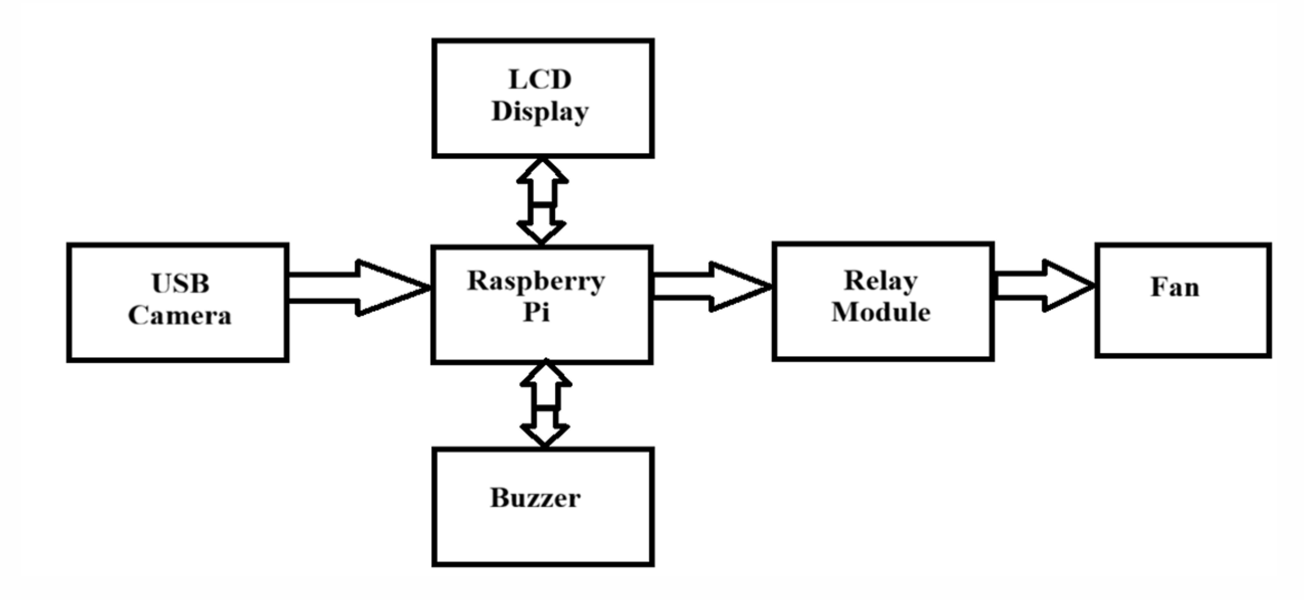


Fig.1 Block Diagram

The block diagram represents the overall structure of the Automated Fire Monitoring and Electrical Control System. It consists of several interconnected components that work together to perform continuous fire monitoring, detection, and control operations.

Description of Components

2.1 Raspberry Pi

The Raspberry Pi is a series of single-board computers. The Raspberry Pi was developed in the UK by the Raspberry Pi Foundation. The Raspberry Pi Foundation's goal is to "advance the education of adults and children, particularly in the field computers, computer science and related subjects."[1]

There are lots of different versions of the Raspberry Pi, and each has different features. All of the versions use a Broadcom system on a chip (SoC) which contains an ARM-compatible central processing unit (CPU), random access memory (RAM) and a graphics processing unit (GPU). All versions use an SD card or MicroSD card for the operating system and file storage. They also have a 40-pin General-Purpose Input/Output (GPIO) connector, which can be used for controlling other electronics.Some versions of the Raspberry Pi have an ethernet connector for connecting to the internet. Some versions can also use Wi-fi to connect to the internet.

The Raspberry Pi comes in three different sizes. The 'standard' size is used for all Model B versions, and is 85.6 mm x 56.5 mm (3.370 in × 2.224 in). The 'compact' size is used for all Model A versions, and is 65 mm × 56.5 mm (2.56 in × 2.22 in). The 'zero' size is used for all Raspberry Pi Zero versions, and is 65 mm × 30 mm (2.56 in × 1.18 in).[2]

The Raspberry Pi serves as the central processing unit and the brain of the system. It receives the input frames from the USB camera and processes them using image processing algorithms implemented in Python. The system analyzes the frames in the HSV color space to detect fire-like colors such as red, orange, and yellow. Based on the analysis and predefined threshold values, the Raspberry Pi determines whether fire is present or not. It then generates appropriate control signals to activate output devices. The Raspberry Pi ensures fast processing, decision-making, and coordination between all components.

2.2 USB Camera

The USB camera serves as the primary input device of the system and plays a crucial role in the fire detection process. It continuously monitors the surrounding environment by capturing images or video frames in real time, ensuring uninterrupted surveillance of the area under observation. These frames contain detailed visual information, including color, intensity, and motion, which are essential for identifying fire-related characteristics such as flames and sudden brightness variations.

The captured frames are directly transmitted to the Raspberry Pi, where they undergo further processing using image processing techniques. By continuously acquiring real-time data, the system is capable of detecting even minor changes in the environment, such as the initial appearance of flames or unusual light patterns. This continuous monitoring significantly improves the responsiveness of the system, allowing early-stage fire detection before the situation becomes critical.

Furthermore, the use of a USB camera enhances the flexibility and scalability of the system, as it can cover a wider area compared to traditional sensors. It also enables visual verification of fire incidents, reducing false alarms and improving overall reliability. Hence, the USB camera acts as a vital component in ensuring accurate, real-time monitoring and effective fire detection.

2.3 Liquid - Crystal Display (LCD)

A liquid-crystal display (**LCD**) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers to display information. Liquid crystals do not emit light directly[3] but instead use a backlight or reflector to produce images in color or monochrome .[4]

LCDs are available to display arbitrary images or fixed images with low information content, which can be displayed or hidden: preset words, digits, and seven-segment displays (as in a digital clock) are all examples of devices with these displays. They use the same basic technology, except that arbitrary images are made from a matrix of small pixels , while other displays have larger elements.

The LCD (Liquid Crystal Display) module is incorporated into the system to provide real-time visual feedback to the user, thereby enhancing the overall usability and interaction of the system. It serves as an output interface that continuously displays important system status messages such as “Fire Detected” or “No Fire,” enabling the user to quickly understand the current operating condition without the need for additional monitoring tools.

The LCD is directly interfaced with the Raspberry Pi, which updates the displayed information based on the results obtained from the image processing module. Whenever a fire condition is identified, the Raspberry Pi sends appropriate signals to the LCD to display an alert message, ensuring immediate awareness. In normal conditions, the LCD indicates the safe status of the environment, thereby providing continuous reassurance of system functionality.

Furthermore, the inclusion of an LCD module improves system independence by reducing dependency on external devices such as computers or mobile applications for basic monitoring. It provides immediate on-site feedback, allowing users to directly observe system status without relying on network connectivity. At the same time, advanced monitoring can still be achieved through remote access using VNC Viewer, offering additional flexibility. Due to its low power consumption, simplicity, and ease of interfacing, the LCD module serves as an efficient and practical solution for real-time status display in embedded fire monitoring systems.

2.4 Relay Module

A relay module is an electrically operated switching device that allows a low-power signal to control a high-power electrical circuit. It functions as an interface between control systems such as microcontrollers and external electrical loads. The relay ensures safe operation by providing electrical isolation between the control circuit and the high-voltage circuit.

A typical relay module consists of a relay switch, driver circuitry, and protective components integrated onto a single board. When a control signal is applied, the internal coil of the relay is energized, causing the switch contacts to either open or close. This mechanism enables effective control of external devices without directly exposing the control unit to high voltages.

The relay module is connected to the GPIO pins of the Raspberry Pi and is used to control an external electrical device based on the detection output. The Raspberry Pi sends a control signal to the relay, allowing automated switching operations without manual intervention.

When a fire condition is detected, the relay is activated to switch the connected device ON or OFF as required, enabling actions such as initiating a basic suppression mechanism or controlling the power supply. This improves system safety by providing an immediate and automatic response during critical situations.

2.5 Fan

The fan is utilized as an output device in the system and is interfaced through a relay module to facilitate controlled operation. As the Raspberry Pi operates at low voltage and current levels, it cannot directly drive high-power electrical devices. Therefore, the relay module serves as an intermediary switching mechanism, enabling safe and reliable control of the fan.

During normal operation, the fan remains in the OFF state. Upon detection of fire through the image processing module, the Raspberry Pi generates a control signal that activates the relay, thereby switching the fan ON automatically. This ensures an immediate and autonomous response without requiring manual intervention.

The primary function of the fan in this system is to provide an initial response by generating airflow in the monitored area. In controlled environments, such as small-scale demonstrations involving a candle flame, the airflow may disturb the flame or slightly reduce its intensity. However, it is important to emphasize that the fan is not intended to serve as a fire suppression mechanism. In real-world fire scenarios, particularly those involving larger flames, the use of a fan may be ineffective and could potentially contribute to fire propagation due to increased oxygen supply.

Thus, the inclusion of the fan primarily demonstrates the concept of automated electrical actuation triggered by real-time fire detection. It highlights the capability of the system to integrate sensing, processing, and control mechanisms, thereby enhancing responsiveness and illustrating the practical implementation of embedded fire monitoring systems.

2.6 Buzzer

A buzzer or beeper is an audio signaling device,[5] which may be mechanical, electromechanical, or piezoelectric .The buzzer is incorporated into the system as an audio output device to provide immediate alert notifications during fire detection. It plays a critical role in ensuring that users are promptly informed about potential fire hazards through audible signals. The buzzer is interfaced with the Raspberry Pi through its GPIO pins, allowing it to be controlled programmatically based on system conditions.

Under normal operating conditions, the buzzer remains in an inactive state. When the image processing module detects the presence of fire, the Raspberry Pi generates a control signal that activates the buzzer. Upon activation, the buzzer produces a continuous or intermittent sound, serving as an alert to notify nearby individuals of the detected fire condition. This immediate auditory feedback enhances the responsiveness of the system and ensures that necessary actions can be taken without delay.

The inclusion of a buzzer significantly improves the safety aspect of the system by providing real-time alerts even in situations where visual monitoring may not be feasible. It is particularly useful in environments where users may not be constantly observing the system display. Due to its low power consumption, simple interfacing, and rapid response capability, the buzzer is an effective and reliable component for alert generation in embedded fire monitoring systems.

2.7 LED Breakout Board

An LED breakout board is a compact module used to simplify the interfacing of light-emitting diodes with control systems such as the Raspberry Pi. It typically includes built-in current-limiting resistors and connection pins, allowing LEDs to be easily integrated without requiring additional external components. This reduces circuit complexity and ensures safe operation.

In the system, the LED breakout board is used to provide visual indication and to simplify wiring. It acts as an intermediate interface between the Raspberry Pi GPIO pins and the LEDs, organizing the connections in a structured manner. This eliminates the need for complex direct wiring and results in a cleaner and more reliable setup.

The use of the LED breakout board enhances system usability by providing clear visual feedback during operation. It contributes to improved reliability, ease of assembly, and better circuit stability, making it particularly useful during testing and demonstration of the system.

2.8 Jump Wires

A jump wire (also known as jumper, jumper wire, DuPont wire) is an electrical wire , or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering .[6]

2.9 Power Supply

A power supply is an essential component in any electronic system that provides the required electrical energy for proper operation. It converts the available electrical input into a stable and regulated output voltage, ensuring that all components function efficiently and safely. A reliable power source is important to maintain consistent performance and prevent system instability.

In the system, a Robotek 12W super fast charger is used as the power supply to provide the required electrical energy. It supplies a stable 5V DC output through a USB connection, which is suitable for powering the Raspberry Pi and associated components. This ensures that the system receives adequate power for continuous operation.

The Raspberry Pi and connected modules such as the relay, LCD display, buzzer, and camera depend on a stable voltage supply for proper functioning. The use of a regulated charger helps in maintaining consistent voltage levels, thereby preventing issues such as voltage drops or fluctuations that may affect system performance.

The use of a reliable power source like the Robotek charger enhances the overall stability and efficiency of the system. It supports uninterrupted operation and ensures that all components function correctly, contributing to the effective performance of the fire monitoring and control system.

III. CONTROLLER DESIGN AND IMPLEMENTATION

The controller of the proposed system is implemented using a Raspberry Pi, which serves as the central processing unit responsible for executing image processing algorithms, making decisions based on fire detection, and controlling connected output devices. The system software is developed in Python, and both the operating system and program files are stored on the Raspberry Pi's SD card. This setup allows the Raspberry Pi to independently perform all processing, monitoring, and control tasks.

The system starts by initializing the General Purpose Input/Output (GPIO) pins to interface with the buzzer, relay module, and LCD display. The buzzer and relay are configured as output devices, while the LCD operates in 4-bit mode, using dedicated control and data pins for transmitting commands and displaying messages. Custom Python functions manage the initialization, command execution, and string display on the LCD, ensuring smooth communication between the Raspberry Pi and hardware components.

A USB camera captures real-time video frames of the monitored environment. Each frame is processed using OpenCV and NumPy libraries. To improve fire detection, frames are converted from RGB to HSV color space, which enhances the identification of fire-like regions. A predefined color range corresponding to red, orange, and yellow is applied to generate a mask highlighting potential fire areas.

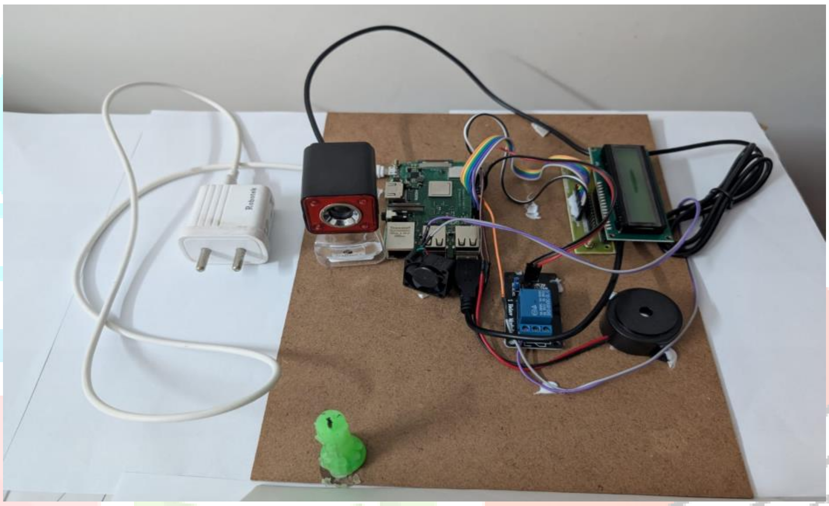
The system calculates the number of pixels within detected fire regions. If the pixel count exceeds a predefined threshold, the Raspberry Pi identifies the presence of fire. Upon detection, the buzzer is activated for an immediate audio alert, and the relay module operates the connected output device in active-low mode (device triggers when relay input is LOW). Simultaneously, the LCD displays “FIRE DETECTED” to provide real-time feedback. In the absence of fire, the buzzer remains OFF, the relay stays in its normal state, and the LCD displays “No Fire.”

For demonstration and remote monitoring purposes, the system supports connection via a mobile hotspot. By connecting the Raspberry Pi to a phone’s hotspot, the device can be accessed remotely using VNC Viewer on a mobile phone. This allows users to execute the fire detection program, monitor the live video feed in real-time and observe alerts, buzzer/relay actions, and LCD messages.

This remote access setup enables the entire system to be demonstrated without a dedicated monitor, making it convenient to showcase real-time operation, fire detection accuracy, and automated control responses during presentations.

The system operates continuously in a loop, providing real-time monitoring and immediate response to fire incidents. By integrating image processing, automated hardware control, and remote monitoring capabilities, the controller delivers a comprehensive, reliable, and demonstrable solution for fire detection and safety management, requiring minimal human intervention.

IV. RESULT



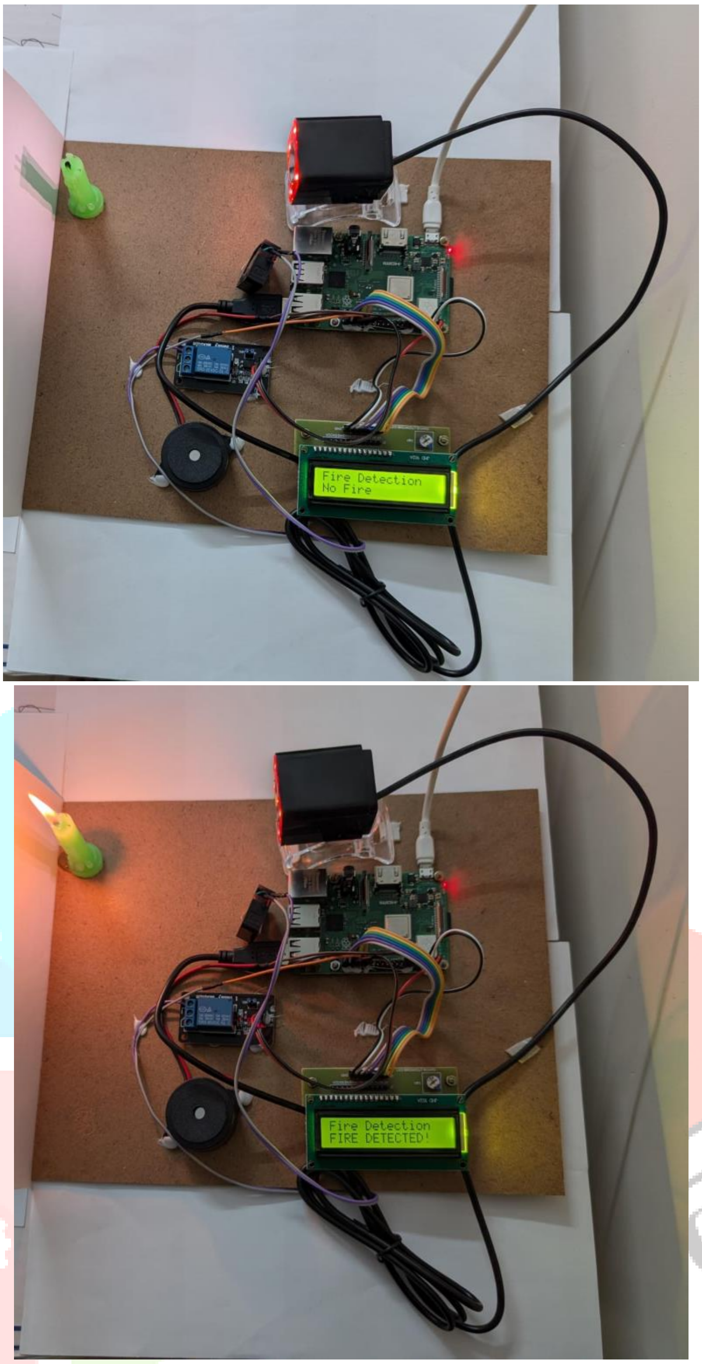


Fig.2 Complete Hardware Setup of the Proposed System

The complete hardware setup of the automated fire monitoring and electrical control system using Raspberry Pi and image processing includes a Raspberry Pi as the central controller, performing real-time image processing, decision-making, and controlling output devices. A camera module captures live video to detect fire, while a buzzer provides audio alerts, a relay module operates external devices like sprinklers, and an LCD display shows system status. The system is powered by a regulated supply and is connected to a mobile hotspot or Wi-Fi for remote monitoring via VNC Viewer. All components are interfaced through the Raspberry Pi’s GPIO pins, forming a compact and reliable real-time fire monitoring setup.

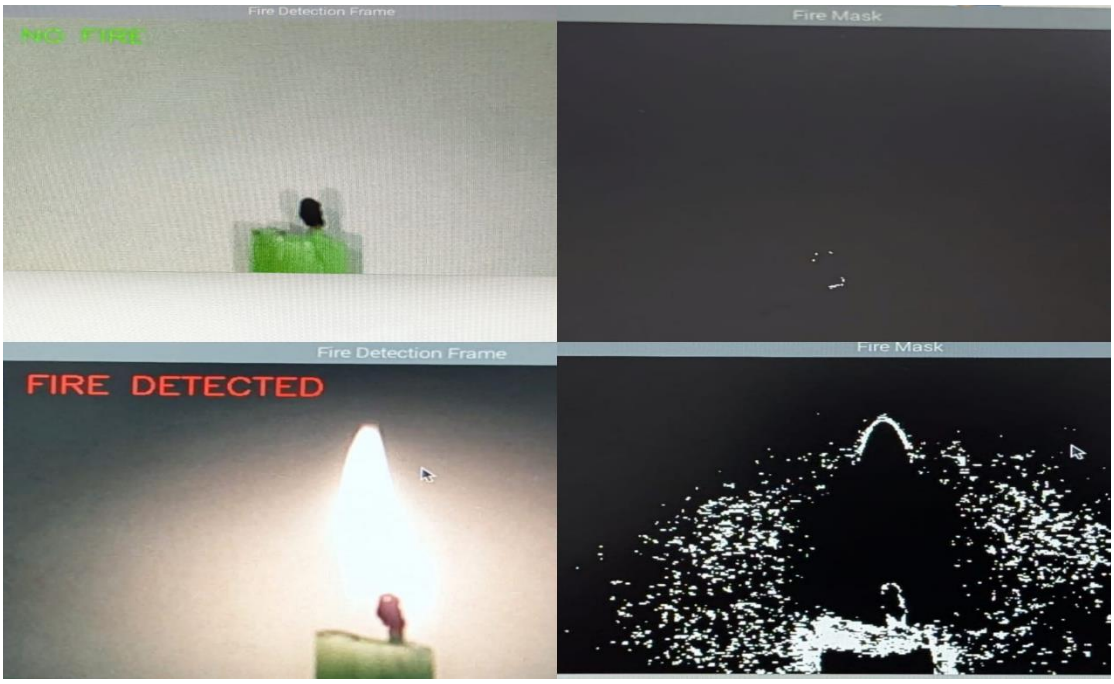


Fig. 3 Fire Detection Frame and Fire Mask Visualization

The image shows the real-time performance of the automated fire monitoring and electrical control system using Raspberry Pi and image processing. The top-left frame displays “NO FIRE” when no flame is detected, with the corresponding fire mask on the top-right showing no highlighted regions. The bottom-left frame shows “FIRE DETECTED” when a flame is present, while the bottom-right fire mask highlights the detected flame area in white. This demonstrates the system’s ability to accurately detect fire and generate a visual mask for controlling output devices such as alarms or sprinklers.

V. CONCLUSION

The proposed **Automated Fire Monitoring and Electrical Control System using Raspberry Pi and Image Processing** provides an efficient and reliable solution for early fire detection and response. By utilizing a camera-based approach, the system is capable of continuously monitoring the environment and detecting fire in real time using image processing techniques. This overcomes certain limitations of conventional sensor-based systems, which may experience delays under varying environmental conditions.

The integration of the Raspberry Pi with peripheral devices such as a buzzer, relay module, fan, and LCD display enables automatic actuation and immediate user notification upon fire detection. The system successfully demonstrates the concept of real-time monitoring and automated control, where appropriate actions are triggered without human intervention. The inclusion of both visual and audio alerts enhances the effectiveness and usability of the system.

Experimental implementation using a small-scale fire source, such as a candle flame, confirms the functionality of the system in detecting fire-like conditions and initiating a response. However, it is important to note that the current setup is intended for demonstration and basic safety applications, and the use of a fan does not constitute a complete fire suppression mechanism in real-world scenarios.

Overall, the system highlights the practical application of image processing in safety systems and demonstrates how integrated hardware and software components can be utilized to improve responsiveness and reliability. Future enhancements may include the incorporation of advanced detection algorithms, integration with IoT platforms for remote alerts, and the use of more effective fire suppression mechanisms to extend its applicability in real-world environments.

VI. REFERENCES

[1] The Raspberry Pi Foundation, "About Us". Retrieved 21 July 2015

[2]*"Mechanical Drawings - Raspberry Pi Documentation". raspberrypi.org. Retrieved 2020-06-11.*

[3] "Bosch's Smart Visor Tracks the Sun While You Drive". *IEEE Spectrum*. January 29, 2020.

[4] "Definition of LCD". *Merriam-Webster.com*. Archived from the original on February 25, 2021. Retrieved February 15, 2015.

[5] *"buzzer - definition of buzzer by The Free Dictionary". Retrieved 22 May 2015.*

[6] Jump wire patents