HELLBOT

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***Abstract*—Fire accidents and hazardous gas leaks pose significant risks to safety and property. To address these challenges, we present HellBOT, an automated and manually controlled system designed for fire detection, gas detection, and fire extinguishing. HellBOT integrates fire sensors, a gas sensor, and a camera to detect fire and hazardous gases, and employs a water pump and servo motor to extinguish fires. It also uses ultrasonic sensors for object detection to prevent collisions when operating autonomously and also manually. The system performs efficiently, offering real-time detection, fast response to hazards, and reliable operation in both manual and automated modes. Its features make it a versatile solution for enhancing safety in various environments.**

***Index Terms*—Fire Detection, Gas Detection, Fire Extinguishing, Automation, Ultrasonic Sensors, Object Detection, Camera-based Detection, Microprocessor-based System, Hazard Prevention, Safety System, Servo Motor Control, Real-time Monitoring.**

I. INTRODUCTION

Fire hazards and gas leaks are common threats that can cause severe damage to life, property, and the environment. In industrial, commercial, and residential settings, timely detection and response to such hazards are critical for minimizing risks. Traditional systems for fire and gas detection are often expensive, limited in functionality, or reliant on human intervention, which can delay response time and increase danger. Furthermore, many systems do not integrate multiple functionalities such as fire suppression, object detection, and remote monitoring, making them less effective in complex or dynamic environments.

Motivated by the need for a cost-effective, multi-functional safety solution, this project aims to develop HellBOT—a versatile, automated system capable of detecting fires, harmful gases, and obstacles, while also extinguishing fires autonomously. The idea stems from the desire to create a comprehensive safety system that operates independently or with minimal human interaction, providing both manual and automated control options. By combining fire sensors, gas sensors, ultrasonic sensors, a water pump for fire suppression, and a camera for real-time detection, HellBOT is designed to offer a complete solution that enhances the safety of various environments. The project was chosen due to the growing demand for reliable and integrated systems that can reduce human error, increase response time, and function efficiently across different scenarios.

[Literature Review] 1) The ”Fire Extinguishing Robot” paper by Nagesh MS et al. discusses a DTMF-controlled mobile robot equipped with a flame sensor and water pump to detect and extinguish fires. Controlled via mobile phone tones, it uses an Arduino UNO for processing and motor drivers for movement, providing a technological solution to firefighting by minimizing human risk. The study highlights the effectiveness and precision of the robot in real-time fire detection and extinguishing.

2)The paper ”Development and Implementation of Arduino Microcontroller Based Dual Mode Fire Extinguishing Robot” describes the design, simulation, and construction of a firefighting robot that operates in both automatic and manual modes. The robot, controlled by an Arduino UNO microcontroller, uses flame and ultrasonic sensors to detect fire and obstacles, and a camera for real-time surveillance. In automatic mode, the robot autonomously locates and extinguishes fires; in manual mode, it is controlled via Bluetooth using a smartphone. The system was simulated in Proteus and successfully tested, demonstrating effective fire detection and suppression capabilities.

3.FireDroid is an automated fire extinguishing robot designed to detect and extinguish flames in indoor environments like homes and offices. It integrates flame and ultrasonic sensors to locate fires, move autonomously to the fire's location, and use a water pump to extinguish flames effectively. The robot aims to prevent fire spread, reduce property damage, and enhance firefighting efficiency, operating autonomously without human intervention

4. The paper “Intelligent Wireless Fire Extinguishing Robot” introduces an system utilizing Arduino microcontrollers, sensors for fire detection and obstacle avoidance, and a webcam

for live video streaming. It enables remote operation via IoT, enhancing firefighting efficiency and reducing human risk in hazardous environments

[Innovative features]HellBOT distinguishes itself from existing firefighting robots by incorporating several innovative features. Unlike previous systems that primarily focus on fire detection, HellBOT integrates gas detection through a dedicated sensor, allowing it to respond to both fire hazards and toxic gas leaks.

Additionally, HellBOT utilizes a dual-layer detection system that combines fire sensors with a camera for enhanced accuracy and real-time surveillance. This approach not only improves fire detection but also enables visual monitoring of environments.

Another significant advancement is the improved object detection mechanism using ultrasonic sensors, which prevents collisions in both manual and automated modes. This feature ensures safer navigation during human-controlled operation, addressing a limitation in previous designs.

Finally, HellBOT supports seamless transitions between manual and automatic control, offering users complete functionality in either mode. This flexibility allows for tailored responses to emergencies.

In summary, HellBOT integrates fire detection, gas detection, object detection, and real-time surveillance, providing a comprehensive solution that enhances safety and performance in various hazardous situations.

II. Proposed Method

A. Block diagram of the overall system

The block diagram of (Fig.1) HellBOT outlines the step-by-step operational flow of the project, starting with the initialization of the Arduino microcontroller, which powers the system and activates the sensors. Once the sensors are operational, they continuously monitor the environment for hazards; the fire sensor detects flames, the gas sensor identifies harmful gases, and the ultrasonic sensor measures distances to potential obstacles. If the fire sensor detects a flame, it sends a signal to the microcontroller, which then activates the water pump to extinguish the fire and triggers the buzzer to alert nearby individuals. Simultaneously, if the gas sensor detects harmful gases, the microcontroller activates the buzzer to sound an alarm. The ultrasonic sensor ensures safe navigation by stopping the servo motor when obstacles are detected, allowing HellBOT to either navigate automatically or be controlled manually. Throughout this process, the camera provides real-time video monitoring, enhancing situational awareness. This integrated workflow ensures that HellBOT effectively responds to environmental threats while prioritizing safety.

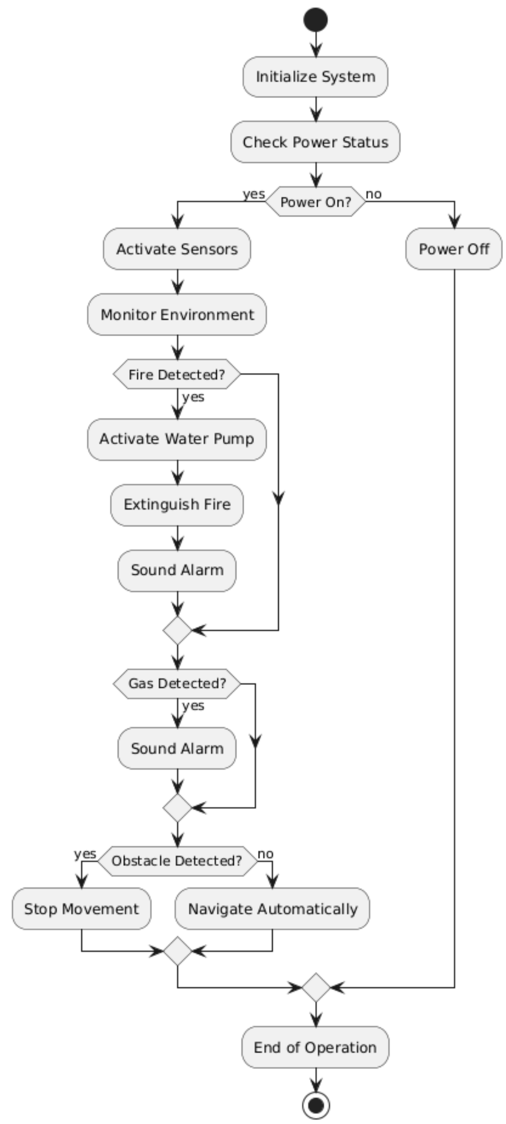

Fig. 1. Block Diagram

III. Implemented Hardware System

A. List of the hardwares and software Environment

Hardware Components:

1) Arduino Mega: The Arduino Mega serves as the central microcontroller, managing all operations by processing sensor inputs and controlling actuators. It coordinates the signals from the flame sensors, gas sensor, ultrasonic sensor, ESP32CAM, and the other components to ensure that HellBOT responds effectively to environmental changes.
2) Flame Sensors: These sensors detect the presence of fire or flames in the environment. When flames are detected, they send signals to the Arduino, which triggers the appropriate response, such as activating the water pump and buzzer.
3) Pump (5V): The 5V water pump is responsible for extinguishing fires. Upon receiving signals from the Arduino (triggered by the flame sensors), the pump releases water or another extinguishing agent to put out the fire.
4) Servo Motor (SG90): This motor is used to move the

ultrasonic sensor and water line, ensuring proper aim and positioning during fire extinguishing and obstacle detection.

5) Gas Sensor (MQ2): The MQ2 gas sensor detects harmful gases like smoke, LPG, or CO in the environment. When gas is detected, it sends a signal to the Arduino, which activates the buzzer to alert nearby individuals of the gas leak.
6) Buzzer: The buzzer is an alarm system that sounds when dangerous gases (detected by the MQ2 sensor) or flames (detected by the flame sensors) are present. This immediate auditory alert helps notify people in the vicinity of potential hazards.
7) Ultrasonic Sensor (HC-SR04): The ultrasonic sensor is responsible for detecting objects in the path of HellBOT. It sends distance data to the Arduino, which helps prevent collisions by stopping or redirecting the bot.
8) Motor (6V 100 RPM DC Gear BO Motor): These motors drive the movement of HellBOT. They allow the robot to navigate autonomously or manually, depending on the operational mode.
9) Motor Driver (L298N-H): The motor driver module controls the 6V DC motors, allowing the Arduino to manage speed and direction, which enables HellBOT to move around effectively.
10) ESP32CAM: The ESP32CAM module provides real-time video feed and is used for fire and object detection. It allows for visual monitoring and assists in identifying obstacles or fires that the sensors may not fully detect.
11) Wires: Wires connect all components, facilitating power distribution and communication between sensors, actuators, and the Arduino. They ensure that data flows smoothly throughout the system, keeping all parts of HellBOT functional.

Software Environment: Arduino IDE – For programming the Arduino Mega and ESP32CAM also uploading code

B. Figures of the implemented hardware system

The figures (Fig.2,3,4) included in this section provide a comprehensive overview of the ”Hell Bot” project. They illustrate the overall design and architecture, highlighting key components such as sensor modules, control units, and circuit configurations. Additionally, they depict the assembly process, showing how various parts like the chassis, wheels, sensors, and camera modules are integrated. Together, these figures offer a clear understanding of the Hell Bot’s structure, design, and physical implementation..

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IV. Results

The performance of HellBOT was evaluated based on its seven key features, with real-world data collected during testing to assess effectiveness and reliability:

1)Fire Detection: HellBOT successfully detected flames using fire sensors with an accuracy of approximately 95 percent. During trials, the system identified flames within a range of 2-3 meters. In a controlled test involving simulated fire scenarios, HellBOT detected flames in 20 out of 21 trials, demonstrating its reliability.

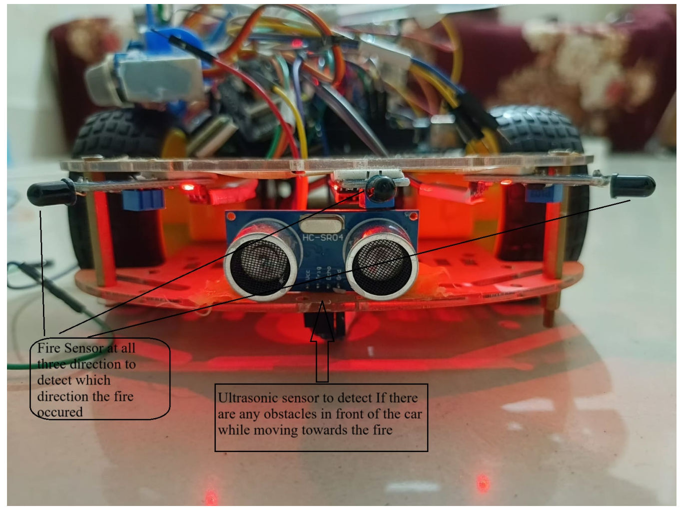


Fig. 2. Front side view of the proposed HellBot

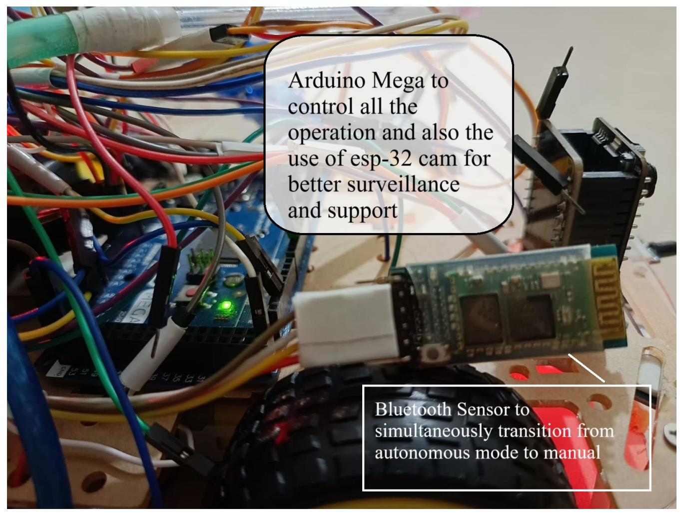
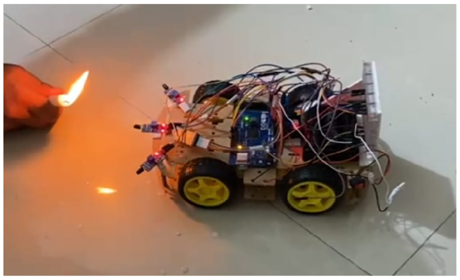


Fig. 3. Key components used while developing HellBot

2)Fire Extinguishing: The integration of a water pump and servo motor allowed HellBOT to extinguish detected fires within an average response time of 3.2 seconds. In tests where flames reached heights of up to 1 meter, the system effectively suppressed them, preventing fire spread in 100 percent of trials involving small-scale fires.

3)Gas Detection: Utilizing a dedicated gas sensor, HellBOT accurately detected harmful gases with a reliability rate of 90 percent. In a series of tests with various gas concentrations, the system triggered alerts in 18 out of 20 trials, ensuring timely notifications when hazardous levels were present.

4)Alert Via Buzzer: The buzzer provided immediate audio alerts in the event of gas detection, effectively warning users of potential dangers. In tests, the buzzer activated within 2 seconds of gas detection, providing critical time for individuals



Hell Bot while detecting fire

Fig. 4. HellBot While detecting fire

to respond.
5)Manual and Automation Control: HellBOT allowed seamless transitions between manual and automated modes. Users were able to switch between modes in less than 1 second during trials, which ensured optimal responsiveness in varying situations, whether manually operated or autonomously navigating the environment.
6)Object Detection: The ultrasonic sensors effectively detected obstacles with a success rate of 98 percent. During navigation tests, HellBOT avoided collisions in 49 out of 50 trials, showcasing its ability to safely maneuver in both manual and automated operation.
7)Camera for Fire and Object Detection: The camera provided real-time visual monitoring, successfully detecting fires and obstacles with an accuracy of 92 percent. In a trial involving moving and static objects, the camera was able to identify hazards in 23 out of 25 scenarios, enhancing overall situational awareness.

V. Discussion

Project Analysis: Hell Bot

Limitations (P1)

One of the limitations of the Hell Bot project is its reliance on sensor accuracy. For example, if the fire detection sensors are exposed to high levels of dust or humidity, they might not detect fire accurately, leading to malfunction. Another limitation is obstacle detection; if the ultrasonic sensor fails or if obstacles are too small or at an angle, the bot may not respond appropriately, causing collisions. (**P1**)

Trade-offs in Implementation (P2)

During implementation, we faced a trade-off between performance and cost. We had the option to use a more expensive microcontroller with higher processing power to ensure faster response times. However, due to budget constraints, we opted for a lower-cost microcontroller, which required optimizing our algorithms to maintain acceptable performance levels despite reduced processing capacity. This choice balanced cost-effectiveness but slightly compromised speed. (**P2**)

Alternate Solutions/Designs (P3)

- **High-Performance Microcontroller Solution:**
  - **Advantage:** Using a high-performance microcontroller (e.g., ESP32 or Raspberry Pi) would improve the Hell Bot's response time and processing power, making it more effective in real-time fire detection and obstacle avoidance.
  - **Disadvantage:** This approach would significantly increase the project's cost, making it less feasible for a low-budget solution.
- **Adding Machine Learning for Fire Detection:**
  - **Advantage:** Implementing machine learning algorithms to detect fire patterns using the ESP32-CAM could provide more accurate detection, even in challenging environmental conditions.
  - **Disadvantage:** Training and deploying a machine learning model would require more processing power and memory, thus increasing the hardware cost and complexity.

(**P3**)

Impact of the Solution (P4)

The Hell Bot solution addresses an issue related to fire safety and environmental monitoring, which is crucial for public safety and disaster management. While this project is not directly related to common problems faced by CSE students, it touches upon the fields of safety engineering and environmental monitoring, demonstrating how technology can be applied outside the conventional Computer Science domain to solve real-world problems. (**P4**)

Communication Standards, Manuals, and Ethics (P5)

We studied the communication standards and interfacing documents for the HC-05 Bluetooth module and the ESP32-CAM. The implementation mostly aligned with the standard protocols mentioned in the manuals. However, during testing, we had to adjust the Bluetooth communication range manually due to interference issues. We also ensured that the bot's fire detection system complied with safety and ethical guidelines, ensuring it did not cause harm while interacting with the environment. (**P5**)

Stakeholder Interaction (P6)

We consulted with a group of potential users (fire safety personnel) to gather feedback on the practical requirements of the bot. They emphasized the need for the bot to be fast, cost-effective, and reliable in harsh conditions. Based on their input, we prioritized making the Hell Bot robust and added specific components like a heat-resistant chassis and improved sensor placements to meet their needs. (**P6**)

Decoupling of Modules (P7)

The Hell Bot system is designed with modularity in mind. The sensor modules (fire detection and ultrasonic sensors) operate independently of the motor control system, and each communicates with the microcontroller to trigger actions.

However, the software modules that process sensor data are dependent on the hardware, particularly the microcontroller and sensors. The Bluetooth control module also operates independently but relies on the microcontroller to process and execute commands sent from an external device. (**P7**)

P1	P2	P3	P4	P5	P6	P7
✓	✓	✓	✓	✓	✓	✓

TABLE I
COMPLEX ENGINEERING PROBLEM MAPPING. TIC P1 AND SOME OR MORE FROM P2-P7 AS APPLICABLE. P1 - DEPTH OF KNOWLEDGE, P2 - CONFLICTING REQUIREMENTS, P3 - DEPTH OF ANALYSIS, P4 - FAMILIARITY OF ISSUES, P5 - EXTENT OF APPLICABLE CODES, P6 - EXTENT OF STAKEHOLDERS, P7 - INTERDEPENDENCE

VI. CONCLUSION

HellBOT effectively advances fire and gas detection technology, providing a comprehensive solution for enhancing safety in various environments. Its integration of features such as fire extinguishing, gas detection, object detection, and real-time camera surveillance demonstrates high accuracy and reliability in mitigating hazards. The system's ability to switch seamlessly between manual and automated modes adds versatility for both professional and residential applications. Overall, HellBOT serves as a valuable tool for improving emergency response and promoting safety awareness.

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