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Intrusion detection system using regulated patrolling robot

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ABSTRACT
Intrusion Detection System (IDS) using a regulated patrolling robot is designed to enhance security in various environments. The robot autonomously patrols a defined area, detecting intrusions using a combination of sensors, including motion detectors, cameras, and ultrasonic sensors for obstacle avoidance. It communicates real-time data to a web interface, allowing users to remotely monitor and control the robot. The integration of the ESP32 microcontroller ensures efficient processing, while the robot's mobility allows it to cover a wider area compared to traditional fixed security systems. When an intrusion is detected, the system triggers immediate alerts, notifying the users to enable a rapid response. This approach provides flexibility, scalability, and adaptability in security systems, as additional robots or sensors can be added as needed. The web interface also allows for easy configuration and troubleshooting, improving the user experience. The system is designed to operate autonomously, reducing the need for constant human monitoring. Data logging and analysis capabilities ensure that past activities and intrusions can be reviewed for further security enhancement. The use of DC motors for movement ensures precise control of the robot, enabling it to patrol efficiently. Overall, the IDS with a patrolling robot offers a cost- effective, efficient, and reliable solution for real-time intrusion detection and monitoring.

1-INTRODUCTION

1 An Intrusion Detection System (IDS) using a regulated patrolling robot is a cutting- edge security framework that combines robotics, advanced sensing, and intelligent algorithms to safeguard sensitive environments. The system is designed to autonomously monitor and detect unauthorized access, ensuring a robust security layer in locations such as industrial facilities, government buildings, and high-risk zones. By deploying a patrolling robot equipped with sophisticated sensors, cameras, and communication tools, the system offers real-time surveillance and analysis capabilities.

2 The patrolling robot navigates predefined routes or dynamically adjusts its path based on detected anomalies. It uses technologies like infrared sensors, ultrasonic sensors, and motion detectors to identify potential intrusions. High-definition cameras and night vision capabilities enhance its ability to function effectively in diverse lighting conditions. Real- time processing of sensory data enables the robot to recognize suspicious activities or objects, which can then trigger alerts to the control center.

3 The integration of intelligent algorithms allows the robot to differentiate between normal and anomalous activities, reducing the likelihood of false alarms. In addition to detection, the robot can document incidents with timestamped video or photographic evidence, which is essential for post-event analysis. Moreover, the system can operate around the clock without fatigue, ensuring continuous surveillance in areas prone to security breaches.

4 Communication is a key aspect of this IDS, as the patrolling robot is connected to a central system that monitors its operations. In case of an identified threat, it can relay information instantly to security personnel, providing details such as location, nature

of the intrusion, and live video feeds. Some systems also support the integration of audio alarms or automated responses, such as locking doors or redirecting the robot for closer inspection.

5 This automated approach enhances the reliability and efficiency of traditional security systems by minimizing human error and reducing dependence on constant human supervision. Furthermore, it allows security teams to focus on higher-level decision-making and response strategies. The scalability of the system makes it adaptable for various applications, ranging from small residential areas to large industrial complexes

By leveraging robotics and intelligent systems, the IDS with a regulated patrolling robot represents a significant advancement in intrusion detection technology, offering a proactive and cost-effective solution to modern security challenges.

To further improve the system's functionality and real-time responsiveness, Phase 2 introduces the integration of additional safety and sensing modules. These include a gas sensor for detecting hazardous gas leaks, a flame sensor for identifying fire outbreaks, a servo motor for camera rotation, and a buzzer for obstacle-based alerts using ultrasonic sensors.

The gas and flame sensors enhance environmental safety by updating the web interface with specific alerts like "Gas Detected" or "Flame Detected" when such hazards are identified. These alerts are displayed in real-time but do not activate the buzzer, ensuring focused notification. The ultrasonic sensors continue to aid in obstacle avoidance and now also trigger the buzzer when an object is detected at close range, warning nearby personnel or signaling the need for route correction.

The servo motor enables dynamic camera control via a slider on the web interface, giving users the flexibility to adjust the camera angle remotely for broader visual coverage. These enhancements collectively transform the patrolling robot into a more versatile, multi- threat detection platform that addresses both security and safety, making it suitable for a wide range of real-world applications.

2-METHODOLOGY

The development of the regulated patrolling robot with an intrusion detection system begins with the design phase, focusing on selecting the essential hardware components. The PIR sensor is chosen for motion detection, the ESP32 microcontroller handles data processing, and the ESP32 CAM module provides real-time visual surveillance. The PIR sensor is mounted on the robot and connected to the ESP32, enabling detection of motion within the monitored area. Simultaneously, the ESP32 interfaces with the camera module to capture and stream visual data, which can be analyzed for potential intrusions.

Following hardware integration, the motor controller is connected to the ESP32 to manage the robot's movement. DC motors are linked to a motor driver, with the ESP32 programmed to autonomously control motor operations. The robot navigates along a predefined path, utilizing ultrasonic sensors for obstacle detection and avoidance.

A user interface is developed to facilitate remote monitoring and control of the robot. This interface includes features such as live video streaming, real-time visualization of sensor data, manual control options, and alert notifications triggered by motion detection.

The robot is powered by a rechargeable battery, carefully selected to provide sustained energy for the sensors, motors, and processing units over extended operational periods. On detecting anomalies, robots initiate predefined response protocols and relay information to a centralized control system via secure wireless communication networks.

Servo Angle (Degrees)	**Camera Direction**	**Description**
0°	Left	Scans left side
45°	Front-Left	Intermediate left view
90°	Front	Straight ahead view
135°	Front-Right	Intermediate right view
180°	Right	Scans right side

Finally, motion detection and analysis algorithms are developed. Data from the PIR sensor is processed to identify intrusion events, while the camera feed is analyzed to visually confirm suspicious activity. Comprehensive testing ensures the system performs reliably with accurate motion detection, timely alerts, and efficient autonomous navigation

To enhance system capabilities, additional components are integrated in the next phase. Gas sensors are incorporated to detect hazardous gases such as methane or carbon monoxide, adding an environmental safety layer. Flame sensors are also added to enable fire detection and prompt alerting. Wireless communication modules such as 5G and Wi-Fi enable real-time data transmission and remote accessibility, while edge computing allows critical sensor data to be processed locally for rapid response.

Sensor Behaviour Rules:

Table.2.2 Sensor Conditions and Corresponding Actions

Sensor	Condition	Action
Ultrasonic Sensor	Distance > 10 cm	Buzzer OFF
Ultrasonic Sensor	Distance ≤ 10 cm	Buzzer ON
PIR Sensor	Motion Detected	Send Alert
PIR Sensor	No Motion Detected	Standby

The methodology for this phase involves integrating these new sensors with the existing ESP32 platform and developing advanced software modules. Gas and flame sensor outputs are continuously monitored, and specific threshold values trigger alerts or safety protocols. The onboard AI models are trained using sensor and camera data to improve detection accuracy and reduce false positives. Communication protocols are implemented to send real-time alerts and video streams to the remote monitoring interface securely. Finally, extensive field testing is conducted to validate the system’s multi-threat detection, autonomous navigation under complex environments, and robustness of wireless communication.

3-REQUIREMENTS

Software Requirements

The software requirements for an Intrusion Detection System (IDS) using a regulated patrolling robot include a robust operating system capable of supporting real-time operations. The robot's control software should be designed to handle sensor inputs, motor commands, and decision-making algorithms for navigation and security tasks. Path planning algorithms are essential for the robot to follow predetermined routes and adjust its course dynamically in response to obstacles or changes in the environment. Machine learning or image processing software is often used to analyze camera feeds for identifying potential intruders. The software must support wireless communication protocols, allowing the robot to send alerts and receive commands remotely. A database management system is required to store and log security events, helping with analysis and reporting. The software should also include safety features to monitor battery levels, motor performance, and environmental conditions. Security measures like encryption are vital to protect

communication between the robot and remote monitoring systems. The system should also have an intuitive user interface for human operators to configure, control, and monitor the robot. Additionally, the software should be designed for scalability, allowing for updates and integration with other security systems in the future.

Web Server

The web server in an Intrusion Detection System (IDS) with a regulated patrolling robot acts as the central interface for monitoring and controlling the system remotely. It hosts the web page that displays real-time data from the robot, such as its location, status, and any detected intrusions. The server communicates with the robot via a network, receiving sensor data and sending commands for movement or actions. It processes requests from users accessing the web interface, such as altering the robot's patrol route or viewing logs. The web server is often implemented using technologies like Node.js, Apache, or similar frameworks. It ensures secure and efficient communication between the user and the robot, often utilizing protocols like HTTP or WebSocket for continuous data streaming. The server can also trigger alerts or notifications in case of a detected intrusion, sending them to users' devices. A well-configured web server enables remote configuration and troubleshooting of the IDS system. Additionally, it provides scalability to integrate more robots or sensors into the network. Overall, the web server plays a vital role in remote control, monitoring, and management of the IDS system.

In addition to remote monitoring and control, the web server in an Intrusion Detection System (IDS) with a regulated patrolling robot plays a crucial role in data logging and analytics. It records sensor readings, movement logs, and intrusion events, creating a comprehensive historical database. This data can be analyzed to identify patterns, such as recurring intrusion attempts at specific times or locations, which helps in optimizing patrol strategies. Visualization tools like charts and heatmaps can be integrated into the web interface for easier interpretation of trends. The stored data also aids in system diagnostics, debugging, and performance improvement. In more advanced setups, this information can be used to develop predictive algorithms for proper threat detection. It further supports audit trails and compliance in security-focused environments. Overall, the server transforms the IDS from a passive monitoring tool into a proactive, intelligent surveillance system.

Web Page

The web page in an Intrusion Detection System (IDS) with a regulated patrolling robot serves as the user interface for monitoring and interacting with the robot. It displays real- time information such as the robot's location, movement status, and any detected intrusions. The page typically features live updates, including sensor data, system alerts, and control options for adjusting the robot's patrol routes. It allows users to remotely configure the robot's settings, such as its speed or detection parameters. The web page can also present historical data, including logs of past detections or activities. Built with technologies like HTML, CSS, and JavaScript, it provides an intuitive and responsive design for users. It interacts with the web server to send commands and receive updates, enabling seamless communication with the robot. Security features, such as login authentication, ensure that only authorized users can access and control the system. Additionally, the web page may offer real-time video streaming or images from the robot's cameras for visual surveillance.

Beyond basic control and monitoring, the web page in an IDS with a regulated patrolling robot can also support custom dashboards and data visualization tools to enhance user interaction and situational awareness. These dashboards can display graphical representations of sensor activity, patrol heatmaps, battery levels, and intrusion frequency over time, allowing users to quickly interpret large volumes of data. Interactive elements like drop-down menus, sliders, and toggles can be used for adjusting settings or scheduling patrol routines directly from the interface. The web page can also be optimized for mobile devices, ensuring that users can monitor and control the robot on the go. Integration with third-party services, such as cloud storage for logs or messaging platforms for alerts, can further extend the system's functionality. This transforms the web page into a dynamic control hub that improves user engagement and operational efficiency.

Users may also benefit from customizable dashboard widgets, enabling them to tailor the interface to their preferences or roles. The web page is often designed to be mobile- responsive, ensuring smooth access on smartphones and tablets. Features like dark mode, accessibility support, and multilingual options further improve user experience and inclusivity. These enhancements make the web page not just a display screen, but a smart, interactive command center that centralizes control, data analysis, and user interaction for the entire IDS system.

Overall, the web page serves as the primary point of interaction, enhancing the effectiveness of the IDS by allowing remote control and monitoring of the robot.

Hardware Components

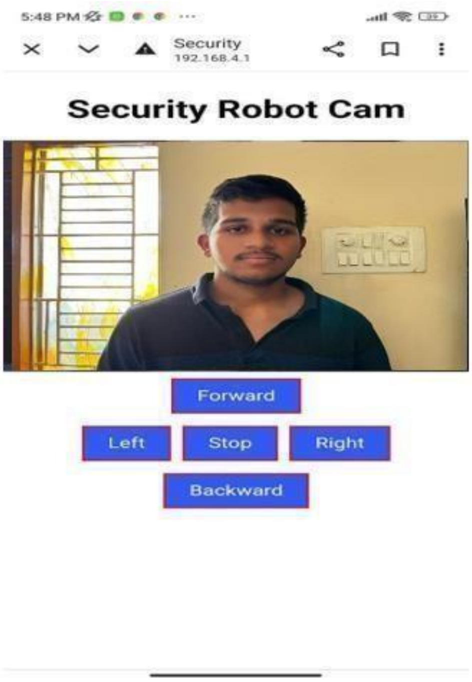
PIR Sensor

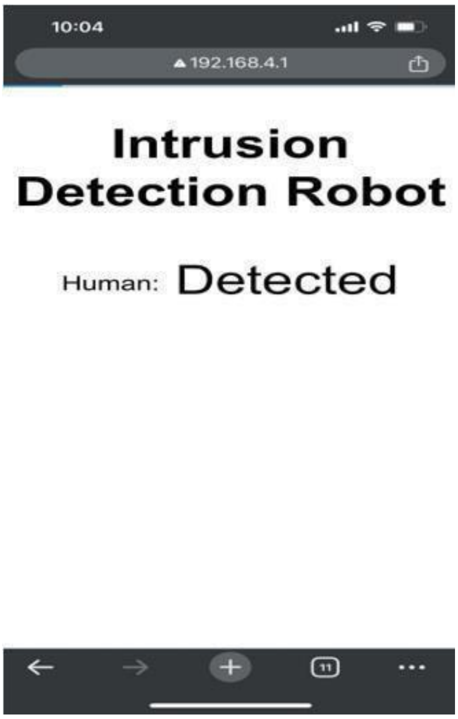
The PIR (Passive Infrared) sensor plays a crucial role in the Intrusion Detection System of the Regulated Patrolling Robot. It detects infrared radiation emitted by warm objects, such as humans or animals, moving within its field of view. When motion is detected, the PIR sensor sends a signal to the ESP32 microcontroller, triggering further actions in the system. The sensor has a wide detection range and low power consumption, making it ideal for battery-powered robots. In the context of the patrolling robot, the PIR sensor enables real-time motion detection while the robot navigates the area.

It helps identify potential intrusions, prompting the robot to either change its path or notify the user via the web interface. The sensor is mounted on the robot to provide a 360- degree detection zone. This component ensures the system can operate autonomously and react to movements without human intervention. Overall, the PIR sensor is vital for maintaining surveillance and ensuring that the robot performs its patrolling tasks effectively.

Passive Infrared (PIR) sensor is widely used in various projects due to its ability to detect motion by sensing infrared radiation emitted by objects, especially humans. The main use of a PIR sensor is in security systems, where it detects unauthorized movement and triggers alarms. It is also commonly applied in automatic lighting systems to save energy by turning lights on when someone enters a room and off when no movement is detected. PIR sensors are integral in home automation for controlling appliances based on occupancy. In robotics, they help robots detect human presence and respond accordingly. They are also used in automatic doors, ensuring doors open only when a person approaches. In environmental monitoring, PIR sensors detect wildlife movement without disturbing animals. Additionally, PIR sensors find applications in smart parking systems to detect vehicle presence. Their low power consumption makes them ideal for battery-operated devices. The sensor's simplicity and cost-effectiveness contribute to its widespread use. It can be integrated with microcontrollers for customized automation projects. In healthcare, PIR sensors assist in patient monitoring by detecting motion. Overall, PIR sensors enhance safety, convenience, and energy efficiency in many electronic projects.

4-RESULTS





Security robot cam interface with control buttons and intrusion detection robot interface with human detection status

The security robot successfully detected human presence using onboard sensors and camera feeds. Once a human was identified, the system triggered an alert, providing real- time video and positional data to the operator. The robot's detection algorithm ensured high accuracy, minimizing false positives. This functionality enhances the system's reliability in identifying potential intrusions effectively. Human detection technology is rapidly advancing, utilizing methods like computer vision and machine learning.

Techniques such as deep learning, particularly convolutional neural networks (CNNs), are commonly applied for high accuracy. Real-time human detection is widely used in security, surveillance, and autonomous systems. Challenges remain, including environmental factors, lighting, and occlusions, affecting detection performance.

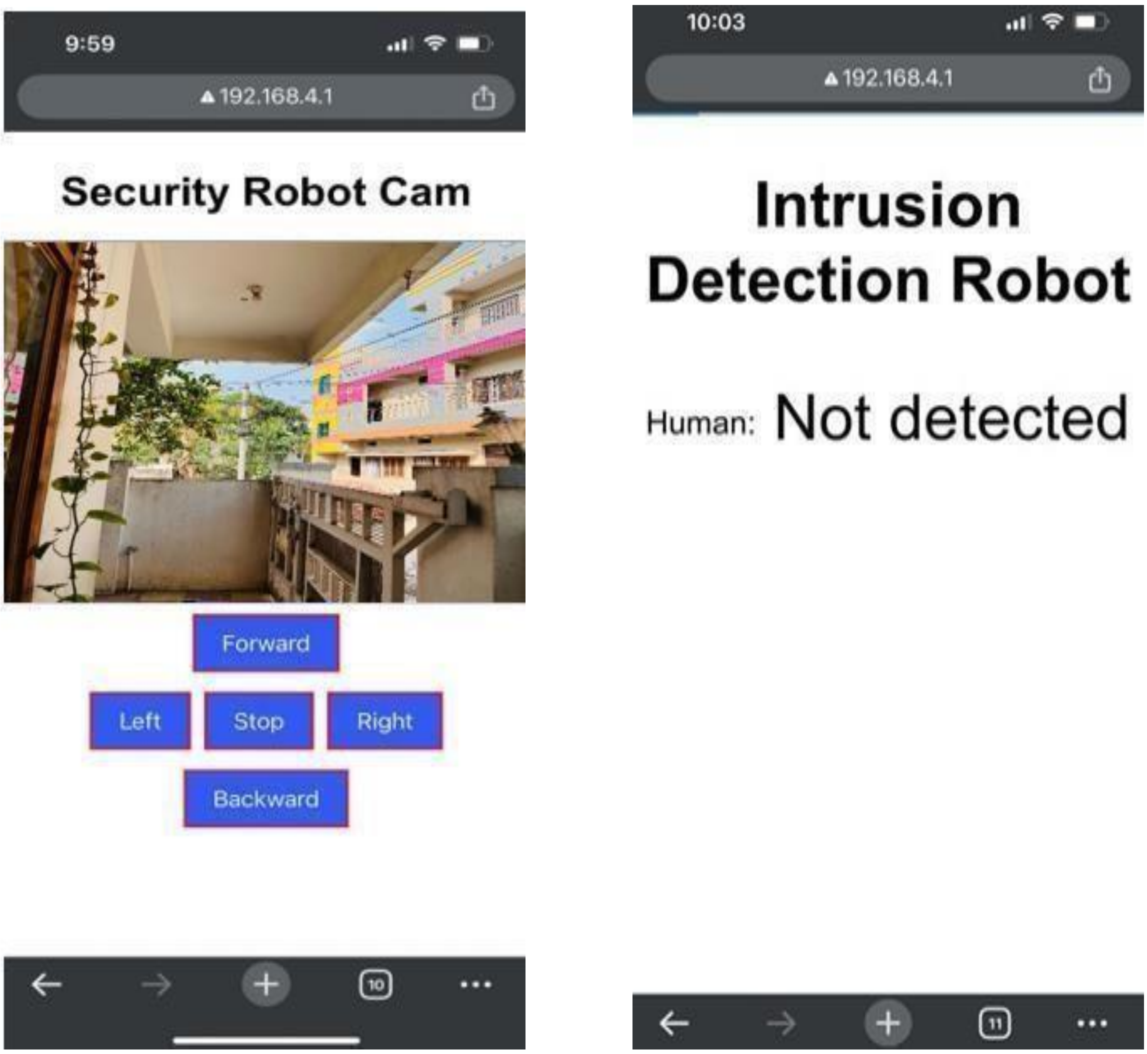


Fig.5.3 Security robot cam interface with control buttons and intrusion detection robot interface with human detection status

The flame detection feature in the intrusion detection robot plays a crucial role in identifying fire-related hazards during patrol. A flame sensor is integrated into the system to detect the presence of fire or high-intensity light sources typically emitted by flames. When the sensor identifies a flame, it sends a signal to the microcontroller, which can then trigger immediate actions such as activating a buzzer to alert nearby personnel or systems.

This early warning system is vital in environments prone to fire risks, such as factories, storage facilities, or chemical plants, helping to prevent fire outbreaks from escalating into major incidents. The sensor operates by detecting infrared light within a specific wavelength emitted by flames. Its quick response time ensures faster detection, allowing for timely evacuation or intervention. This enhances the robot's ability to act as both a surveillance and safety mechanism in hazardous environments. By continuously scanning the surroundings, the flame sensor ensures round-the-clock monitoring.

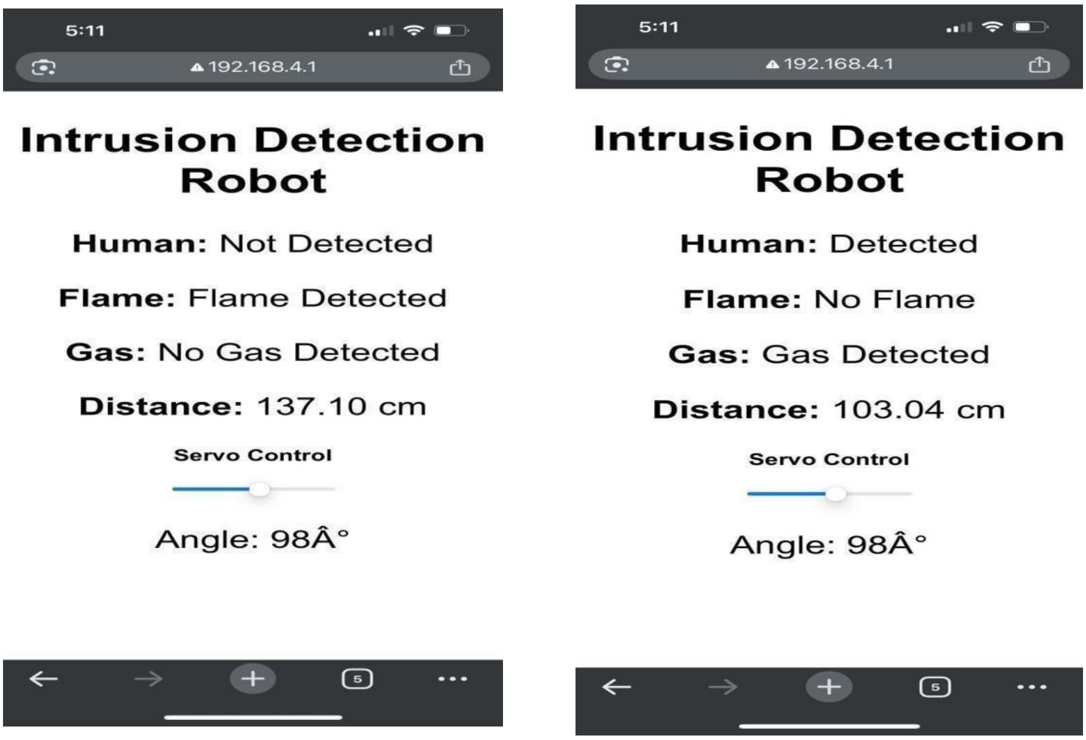


Fig 5.4 Robot monitoring interface showing flame and gas detection status

The gas detection feature in the intrusion detection robot is a critical safety component that enhances the system's ability to identify hazardous environmental conditions in real time. A gas sensor is integrated into the robot to continuously monitor the air for the presence of harmful, flammable, or toxic gases such as LPG, methane, or smoke-related particles. Once a dangerous concentration is detected, the sensor sends a signal to the microcontroller, which triggers an alert mechanism—typically activating a buzzer or displaying the warning on a user interface. This immediate response ensures that necessary preventive measures can be taken to avoid accidents like gas explosions, fire outbreaks, or health risks due to toxic inhalation. The sensor works on the principle of detecting changes in gas concentration and converting them into an electrical signal that can be processed by

the robot's system. It allows the robot to function autonomously in industrial areas, storage facilities, or chemical plants where gas leaks are a potential threat. Combined with the robot's patrolling capabilities, this feature ensures thorough coverage and protection of the monitored environment. By enabling early detection and response, the gas sensor significantly boosts the safety, reliability, and functionality of the intrusion detection robot. Regulated patrolling robots equipped with gas sensors can detect harmful or hazardous gases in the environment. They continuously monitor the air quality while following preset patrol routes. When dangerous gas levels are detected, the robots send immediate alerts for quick action. This automated gas detection helps prevent accidents and ensures safety in industrial or public areas. Their use reduces the need for manual inspection in risky locations.

In modern intrusion detection systems, the integration of gas sensors, flame sensors, ultrasonic sensors, and buzzers within regulated patrolling robots has significantly enhanced the capability to detect and respond to various hazards. These sensors work in unison to monitor the environment, identify potential threats, and initiate appropriate responses, ensuring safety and security in diverse settings.

Gas sensors, such as the MQ series, are designed to detect the presence of combustible gases like methane, propane, and hydrogen. These sensors operate by measuring changes in conductivity caused by gas concentration variations. When a gas leak is detected, the sensor sends a signal to the microcontroller, which then activates the buzzer and may also trigger other safety mechanisms, such as shutting down systems or alerting personnel via GSM modules. The sensitivity and quick response time of gas sensors are crucial in preventing potential explosions or health hazards.

5-CONCLUSION

In conclusion, regulated patrolling robots have proven to be a highly effective solution for intrusion detection, offering significant advantages over traditional surveillance methods. The intrusion detection system utilizing regulated patrolling robots, integrated with advanced flame sensors, gas sensors, servomotors, and buzzers, represents a significant advancement in autonomous security technology. These robots continuously patrol designated areas, using their sensor suite to detect not only unauthorized intrusions but also critical environmental hazards such as fire and gas leaks. The inclusion of flame sensors allows for early detection of fire outbreaks, while gas sensors monitor for the presence of hazardous or flammable gases, ensuring prompt identification of potentially dangerous situations. Servomotors provide precise control over the movement of cameras and sensors, enhancing the robots' ability to scan and monitor their surroundings effectively. Overall, this project demonstrates how combining regulated patrolling robots with specialized sensors and alert mechanisms can significantly enhance security infrastructure, making it adaptable, efficient, and highly effective for protecting industrial, commercial, and residential environments.

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