

Research Paper

Embedded system For Safe Exploration and Rescue Operation in Dangerous Environment

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ABSTRACT

The Embedded System for Safe Exploration and Rescue Operations in Dangerous Environments is designed to improve the safety and efficiency of rescue missions in disaster-prone and hazardous areas. The system employs a Raspberry Pi Pico-based robotic platform integrated with multiple sensors such as ultrasonic sensors, oxygen sensors, and environmental monitoring modules. It can remotely explore dangerous locations including collapsed buildings, mines, industrial accident sites, and fire-affected zones where human access is risky. The ultrasonic sensor detects obstacles and assists navigation, while the oxygen sensor monitors air quality for the presence of breathable air. Real-time information is displayed through an LCD and alert signals are generated using a buzzer when hazardous conditions are

detected. The robotic platform reduces direct exposure of rescue personnel to dangerous environments and enables rapid assessment of disaster zones. Wireless

communication and embedded intelligence improve situational awareness and support timely decision-making. The proposed system offers a reliable, cost-effective, and efficient solution for search and rescue operations, helping emergency responders locate victims and assess environmental conditions more effectively.

Keywords: Embedded System, Rescue Robot, Raspberry Pi Pico, Ultrasonic Sensor, Oxygen Sensor, Disaster Management, Hazard Detection,

Environmental Monitoring, Victim Detection, Search and Rescue.

INTRODUCTION

Natural disasters, industrial accidents, mine collapses, and fire incidents frequently create environments that are unsafe for human rescuers. Rescue personnel often face challenges such as toxic gases, unstable structures, poor visibility, and extreme temperatures while attempting to save victims. These conditions significantly increase the risk of injury and delay rescue operations. To overcome these limitations, advanced embedded systems and robotic technologies have become essential in modern disaster management. The proposed Embedded System for Safe Exploration and Rescue Operations utilizes a Raspberry Pi Pico-controlled robotic platform capable of entering hazardous areas and collecting critical environmental information. The system integrates sensors for obstacle detection, oxygen monitoring, and environmental assessment to ensure safe exploration. Ultrasonic sensors help the robot navigate through debris and confined spaces by identifying obstacles in its path. The oxygen sensor continuously monitors air quality and alerts rescue teams about unsafe conditions.

LITERATURE SURVEY

Research in rescue robotics has grown significantly due to the increasing need for safer disaster response systems. Several researchers have developed robotic platforms capable of exploring hazardous environments and transmitting real-time information to rescue teams. Search and rescue robots equipped with cameras and wireless communication systems have demonstrated effective victim detection and environmental monitoring in disaster zones. IoT-based disaster monitoring systems have enabled continuous observation of environmental parameters such as temperature, humidity, smoke, and toxic gases. Gas detection robots utilizing MQ-series sensors have been widely adopted in industrial and mining applications to detect hazardous gases and prevent accidents. Autonomous navigation techniques based on ultrasonic and infrared sensors have improved robot mobility in unknown and complex environments. Wireless surveillance robots have provided live video streaming capabilities that enhance situational awareness during rescue missions. Recent studies have emphasized the use of Raspberry Pi platforms due to their computational power and compatibility with multiple sensors and communication modules.

EXISTING SYSTEM

Existing rescue operations primarily depend on human rescue teams supported by basic monitoring equipment and manually controlled robots. In hazardous situations such as mine collapses, earthquakes, and industrial accidents, rescuers often enter dangerous environments to locate victims and assess conditions. Some systems use surveillance cameras and gas detectors to provide limited environmental monitoring. Although robotic platforms can transmit video footage and detect obstacles, they generally perform only specific tasks. Most existing systems require continuous human control and lack autonomous navigation capabilities. Environmental monitoring and victim detection are often implemented separately, reducing overall efficiency. Real-time decision-making support is limited due to inadequate sensor integration. Communication range and reliability can also be affected in complex disaster environments. These limitations increase rescue response time and expose personnel to significant risks. Therefore, a more integrated and intelligent rescue system is required.

PROPOSED SYSTEM

The proposed system introduces a Raspberry Pi Pico-based robotic platform designed for safe exploration and rescue operations in hazardous environments. The

robot integrates ultrasonic sensors, oxygen sensors, an LCD display, and a buzzer to provide comprehensive environmental monitoring. Ultrasonic sensors enable obstacle detection and safe navigation through debris-filled areas. The oxygen sensor continuously measures air quality and alerts rescue personnel when oxygen levels become unsafe. The LCD module displays real-time environmental data for monitoring purposes. A buzzer generates warning signals whenever hazardous conditions are detected. The robotic platform can access locations that are difficult or dangerous for humans to reach. Continuous monitoring allows rescue teams to assess environmental conditions before entering the area. The system improves rescue efficiency, enhances situational awareness, and reduces operational risks. Its cost-effective design makes it suitable for widespread deployment in disaster management applications.

ARCHITECTURE

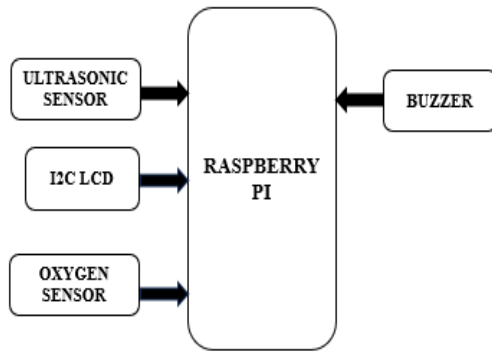


Fig: 1 Architecture of Embedded system For Safe Exploration and Rescue Operation in Dangerous Environment

The architecture of the proposed system consists of a Raspberry Pi Pico microcontroller serving as the central processing unit. The ultrasonic sensor is connected to the controller for obstacle detection and distance measurement. An oxygen sensor continuously monitors the concentration of oxygen in the environment and sends data to the controller. An I2C LCD module displays sensor readings and system status information in real time. A buzzer is integrated into the system to generate audible alerts during hazardous conditions. The Raspberry Pi Pico collects data from all connected sensors and processes it according to predefined thresholds. When abnormal conditions are detected, warning messages are displayed and alarms are activated. The controller coordinates the operation of all modules to ensure efficient system performance. The architecture supports reliable

environmental monitoring and navigation in dangerous locations. This integrated design enhances rescue effectiveness and operational safety.

MEDHOLOGY DISCRIPTION

The methodology begins with initializing the Raspberry Pi Pico and all connected sensors when the system is powered on. The ultrasonic sensor continuously measures the distance between the robot and surrounding obstacles. These measurements help the robot navigate safely through hazardous environments. Simultaneously, the oxygen sensor monitors air quality and determines whether oxygen levels are safe for human survival. The collected sensor data is processed by the microcontroller in real time. Sensor readings are displayed on the LCD module to provide immediate feedback to rescue personnel. Whenever oxygen levels fall below a predefined threshold or dangerous conditions are detected, the buzzer is activated to generate an alert. The robot continues monitoring environmental conditions while moving through the disaster area. Continuous sensing and processing enable rapid identification of hazards and potential victim locations. The integrated system improves situational awareness and assists rescue teams in planning safe operations. Environmental data is

continuously updated to ensure accurate monitoring. The robot minimizes human exposure to dangerous conditions while providing valuable information from inaccessible locations.

HARDWARE AND SOFTWARE REQUIREMENTS



Fig: 2 Raspberry Pi

The Raspberry Pi acts as the main controller and processing unit of the system. It receives data from the ultrasonic sensor and oxygen sensor for analysis. Based on the received information, it controls the output devices such as the LCD display and buzzer. The Raspberry Pi processes all sensor readings in real time and makes necessary decisions. It ensures smooth communication and coordination between all components of the rescue system.



Fig:3 LCD display

The I2C LCD is used to display sensor readings and system status information. It communicates with the Raspberry Pi through the I2C communication protocol using only two data lines. The display shows important information such as oxygen levels and obstacle distances.



Fig:4 Ultrasonic sensor

The ultrasonic sensor is used to detect obstacles and measure the distance between the robot and nearby objects. It works by transmitting ultrasonic waves and receiving the reflected echo signals. The sensor calculates the distance based on the time taken for the echo to return. This helps the robot navigate safely through hazardous environments. It plays

an important role in preventing collisions during rescue operations.



Fig: 5 Oxygen Sensor

The oxygen sensor continuously monitors the oxygen concentration in the surrounding environment. It helps identify low-oxygen conditions that may be dangerous for human survival. The sensor sends real-time oxygen level data to the Raspberry Pi for processing.



Fig: 5 Buzzer

The LED traffic signal module The buzzer functions as an alert and warning device in the system. It produces an audible sound whenever dangerous conditions are detected. The Raspberry Pi activates the buzzer when oxygen levels become unsafe or other hazards are identified. The warning sound

helps rescue teams respond quickly to critical situations. The buzzer enhances safety by providing immediate and effective alerts.

A. Arduino IDE

The Arduino Integrated Development Environment (IDE) is utilized for developing, compiling, and uploading the embedded program to the NodeMCU (ESP8266). It provides a user-friendly platform for writing code in Embedded C and supports a wide range of libraries for sensor interfacing and device control. The IDE enables efficient implementation of data acquisition, processing logic, and actuation control within the system.

RESULTS AND DISCUSSION

The implemented system successfully demonstrated safe exploration and environmental monitoring in hazardous environments. The ultrasonic sensor accurately detected obstacles and enabled safe navigation through confined spaces. The oxygen sensor effectively monitored air quality and identified unsafe oxygen levels. Real-time sensor readings were displayed on the LCD module for easy observation. The buzzer generated immediate alerts whenever hazardous conditions were detected. Experimental testing showed that the system responded

quickly to environmental changes. The integration of multiple sensors improved monitoring accuracy and operational reliability. The robotic platform reduced the need for direct human exposure to dangerous environments. Overall system performance was stable and suitable for rescue applications. The results confirm the effectiveness of the proposed embedded system in supporting search and rescue operations.

CONCLUSION

The Embedded System for Safe Exploration and Rescue Operations in Dangerous Environments provides an effective solution for improving rescue mission safety and efficiency. The system combines a Raspberry Pi Pico, ultrasonic sensor, oxygen sensor, LCD display, and buzzer into a unified platform. It enables real-time environmental monitoring and obstacle detection in hazardous areas. The robot can access locations that may be unsafe or inaccessible for human rescuers. Continuous monitoring of oxygen levels helps identify dangerous environmental conditions. Alert mechanisms provide immediate warning notifications to rescue teams. The system reduces operational risks and improves situational awareness during emergency response activities. Experimental results demonstrate reliable

performance and effective hazard detection capabilities. The proposed design is economical, practical, and suitable for disaster management applications. Therefore, the system represents a valuable contribution to modern search and rescue technology.

FUTURE SCOPE

The future scope of the project includes the integration of advanced communication technologies such as Wi-Fi, LoRa, and GSM for long-range monitoring. Additional sensors can be incorporated to detect toxic gases, smoke, humidity, and temperature. Camera modules can be added for real-time video surveillance and victim identification. Artificial Intelligence and computer vision techniques may improve automatic victim detection and environmental analysis. GPS integration can enhance location tracking during rescue missions. Autonomous navigation algorithms can be developed to reduce dependence on manual control. Cloud-based monitoring systems can provide remote access to environmental data. Machine learning models can be used to predict hazardous conditions and optimize rescue strategies. Solar-powered operation may increase system endurance in field deployments. These enhancements can transform the proposed system into a

fully autonomous and intelligent rescue platform capable of handling complex disaster scenarios.

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