STRANDBEEST:COAL MINE ROBOT FOR DETECTION OF HAZARDOUS GAS AND OBJECTS

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY IN

ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

S. PRABHAS AKHIL REDDY (A21126512112) **B. SUVARNA (A21126512068)**

G. UDAY RAHUL (A2116512080) **D. V. SAI RAMESH (A21126512076)**

UNDER THE GUIDANCE OF

Prof. V. RAJYA LAKSHMI

Head Academics Anits

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

PRAGNANAM BRAHMA

ANITS

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

(UGC AUTONOMOUS)

(Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC)

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

(UGC AUTONOMOUS)

(Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA &NAAC with A+ grade) Sangivalasa, Bheemili mandal, Visakhapatnam dist. (A.P)

CERTIFICATE

This is to certify that the project report entitled **"STRANDBEEST: COAL MINE ROBOT FOR DETECTION OF HAZARDOUS GAS AND OBJECTS"** submitted by **S. Prabhas Akhil Reddy(A21126512112),B.Suvarna(A21126512068), G.UdayRahul (A21126512080), D. V. Sai Ramesh (A21126512076)** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electronics & Communication Engineering of Anil Neerukonda Institute of technology and Sciences(A), Visakhapatnam is a record of Bonafide work carried out under my guidance and supervision.

Project Guide	Head of the Department
Prof. V. RAJYA LAKSHMI	**Dr.B. JAGADEESH**
Head Academics	M.Tech(Ph.D)Professor&HOD
Department of ECE	Department of ECE
ANITS	ANITS

Signature of External Examiner

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Project Students
S. Prabhas Akhil Reddy (A21126512112),
B. Suvarna (A21126512068),
G. Uday Rahul (A21126512080),
D. V. Sai Ramesh (A21126512076)

ABSTRACT

Worker safety in coal mines is of utmost significance, given the high likelihood of hazards in mining processes, ranging from harmful gases and unforeseen objects. Here, we report the design of an autonomous robot for detecting hazards such as gases and objects in coal mines. Based on state-of-the-art sensors, comprising gas sensors for detecting methane, carbon monoxide, and oxygen content, as well as infrared cameras to detect potential gas leaks and dangerous atmospheric pressure, temperature, and oxygen level conditions, and physical obstacles endangering worker lives, the robot can detect hazards automatically. With real-time data transmission capabilities for reporting its observations to centers in charge, it can respond instantly in emergency conditions. Its mobility system, capable of accessing tight and risky places, can detect hazards in difficult-to-reach and risky locations, improving the efficiency and effectiveness of hazard identification. This robot is expected to greatly increase worker protection through reduced exposure to risky scenarios and offer an active, sturdy approach to hazard identification and risk mitigation in coal.

KEYWORDS: Autonomous Robot, Safety in Coal Mines, Detection of Hazardous Gas, ObstaclDetection.

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CHAPTER -1 INTRODUCTION

1.1 INTRODUCTION:

The Internet of Things (IoT) facilitates communication between machines via the internet, with diverse applications across sectors like smart buildings, transport, power, business, health, and environment. IoT technology stores sensor data in the cloud for easy accessibility and employs sensors, actuators, and cloud-based analytics for data collection and distribution. It enhances efficiency in various domains such as agriculture, health, and smart homes. Cloud computing's features like on-demand service delivery, connectivity, resource pooling, and elasticity support IoT operations. In India, there are 493 coal mines, highlighting the significance of coal as a global commodity for energy production. However, coal mining poses risks to workers due to mishaps caused by outdated equipment and poor lighting conditions. To address these challenges, a coal mine protection system has been developed, utilizing sensor data analysis via the ThingSpeak system and control mechanisms powered by the NODEMCU microcontroller. This system aims to mitigate risks and enhance safety for coal miners.

Embedded systems are specialized computer systems designed to perform specific tasks or functions within a larger system. Unlike general-purpose computers, embedded systems are dedicated to particular applications, offering optimized performance, reliability, and efficiency. These systems integrate hardware and software to control devices, often in real-time, and are found in a wide range of applications, from household appliances and automotive systems to industrial machines and medical devices.

Key characteristics of embedded systems include:

- Specific Functionality: Designed to perform a singular or limited range of tasks.
- Real-time Operations: Many embedded systems operate under strict time constraints.
- Compact Size: Typically smaller in size and highly integrated

  Low Power Consumption: Optimized for energy efficiency.
- Reliability: Built to operate continuously and robustly in various environments.
- Examples include microcontrollers in washing machines

1.2 PREFACE:

A coal mine is an underground tunnel system. There only a few pitheads on ground. If there are some accidents, people are easily trapped in tunnel and often cannot escape from it. It has dangerous accidents as collapse, gas explosion, CO, CO2 poison gas, low O2 content, high temperature, smoke, coal dust, fire, water, etc. All these accidents can kill people easily. CH4 gas is intergrowth with coal. When coal is mined, CH4 gas is released. Gas is pushed off by forced ventilating system. But if the ventilating system is faulty or gas is leaked from coal layer, gas diffuses throughout the tunnel. A flame current can cause a heavy gas explosion. Mine tunnel passageway is narrow, so the explosion wave can destroy any thing in the tunnel. All devices and people may be affected, and the gas of CH4, CO, CO2 and coal dust are filled in the tunnel, and the environment of the tunnel comprises of low O2 content and high temperature**.** Besides, the forced ventilate system has been damaged, the gases cannot be push out and gets accumulated in tunnel. A fire may cause a second explosion. People in tunnel could be poisoned by CO, stifled by CO2 and low O2 content, high temperature and coal dust. Rescuers on ground daren't go into explosion mine tunnel. Because situation is not known, any one may be killed by second explosion. So detect of mine tunnel situation is the first mission to the rescuers. Robot is an ideal tool in coal mine disaster. The robot used in coal mine tunnel must have many special characters which are different from other robots on ground. Coal mine tunnel is a special environment. The first problem is explosion gas is everywhere in tunnel. Any fire can cause an explosion. Robot must be designed as a flame-proof device to avoid malfunction of components. The second problem is the mine have narrow tunnel and rugged. The middle of the tunnel is railway. One side of the railway is belt transmission. The other side is a narrow road on coal. The mine passageway is filled with many obstacles and rugged coal road, so it is difficult to move on the mine tunnel. But various obstacles must be crossed. Communication is another difficult problem in mine tunnel because electromagnetic wave is absorbed and echoed in a coal tube. Because of many corners in the tunnel, Wave cannot cross these corners easily.

1.3PURPOSE:

The Coal Mine Detection using IoT aims to enhance safety in coal mines by detecting hazards and alerting in real-time. It utilizes IoT to monitor parameters like gas levels, temperature, and objects activity. Key goals include improving safety, operational efficiency, compliance, and cost- effectiveness. It enables data collection and analysis for better decision-making and predictive maintenance, offers real-time monitoring for quick responses to emergencies, and supports remote operation to reduce physical presence in hazardous areas. Overall, the system aims to create a safer, more efficient, and technologically advanced mining environment.

1.4 SCOPE:

The scope of a Coal Mine Detection of harmful gases and objects using IoT is extensive, covering safety, efficiency, and environmental monitoring in coal mining operations. It includes gas detection for preventing explosions or health hazards, continuous monitoring of temperature ensure optimal working conditions. The system also monitors equipment health to prevent breakdowns, tracks miners' locations for safety and rescue operations monitors environmental parameters to comply with regulations and minimize environmental impact. Data analytics are used to identify patterns, trends, and hazards for optimizing mining operations, while a communication network and alerting system ensure quick notification during emergencies. Integration with other mine systems enhances overall safety and efficiency

1.5MOTIVATION:

The development of a Coal Mine Detection and Alerting System using IoT is motivated by the urgent need to enhance safety, efficiency, and sustainability in coal mining operations. This initiative arises from several key drivers: firstly, the system addresses safety concerns inherent in coal mining, such as gas explosions and roof collapses, by providing early hazard detection and alerts. Secondly, it ensures compliance with stringent regulatory standards, fostering a safe working environment and avoiding penalties. Thirdly, by continuously monitoring environmental conditions, equipment health, and personnel location, the system boosts operational efficiency, preventing costly breakdowns and optimizing workflows. Moreover, it contributes to environmental protection by monitoring and mitigating the impact of mining activities on air and water quality.

Additionally, the system offers significant cost savings in the long term, through accident prevention and operational optimization

Lastly, its adoption represents a technological advancement in the industry, demonstrating a commitment to innovation and improving mining practices.

1.6FUNDAMENTAL CONCEPTS:

The foundation of a Coal Mine Detection of objects and harmful gases using IoT rests on monitoring, detection, communication, and automation principles. Key fundamentals include deploying a sensor network throughout the mine to monitor parameters like gas levels, temperature, and equipment health. Real-time data collection enables

Continuous monitoring, with analysis identifying potential hazards or equipment malfunctions. An alerting system notifies miners and authorities of emergencies, utilizing alarms or mobile notifications. Robust communication infrastructure ensures seamless data transmission, while automation allows the system to take predefined actions in response to detected hazards, such as equipment shutdown or evacuation procedures initiation.

CHAPTER 2

LITERATURE SURVEY

LITERATURE SURVEY

The development of robots for hazardous environments, such as coal mines, has been a significant area of research due to the inherent dangers and complexities involved in mining operations. The Strandbeest robot, inspired by the kinetic sculptures of Theo Jansen, has been adapted for various applications, including the detection of objects and gases in coal mines. This essay surveys the literature on the Strandbeest robot and its applications in coal mine detection.

In the year 200AD the china maker Zhunge Liang was designed a walking mechanism i.e Wooden ox, a transport vehicle used for military supply. Something it refers to the wheel barrow. In the year 1770 the UK maker Richard Edge worth was designed a walking mechanism i.e A wooden horse with eight legs, capable of leaping over high walls. In spite of forty years work and hundreds of models, he was never able to make the idea work. In this year 1968 the U.S.A maker General Electric was designed a walking mechanism i.e Walking truck. Capable of up to5 mp hand could climb over large obstacles. In this year 1976 U.S.A maker Frank & McGhee was designed a walking mechanism i.e “Phony Pony”. First computer-controlled walking machine.

2.1 OVERVIEW OF STRANDBEEST ROBOTS

Strandbeest robots are known for their unique design, which mimics the movement of animals using wind power and mechanical .These robots are typically lightweight, modular, and capable of traversingvarious terrains. The adaptability of Strandbeest robots makes them suitable for exploration and detection tasks in challenging environments like coal mines.

2.1 APPLICATIONS IN COAL MINE DETECTION

- Object Detection: Coal mines are prone to collapses and other hazards that can trap miners and equipment. Strandbeest robots equipped with sensors and cameras can navigate through narrow tunnels, detect obstacles, and provide real-time data to rescue teams. This capability enhances the safety and efficiency of rescue operations.

- Gas Detection: One of the most critical aspects of coal mine safety isthe detection of hazardous gases such as methane (CH_4), carbon monoxide (CO), and carbon dioxide (CO_2). Strandbeest robots can be equipped with gas sensors to monitor the air quality in real-time. This information is crucial for preventing explosions and ensuring the safety of miners.

2.2 CONCLUSION

The Strandbeest robot represents a promising solution for enhancing safety and efficiency in coal mines. Its adaptability, combined with advanced sensors and navigation algorithms, makes it an ideal candidate for detecting objects and hazardous gases in these challenging environments. Future research will likely focus on further improving the robot's capabilities and expanding its applications in other hazardous environments

CHAPTER 3
SYSTEM ANALYSIS

SYSTEM ANALYSIS

3.1 INTRODUCTION

Coal mining is a vital industry that plays a significant role in meeting the global energy demand. However, it is also fraught with numerous safety hazards, particularly due to the presence of harmful gases such as methane (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). These gases can accumulate in confined spaces, posing serious risks of explosions, asphyxiation, and long-term health issues for miners. Traditional methods of gas detection and monitoring often rely on stationary sensors and manual inspections, which can be insufficient in dynamic and challenging underground environments. This can lead to delayed responses to gas leaks and increased risks to miner safety.

In response to these challenges, the development of an innovative robotic solution, the STRANDBEEST: Coal Mine Robot for Detection of Hazardous Gas and Objects, aims to enhance safety and operational efficiency in coal mining operations. Inspired by the kinetic sculptures of artist Theo Jansen, the STRANDBEEST robot features a unique legged design that allows it to navigate the rugged and uneven terrain of coal mines while simultaneously detecting harmful gases.

This robot is equipped with advanced multi-gas sensors that provide real- time monitoring of air quality, enabling immediate detection of hazardous gas concentrations. Its autonomous navigation capabilities allow it to traverse complex environments without human intervention, reducing the need for personnel to enter potentially dangerous areas.

Additionally, the robot is designed to communicate wirelessly with a central monitoring system, providing operators with critical data and alerts regarding gas levels and environmental conditions.

The introduction of the STRANDBEEST robot represents a significant advancement in the use of robotics and automation in the mining industry. By integrating innovative technology with a focus on safety, this robotic solution aims to protect the health and well-being of miners while improving operational efficiency. In the following sections, we will explore the system's requirements, components, functionalities, and the potential impact of the STRANDBEEST robot on coal mining operations

3.2 PROBLEM STATEMENT

Coal mining operations are inherently dangerous due to the presence of hazardous gases such as methane (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). These gases can accumulate in confined spaces, leading to severe safety risks, including explosions, asphyxiation, and long-term health issues for miners. Traditional gas detection methods, which often rely on stationary sensors and manual inspections, are insufficient in addressing the dynamic and challenging conditions of underground mining environments.

The primary challenges faced in coal mines include:

- **Inadequate Gas Monitoring:** Existing gas detection systems may not provide comprehensive coverage, leaving certain areas of the mine unmonitored. Stationary sensors can miss gas accumulations in remote or hard-to-reach locations.**Delayed Response to Hazards:** Manual monitoring and reporting can result in delays in identifying and responding to hazardous gas levels. This can lead to dangerous situations where miners are exposed to harmful gases for extended periods.
- **Limited Mobility and Accessibility:** The rugged and uneven terrain of coal mines makes it difficult for conventional robotic systems to navigate effectively. This limits their ability to perform inspections and monitor air quality in areas that are not easily accessible.
- **Human Exposure to Risks:** The reliance on human personnel to conduct gas monitoring in potentially dangerous areas exposes them to unnecessary risks, increasing the likelihood of accidents and injuries situations where miners are exposed to harmful gases for extended periods.
- **Limited Mobility and Accessibility:** The rugged and uneven terrain of coal mines makes it difficult for conventional robotic systems to navigate effectively. This limits their ability to perform inspections and monitor air quality in areas that are not

easily accessible.

- **Human Exposure to Risks:** The reliance on human personnel to conduct gas monitoring in potentially dangerous areas exposes them to unnecessary risks, increasing the likelihood of accidents and injuries.

3.3 EXISTING SYSTEM

The current systems used for gas detection and monitoring in coal mines primarily rely on a combination of stationary sensors, manual inspections, and traditional safety protocols. While these systems have been effective to some extent, they present several limitations that can

compromise the safety and efficiency of mining operations. Below are the key components and characteristics of existing systems:

3.3.1 Stationary Gas Detection Systems

- **Description:** Fixed gas detection sensors are installed at various locations within the mine to monitor air quality and detect harmful gases such as methane (CH_4) and carbon dioxide (CO_2).
- **Limitations:**

Limited Coverage: Sensors are often placed in specific areas, which may leave other parts of the mine unmonitored and vulnerable to gas accumulation.

Inability to Adapt: Stationary sensors cannot move to areas where gas concentrations may change or where new hazards may arise, leading to potential blind spots.

3.3.2 Manual Monitoring and Inspections

- **Description:** Miners or safety personnel conduct regular inspections and use handheld gas detectors to check for harmful gas levels in different areas of the mine.
- **Limitations:**

Human Error: Manual monitoring is subject to human error, which can lead to missed detections or delayed responses to hazardous conditions. **Safety Risks:** Personnel entering potentially dangerous areas expose themselves to the very hazards they are monitoring, increasing the risk of accidents.

3.3.3Alarm Systems

personnel when gas concentrations exceed safe levels.

- **Limitations:**

Delayed Response: Alarms may not provide immediate information about the location and extent of gas accumulation, leading to delayed evacuation or response efforts.

False Alarms: Inaccurate readings can lead to unnecessary evacuations and disruptions in mining operations, causing operational inefficiencies.

3.3.3 Data Logging and Reporting

- **Description:** Data from gas sensors is often logged for later analysis, and reports are generated periodically to assess air quality.
- **Limitations:**

Lack of Real-Time Data: Delays in data reporting can hinder timely decision-making and response to hazardous conditions.

Limited Analysis: Manual data analysis may not provide comprehensive insights into gas trends and patterns, making it difficult to predict potential hazards.

3.3.4 Regulatory Compliance

- **Description:** Mining operations must comply with safety regulations that mandate regular monitoring and reporting of air quality.
- **Limitations:**

Compliance-Driven Approach: Existing systems often focus on meeting regulatory requirements rather than proactively enhancing safety and efficiency, which can lead to a reactive rather than proactive safety culture.

3.4 PROPOSED SYSTEM

The proposed system involves the development of the STRANDBEEST: Coal Mine Robot for Detection of Hazardous Gas and Objects. This innovative robotic solution is designed to enhance safety and operational efficiency in coal mining operations by integrating advanced gas detection technology with autonomous navigation capabilities. Below are the key components, features, and functionalities of the proposed system:

3.4.1 Robotic Platform Design Legged Mobility:

The robot will utilize a unique legged design inspired by the Strandbeest, allowing it to traverse uneven and rugged terrain commonly found in coal mines. The leg mechanism will be engineered for stability and agility, enabling the robot to navigate obstacles and adapt to changing environments.

- **Lightweight and Durable Materials:**

The use of lightweight materials (e.g., carbon fiber or advanced polymers) will enhance the robot's mobility and reduce energy consumption while ensuring durability in harsh mining conditions.

- **Gas Detection System:**

Sensors will utilize technologies such as electrochemical sensors, infrared sensors, or TDLAS (Tunable Diode Laser Absorption Spectroscopy) for high sensitivity and accuracy.

- **Real-Time Monitoring:**

The gas detection system will provide continuous real-time monitoring of air quality, allowing for immediate detection of hazardous gas concentrations and timely alerts to operators.

*3.4.*2Autonomous Navigation and Control Autonomous Movement:

The robot will be equipped with autonomous navigation capabilities, allowing it to move through the mine without human intervention. Obstacle detection and avoidance algorithms will be implemented using sensors such as LIDAR, ultrasonic sensors, or cameras to ensure safe navigation.

- **Microcontroller and Software:**

A microcontroller (e.g., Raspberry Pi or STM32) will be used to process sensor data, control movement, and execute navigation algorithms.

Custom software will be developed for data analysis, decision- making, and communication with the ***central*** monitoring system.

3.4.3 SafetyFeatures Integrated Alarm System:

An intelligent alarm system will notify operators of hazardous gas levels, providing both visual and audible alerts.

The system will include redundancy features to ensure reliability in case of sensor failure.

- **Emergency Protocols:**

The robot will be programmed with emergency protocols to follow in the event of detecting dangerous gas levels, such as retreating to a safe area or returning to a designated base station.

- **Testing and Validation Prototype Development:**

A **prototype** of the robot will be developed and tested in controlled environments to evaluate its performance in gas detection and navigation.

- **Field Trials**:

Field trials will be conducted in actual coal mine environments to assess therobot's effectiveness, gather feedback from mining personnel, and refine the design and functionality.

3.5KEY FEATURES AND FUNCTIONALITY OF THE STRANDBEEST:

Coal Mine Robot for Detection of Hazardous Gas and Objects. The STRANDBEEST robot is designed to enhance safety and operational efficiency in coal mining operations through a combination of advanced technologies and innovative design.

3.6CHALLENGES AND CONSIDERATIONS

Technical Challenges:

Ensuring sensor accuracy and reliability in harsh mining conditions. Developing robust navigation algorithms to handle complex environments.

- **Operational Challenges**:

Integrating the robot with existing mine infrastructure and safety protocols. Training personnel to operate and maintain the robot effectively.

- **Safety and Regulatory Considerations:**
- Compliance with mining safety regulations and standards.
  Developing emergency protocols for the robot in case of system failures.

CHAPTER 4

SYSTEM REQUIREMENTS SPECIFICATION

SYSTEM REQUIREMENTS SPECIFICATION

SOFTWARE REQUIREMENTS SPECIFICATION (HRS) FOR STRANDBEEST COAL MINE ROBOT

4.1.1 Introduction

This section outlines the software requirements for the *Strandbeest Coal Mine Robot*. The software will handle the robot's navigation, sensor data processing (including gas detection), communication with the central monitoring system, and decision-making processes.

- **System Overview**

The software will be responsible for:

Managing sensor data (e.g., gas concentration and object detection). Processing environmental data for autonomous navigation.

Communicating with the central monitoring system for data transmission and alerts.

Managing robot health and safety functions (e.g., battery level monitoring, emergency stops).

4.1.2 Functional Requirements

- **Gas Detection and Monitoring Software Sensor Integration:**

The software must interface with electrochemical or infrared sensors for gas detection (e.g., methane, carbon monoxide, CO_2).

It must continuously collect data from these sensors at intervals of ≤ 1 second.

- **Threshold Management:**

Users must be able to set configurable gas concentration thresholds for different gases (e.g., alert levels for methane).

The software should trigger an alert if gas concentrations exceed predefined safe levels.

- **Real-time Monitoring:**

The software should visualize gas concentration levels on a graphical user interface (GUI) in real time.

Alerts and notifications should be triggered when dangerous gas levels are detected.

Obstacle Detection and Navigation Software Sensor Integration:

The software should collect data from object detection sensors (e.g., LiDAR, ultrasonic sensors, cameras) to detect obstacles in the robot's path.

The data should be processed to recognize obstacles such as fallen debris, rocks, or equipment.

- **Pathfinding and Mapping:**

The software must implement algorithms for autonomous navigation using real-time sensor data (e.g., SLAM – Simultaneous Localization and Mapping).
The software should enable the robot to create and update a map of the mine environment as it moves, allowing it to navigate around obstacles in real-time.

- **Collision Avoidance:**

The system must be able to stop or re-route the robot if an obstacle is detected within a critical distance (e.g., 0.5 meters).
The software should include a failsafe to stop robot motion when hazardous obstacles are detected (e.g., a large rock blocking the path).

- **Communication Software Wireless Communication:**

The robot must communicate wirelessly with the central monitoring system. The software should manage communication protocols (e.g., Wi-Fi, Zigbee, or other underground communication technologies).
The software must ensure the transmission of real-time data, including gas levels, robot status, location, and sensor diagnostics.

4.1.3 Data Logging:

The software must continuously log critical data for analysis and reporting.This includes gas concentrations, sensor data, robot status, and navigation history.In the event of communication failure, the robot should store data locally and transmit it once a connection is re-established

- **Robot Health and Safety Software Battery Monitoring:**

The software should monitor the robot's battery level in real-time.

It should trigger an alert to the control station when the battery is critically low (e.g., < 20%)

and, if applicable, automatically direct the robot to a charging station.

- **Emergency Stop:**

In case of critical failures (e.g., gas leak detection or obstacle collision), the software should initiate an immediate emergency stop.

It should also send a signal to the control station with a reason for the stop (e.g., "Critical gas leak detected" or "Obstacle encountered").

- **Diagnostics:**

The software should continuously monitor the status of all major components (sensors, motors, battery, communication systems).

It should provide diagnostic reports that include any detected issues and recommend actions for maintenance.

4.1.4 User Interface Software

- **Control and Monitoring Interface:**

The central monitoring system should feature a graphical user interface (GUI) that provides: Real-time gas levels for all detected gases.

A map of the mine with the robot's location and path shown in real-time. A log of robot ovements and gas detection events.

Alerts for gas levels, obstacles, and robot status changes.

- **Alert System:**

The interface should feature visual (e.g., red/yellow indicators) and audio
some extent, they present several limitations that can
compromise the safety and efficiency of mining operations. Below are the key components and characteristics of existing systems:

--Stationary Gas Detection Systems

- **Description:** Fixed gas detection sensors are installed at various locations within the mine to monitor air quality and detect harmful gases such as methane (CH_4) and carbon dioxide (CO_2).
- Limitations:

Limited Coverage: Sensors are often placed in specific areas, which may leave other parts of the mine unmonitored and vulnerable to gas accumulation.

Inability to Adapt: Stationary sensors cannot move to areas where gas concentrations may change or where new hazards may arise, leading to potential blind spots.

--Manual Monitoring and Inspections

- **Description:** Miners or safety personnel conduct regular inspections and use handheld gas detectors to check for harmful gas levels in different areas of the mine.
- **Limitations:**

Human Error: Manual monitoring is subject to human error, which can lead to missed detections or delayed responses to hazardous conditions.

Safety Risks: Personnel entering potentially dangerous areas expose themselves to the very hazards they are monitoring, increasing the risk of accidents.

3.4.2 Alarm Systems

Description: Alarm systems are integrated with gas sensors to alert The software must allow the user to configure gas thresholds, navigation paths, and other key parameters.

Settings and Configuration:

The interface should allow mine operators to adjust settings, including: Gas concentration thresholds.

Robot path planning (if applicable).

Update communication preferences and diagnostic settings.

4.1.5 Non-Functional Requirements Performance

- **Real-time Data Processing:**

The system must process sensor data with a maximum latency of 1 second to ensure real-time monitoring and navigation.

- **Reliability:**

The software must be highly reliable, with error detection and recovery mechanisms.
It should be capable of running for extended periods (8+ hours) without crashes or system downtime.

- **Scalability**

The software should be designed to scale for future expansions. More robots or additional

sensors should be able to be added with minimal changes to the existing system.
The monitoring system should be able to handle multiple robots deployed across large mining sites.

Security

Data Encryption:

All communication between the robot and the control station should be encrypted to ensure data security and prevent unauthorized access.

- **Conclusion:**

This software specification defines the software requirements for the Strandbeest Coal Mine Robot, ensuring that it meets all functional, non- functional, and safety requirements for gas and object detection, autonomous navigation, and communication with the central monitoring system. The software will support the robot's role in enhancing mine safety through real-time hazard detection and effective decision-making.

4.2 HARDWARE REQUIREMENTS SPECIFICATION (HRS) FOR STRANDBEEST COAL MINE ROBOT

4.2.1 Hardware Components

Microcontroller (Arduino UNO ATmega328P):
The robot will require a robust, industrial-grade embedded computer or microcontroller to handle sensor data processing, real-time navigation, and communication.

Requirements:

Processor: Quad-core ARM-based processor or equivalent, with a clock speed of at least 1.5 GHz.
Memory: Minimum 4 GB RAM.
Storage: 32 GB of non-volatile storage (e.g., SSD or flash storage).

Operating System: Linux or a real-time operating system (RTOS) compatible with the robotic

Figure 4.2.1 Arduino

Interfaces: Multiple GPIO, serial, and I2C interfaces for connecting sensors.

4.2.1.1 Gas Detection

Sensor (MQ9) Types of Sensors:

The robot should be equipped with multiple gas sensors for detecting various hazardous gases in the mining environment, including:

Methane (CH_4) Sensor

Carbon Monoxide (CO) Sensor Carbon Dioxide (CO_2) Sensor

- Requirements:

Sensor Type: Electrochemical or infrared sensors for accurate gas detection. Detection Range:
Methane: 0 to 100% LEL (Lower Explosive Limit) Carbon Monoxide: 0 to 1000 ppm
Carbon Dioxide: 0 to 5000 ppm
Response Time: ≤ 5 seconds for gas detection. Accuracy: ±5% of full scale for all gases.

Power Consumption: Low power consumption (around 50mW per sensor).

- **Obstacle Detection (IR Sensor):**

Types of Sensors:

The robot will be equipped with various sensors for obstacle detection and navigation:LiDAR: To create 3D maps of the robot's environment and detect obstacles at long range.

Ultrasonic Sensors: For close-rang obstacle detection and collision avoidance.

Requirements:

Ultrasonic Sensors: Range from 0.2 meters to 5 meters, with a minimum of 4 sensors for front, back, left, and right detection.

Power Consumption: Low power (LiDAR < 5W, Ultrasonic < 1W, Cameras

< 5W).

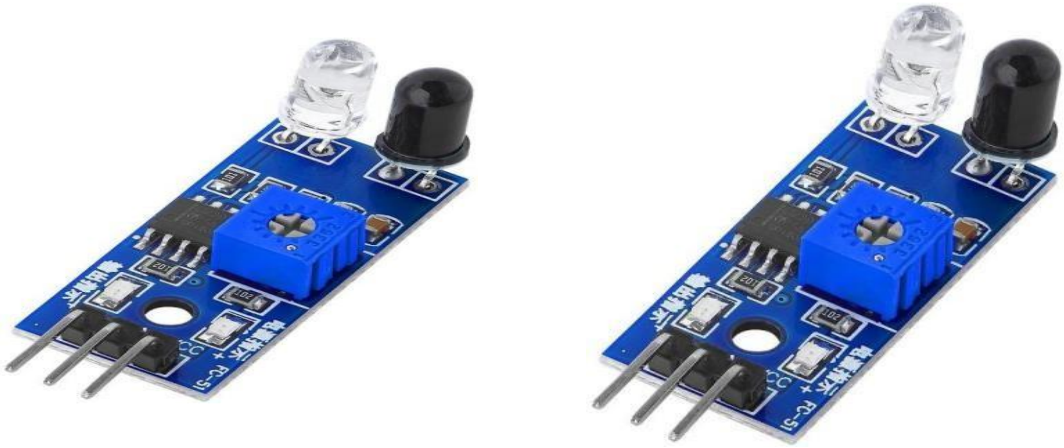


Figure 4.2.3 IR **Sensor**

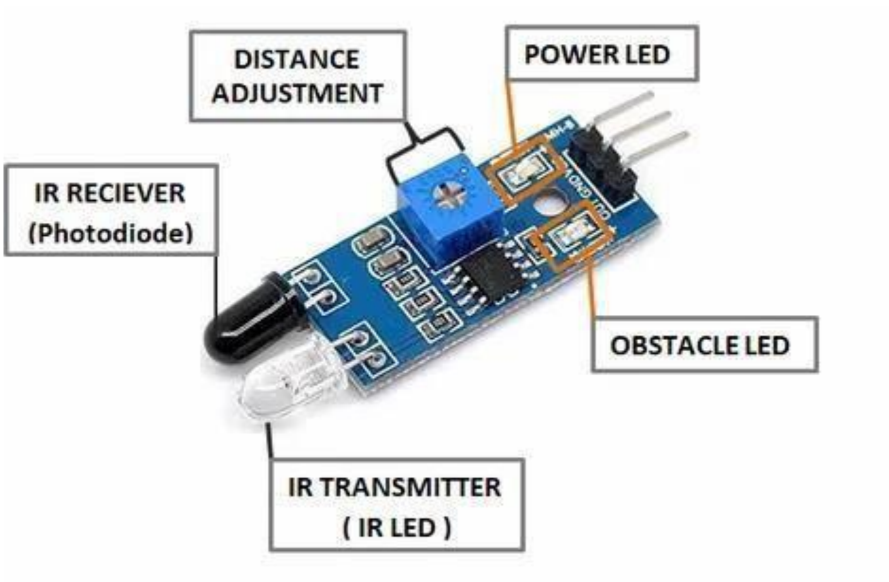


Figure 4.2.4 IR **Sensor**

- **Mobility and Locomotion Wheels/Tracks:**

The robot will need a robust locomotion system to navigate through rough underground terrain. This can be achieved through either wheels or tracks.

Requirements:

Drive System: A 4WD or 6WD system with electric motors for mobility. Tracks: Durable rubber or metal tracks for stability on rough terrain.

Speed: Maximum speed of 1 m/s.
Torque: Sufficient torque to handle uneven surfaces and climb slight inclines (up to 20-degree slope).
Wheelbase/Track Design:Compact design to navigate tight corridors.

- **Power Supply and Management Battery:**

The robot will need a high-capacity rechargeable battery to ensure long operation times without frequent recharging.

*R*equirements:

Battery Type: Lithium-ion or lithium-polymer battery with high energy density.
Capacity: Minimum 15,000 mAh (for up to 8 hours of operation). Voltage: 12V to 24V DC.
Power **Consumption**: Average consumption of 20W, with peaks up to 40W during active operation.
Charging: Capability to charge autonomously at a charging station or base station.

Power Management:

The robot should have a power management system to monitor battery levels, manage charging cycles, and protect against overcharging or deep discharging.

Requirements:

Battery Life Monitoring: Integrated monitoring system with low- battery warning.

- **Communication Hardware**

Wireless Communication (HM-10 Bluetooth Module):

The robot must be capable of communicating wirelessly with a central monitoring station in the mine.

Communication Range: At least 100 meters in open space, with the ability to operate in confined underground environments.

Data Transmission: Secure, low-latency data transmission for real- time monitoring of gas levels, robot location, and status.

4.2.1.2 Safety and Emergency Systems

Emergency Stop Mechanism: The robot should include a physical emergency stop button or software-based emergency stop to halt all activities immediately in case of malfunction or hazard detection. **Requirements:**

Physical Stop: A physical emergency stop button on the robot.

Software Stop: Automatic shutdown when critical hazards are detected (e.g., hazardous gas detection or collision).

Temperature Range: Operational in temperatures ranging from - 20°C to 50°C. Durability: Rugged construction to survive minor collisions and impacts.

Interfaces and Integration Sensor Interface:

The hardware must support various sensor interfaces, including I2C, UART, and analog/digital inputs, to connect to the gas sensors, LiDAR, ultrasonic sensors, and cameras.

Robot Control Interface:

The embedded computer must support control over the mobility and sensor systems, including motor drivers for the wheels/tracks and power

Charging and Docking Interface:

The robot should be able to autonomously connect to a charging station using a standardized docking interface.

- ## Assumptions and Constraints

The robot will be deployed in hazardous underground coal mines where high levels of dust, humidity, and potentially explosive gases may be present.

The robot must operate for extended periods without human intervention, with a minimum 8-hour operational window.

All hardware components should be compliant with mining safety standards such as MSHA.

- ## Conclusion

This hardware specification defines the essential components required for the *Strandbeest Coal Mine Robot*. The robot will need a robust set of sensors, mobility systems, power management, communication hardware, and safety features to operate autonomously in challenging underground coal mine environments. The hardware should be durable, efficient, and reliable to ensure continuous safety monitoring and ha

CHAPTER 5
SYSTEM DESIGN

SYSTEM ANALYSIS

5.1 INTRODUCTION

The Strandbeest Coal Mine Safety Robot is an autonomous robotic system designed to improve safety in coal mines by detecting hazards such as gas leaks, cave-ins, and structural weaknesses. Inspired by Theo Jansen's Strandbeest, it uses legged locomotion for superior mobility on rough terrain.

System analysis evaluates its design, functionality, and performance, ensuring compliance with safety standards and operational efficiency.

Key aspects include:

- **Functional Analysis**: Sensing, autonomous movement, and hazard detection.
- **Structural Analysis**: Stability and durability in mine conditions.
- **Software & AI**: Decision-making and communication with control centers.
- **Safety Compliance**: Adherence to mining safety regulations. This analysis ensures the robot operates effectively, reducing risks to human miners and enhancing overall safety in coal mining operations.

5.2 REMENT CHART

Parameter	**Specification**	**Remarks**
Height	~1.5 - 2 meters	Adjustable based on mine tunnel size
Length	~2 - 3 meters	Ensures stability in uneven terrains

Weight	~50 - 100 kg	Lightweight for better maneuverability
Locomotion Type	Legged (Strandbeest-inspired)	Better adaptability on rough surfaces
Material	High-strength alloys, carbon fiber	Ensures durability in extreme conditions
Sensors	Gas, temperature, motion, pressure	Detects hazards like gas leaks & cave-ins
Battery Life	6 - 12 hours	Rechargeable; depends on operation load
Speed	~0.5 - 1.5 m/s	Optimized for stability over speed
Communication	Wireless (Wi-Fi, Bluetooth, RF)	Real-time data transmission
Payload Capacity	~10 - 20 kg	Can carry additional tools or sensors

Table 1 Measurement Chart

This chart provides a concise overview of the Strandbeast coal mine safety robot's key measurements and capabilities, ensuring effective deployment in mining environments

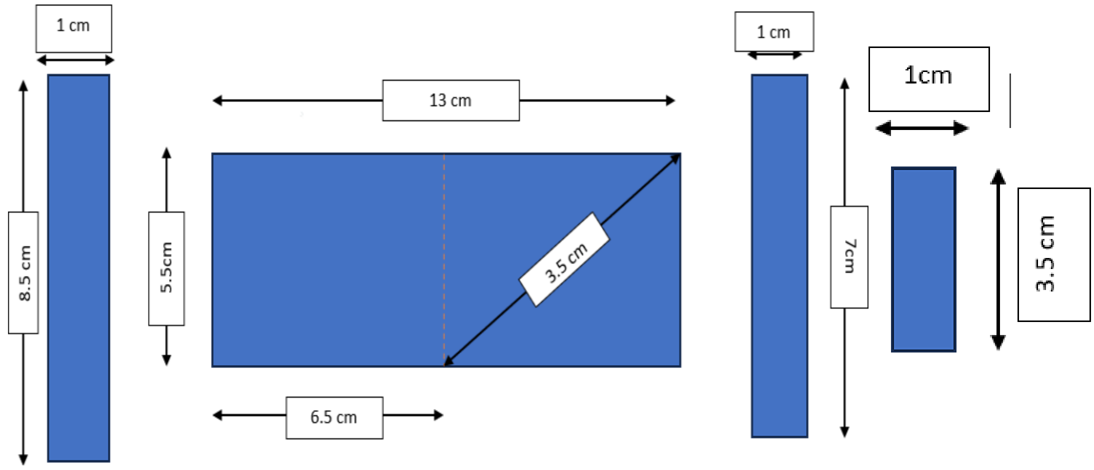


Figure 5.2 Measurement Chart

5.3 INTERFACING OF MOTORS TO ARDUINO UNO

To control the legged movement, motors are interfaced with an Arduino Uno using a motor driver.

Components:

- Arduino Uno (controller)
- DC/Stepper/Servo Motors (for movement)
- Motor Driver (L298N/L293D) (for speed & direction control)
- Power Supply (12V battery for motors, 9V for Arduino)

Connections:

- **Motor Driver to Arduino:**
  - IN1, IN2 → Digital Pins (e.g., 5, 6) (Direction control)
  - ENA → PWM Pin (e.g., 9) (Speed control)
  - VCC, GND → Power source
- **Motors to Driver:**
  - Motor A & B connected to driver outputs

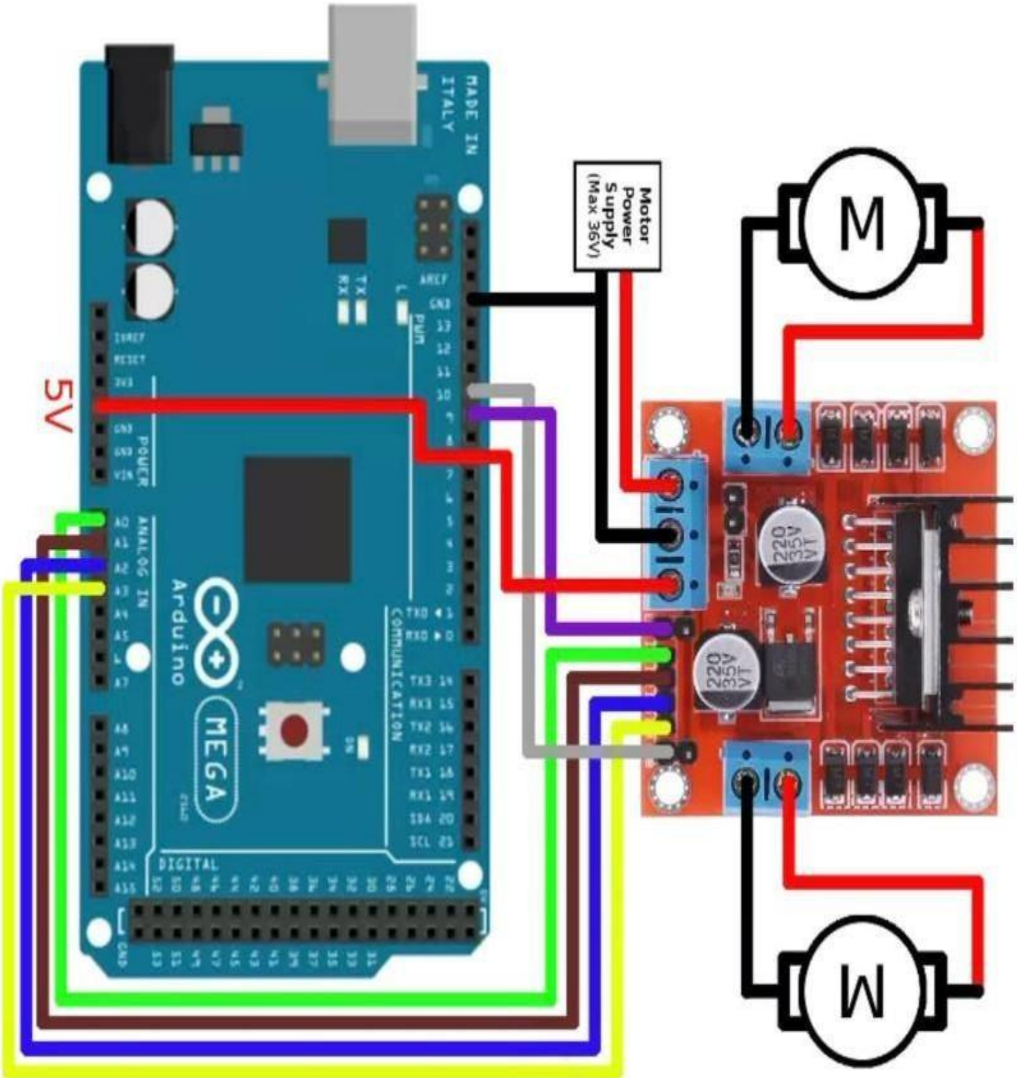


figure 5.3 DC Control

Basic Code (DC Motor Control)

```
#define ENA 9
#define IN1 5

{

pinMode(ENA, OUTPUT);

pinMode(IN1, OUTPUT);

pinMode(IN2, OUTPUT);

}

void loop() {
digitalWrite(IN1,                HIGH);

digitalWrite(IN2,                LOW);

analogWrite(ENA,              150);   //

Speed control delay(2000); digitalWri

te(IN1,LO W);

digitalWri    te(IN2,HI

GH);

delay(200 0);

}
```

5.4INTERFACING OF SENSORS TO ARDUINO UNO

IR Sensor

The IR sensor helps the Strandbeest coal mine safety robot detect obstacles, navigate rough terrain, and identify hazards in dark mining environments.

Components Required:

- Arduino Uno (microcontroller)
- IR Sensor Module (e.g., IR proximity or obstacle detection)
- Jumper Wires

Connections:

- VCC → 5V (Arduino)

- GND → GND (Arduino)
- OUT → Digital Pin (e.g., 7) (Reads sensor signal)

Basic Code (Obstacle Detection)

```
#define
IR_Sens
or 7 void
setup() {
      pinMode(
  IR_Se     nsor,
  INPUT);
  Serial.begin(960
  0);
}
void loop() {
  int       obstacle       =
  digitalRead(IR_Sensor);
  if (obstacle == LOW) {
  Serial.println("Obstacle
  Detected!");
  } else {
    Serial.println("Clear Path");
  }
   Delay(500)
```

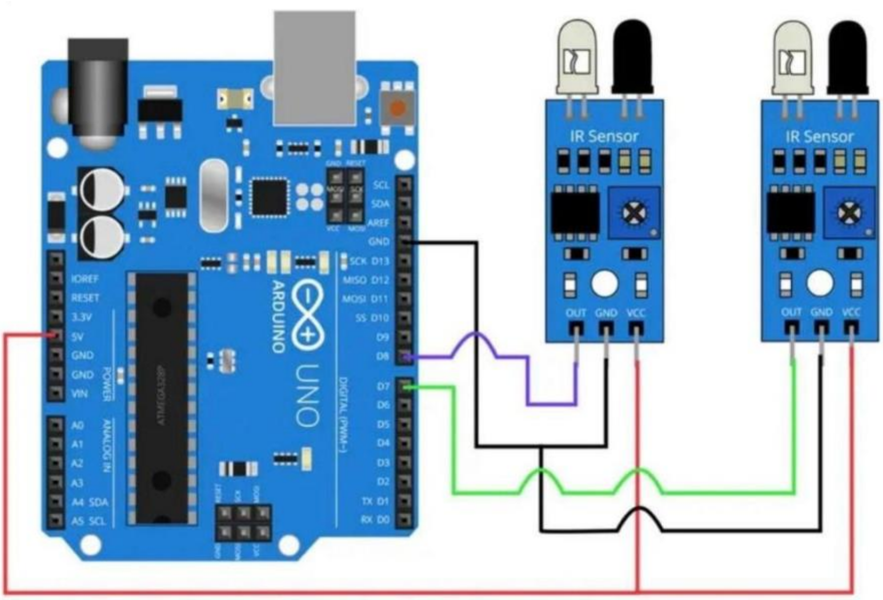


Figure 5.4.1 Interfacing of IR Sensor to aurdino uno

Gas Sensor (MQ9)

The MQ-9 gas sensor detects carbon monoxide (CO), methane (CH4), and LPG in coal mines, helping prevent hazardous gas exposure.

Components Required:

- Arduino Uno (microcontroller)

  MQ-9 Gas Sensor
- Jumper Wires

  Connections:

- VCC → 5V (Arduino)
- GND → GND (Arduino)
- A0 (Analog Output) → Analog Pin A0 (Reads gas concentration)
- D0 (Digital Output) → Digital Pin 7 (Threshold-based alert)

Basic Code (Gas Detection & Alert)

```
#define MQ9_A
0                          A0
#define MQ9_D
0 7 void setup () {
Serial.be gin (960 0);
pinMode(MQ9_D0, INPUT);
}
void loop() {
int                          gasValue          =
analogRead(MQ9_A0);  int               alert
                             =
digitalRead(MQ9_D0); Serial.print("Gas
                              Level:
");
Serial.println(gasValue); if (alert ==
LOW) {
Serial.println("Warning! High Gas Level Detected!");
}
delay(1000);
}
```

This setup enables the Strandbeest robot to detect hazardous gases and alert miners, enhancing coal mine safety.

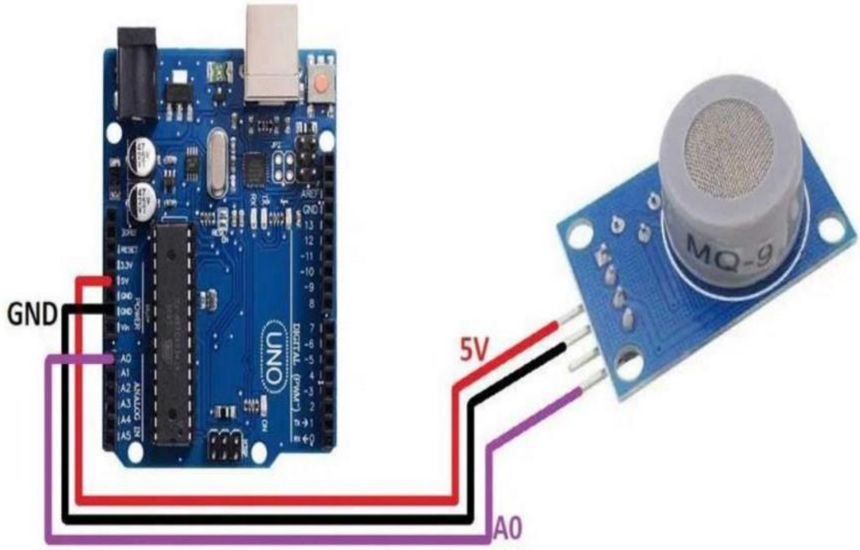


Figure 5.4.2 Interfacing of MQ9 sesnor to Aurdino Uno

5.5 INTERFACING OF BLUETOOTH MODULE TO ARDUINO UNO

The HM-10 Bluetooth module enables wireless communication between the Strandbeest robot and a remote device (smartphone or PC) for monitoring and control in coal mines.

Components Required:

- Arduino Uno
- HM-10 Bluetooth Module
- Jumper Wires

Connections:

- VCC → 5V (Arduino)
- GND → GND (Arduino)
- TX (HM-10) → RX (Arduino Pin 2 via SoftwareSerial)

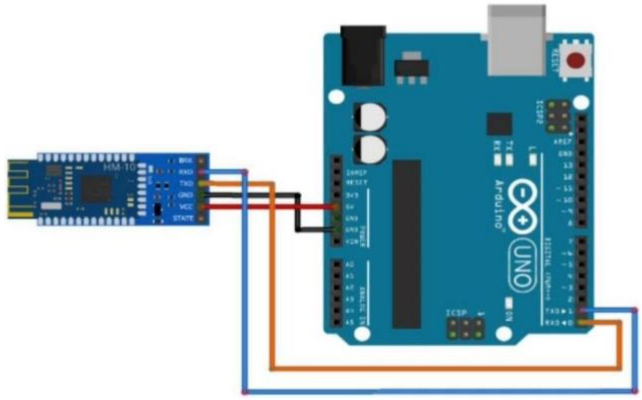


figure 8 Interfacing of Bluetooth Module To Aurdnio UNO

- RX (HM-10) → TX (Arduino Pin 3 via SoftwareSerial)

```
#include <SoftwareSerial.h> SoftwareSerial BTSerial(2, 3);

// RX, TX void setup() { Serial.begin(9600); BTSerial.begin(960

0);

}

void loop() { if

(BTSerial.available()) { char data = BTSerial.read ();

Serial.print(" Received: "); Serial.println( data);

}

if (Serial.available()) {

char
s
endData = Serial.read();

BTSerial.write(sendData);

}

}
```

This setup allows remote control and data transmission, improving coal mine safety by enabling real-time monitoring of the Strandbeest robot. 📡

CHAPTER 6
IMPLEMENTATION

6.1 INTRODUCTION

The Strand beest Coal Mine Safety Robot enhances safety and monitoring in underground coal mines using legged locomotion for better mobility on rough terrains.

Key Implementation Aspects:

- **Hardware:**
  - Arduino Uno / Raspberry Pi (Controller)
  - DC/Stepper Motors (Movement)
  - MQ-9 Gas Sensor, IR Sensors (Hazard detection)
  - HM-10 Bluetooth / Wi-Fi Module (Communication)
- ***Software:***
  - Arduino IDE & C++ (Programming)
  - Sensor data processing & motor control
  - Wireless real-time monitoring
- ***Power Management:***
  - 12V Li-ion battery for extended operation

Expected Outcomes:

- Real-time hazard detection (gas leaks, cave-ins)
- Improved mobility in unstable terrains
- Reduced risks for human workers

This robot integrates advanced robotics and IoT, ensuring safer and more efficient mining operations.

6.2 CODE FOR OBJECT DETECTION

The robot uses infrared (IR) sensors to detect and follow a line on the ground, allowing the Strandbeest Coal Mine Safety Robot to autonomously navigate pre-defined paths in a mine or test area.

Components Required:

- Arduino Uno
- 2 IR Sensors (for line detection)
- 2 DC Motors (for movement)
- Motor Driver (L298N or L293D)
- Jumper Wires

Connections:

- **IR Sensors:**

  VCC → 5V (Arduino)

  - GND → GND (Arduino)
  - OUT → Digital Pins (e.g., Pin 2 and Pin 3)

- **DC Motors:**
  - Connect to the Motor Driver (L298N), with the appropriate IN1, IN2, ENA pins connected to Arduino digital pins (e.g., Pin 4, 5, 6, 7).

- **Motor Driver (L298N):**
  - VCC → Battery (12V)
  - GND → GND (Arduino)

Code for Line Following:

```
#define rightSensor 3   // Right IR sensor pin
#define motorLeftForward 4  // Motor forward f
#define motorLeftBackward 5  // Motor A backward
 #define motorRightForward 6  // Motor B forward
#define motorRightBackward 7  // Motor backward void setup()
{
  pinMode(leftSensor, INPUT);
  pinMode(rightSensor, INPUT);
  pinMode(motorLeftForward, OUTPUT);
  pinMode(motorLeftBackward, OUTPUT);
   pinMode(motorRightForward, OUTPUT);
  pinMode(motorRightBackward, OUTPUT);
}
void loop() {
  int leftValue = digitalRead(leftSensor);  // Read left sensor
  int rightValue = digitalRead(rightSensor);  // Read right
  sensor if (leftValue == LOW && rightValue == LOW)

  {
    // Move forward digitalWrite(motorLeftForward, HIGH);
    digitalWrite(motorLeftBackward, LOW);
    digitalWrite(motorRightForward, HIGH);
    digitalWrite(motorRightBackward, LOW);
  }
  else if (leftValue == LOW && rightValue == HIGH) {
// Turn left
    digitalWrite(motorLeftForward,
```

```
    LOW);

    digitalWrite(motorLeftBackward, LOW);
    digitalWrite(motorRightForward, HIGH);
    digitalWrite(motorRightBackward, LOW);
  }
  else if (leftValue == HIGH && rightValue == LOW) {
    // Turn right digitalWrite(motorLeftForward, HIGH);
    digitalWrite(motorLeftBackward, LOW);
    digitalWrite(motorRightForward, LOW);
    digitalWrite(motorRightBackward, LOW);
  }
  else {
    // Stop
    digitalWrite(motorLeftForward, LOW);
    digitalWrite(motorLeftBackward, LOW);
    digitalWrite(motorRightForward, LOW);
    digitalWrite(motorRightBackward, LOW);
  }
}
```

6.3 CODE FOR GAS DETECTION

Components:

- Arduino (or similar microcontroller)
- MQ-9 Gas Sensor (for detecting CO, methane, LPG)
- Buzzer/LED for alert
- (Optional) Display for showing values

Wiring:

- VCC to 5V
- GND to GND
- Analog Output (A0) to analog input pin (e.g., A0)

Code:

```
const int gasSensorPin = A0;  // MQ-9 sensor analog

output const int buzzerPin = 9;  // Buzzer pin

int threshold = 300;                // Set gas concentration threshold (adjust based on testing)

void setup() {

  Serial.begin(9600);               // Start serial communication pinMode(buzzerPin,

  OUTPUT); // Set buzzer as output

}

void loop() {
  int gasValue = analogRead(gasSensorPin);  // Read sensor value Serial.println(gasValue);

  // Output to Serial Monitor

  if (gasValue > threshold) {
    digitalWrite(buzzerPin, HIGH);  // Trigger buzzer if gas level exceeds threshold

  } else {

    digitalWrite(buzzerPin, LOW);           // Turn off buzzer if safe

}

  delay(1000);  // 1-second delay for stability

}
```

CHAPTER - 7
WORKING

7.1 INTRODUCTION

In the ever-evolving field of robotics and safety engineering, innovative solutions are being developed to address the hazardous conditions of underground mining. One such innovation is the Strandbeest-inspired coal mine robot — a walking mechanical system modeled after the kinetic sculptures of Theo Jansen, designed to navigate rough and uneven terrain with ease.This working model leverages the unique legged motion of the Strandbeest to traverse narrow, debris-filled tunnels where traditional wheeled robots struggle. Equipped with advanced sensors for gas detection and object recognition, the robot acts as a smart safety scout. It can identify the presence of toxic gases such as methane (CH_4), carbon monoxide (CO), and hydrogen sulfide (H_2S), which pose significant risks to miners. Additionally, it detects physical obstructions or unstable structures, helping prevent accidents and improve operational efficiency.By integrating mechanical design, sensor technology, and automation, this project aims to create a cost-effective, adaptable, and safe robotic solution to enhance underground mining operations. The Strandbeest coal mine robot is not just a technical model — it's a step toward a safer and smarter future in mining.

7.2 WORKING PROTOTYPE

This project showcases a Strandbeest-inspired coal mine robot designed for enhanced underground safety and exploration. The robot uses a walking mechanism to move through rough and narrow mining paths where wheeled robots struggle.
It is equipped with:
Gas sensors (e.g., MQ-2, MQ-135) to detect dangerous gases like methane (CH_4), carbon monoxide (CO), and hydrogen sulfide (H_2S)

Ultrasonic or IR sensors for obstacle detection
A camera module (e.g., ESP32-CAM or Pi Camera) for real-time video monitoring or image capturing, allowing operators to visually inspect mine conditions remotely.
Controlled by a microcontroller (Arduino or Raspberry Pi) and powered by a rechargeable battery pack, the robot enhances mine safety by providing gas alerts, obstacle detection, and live visual feedback, making it a valuable tool for hazardous environment surveillance

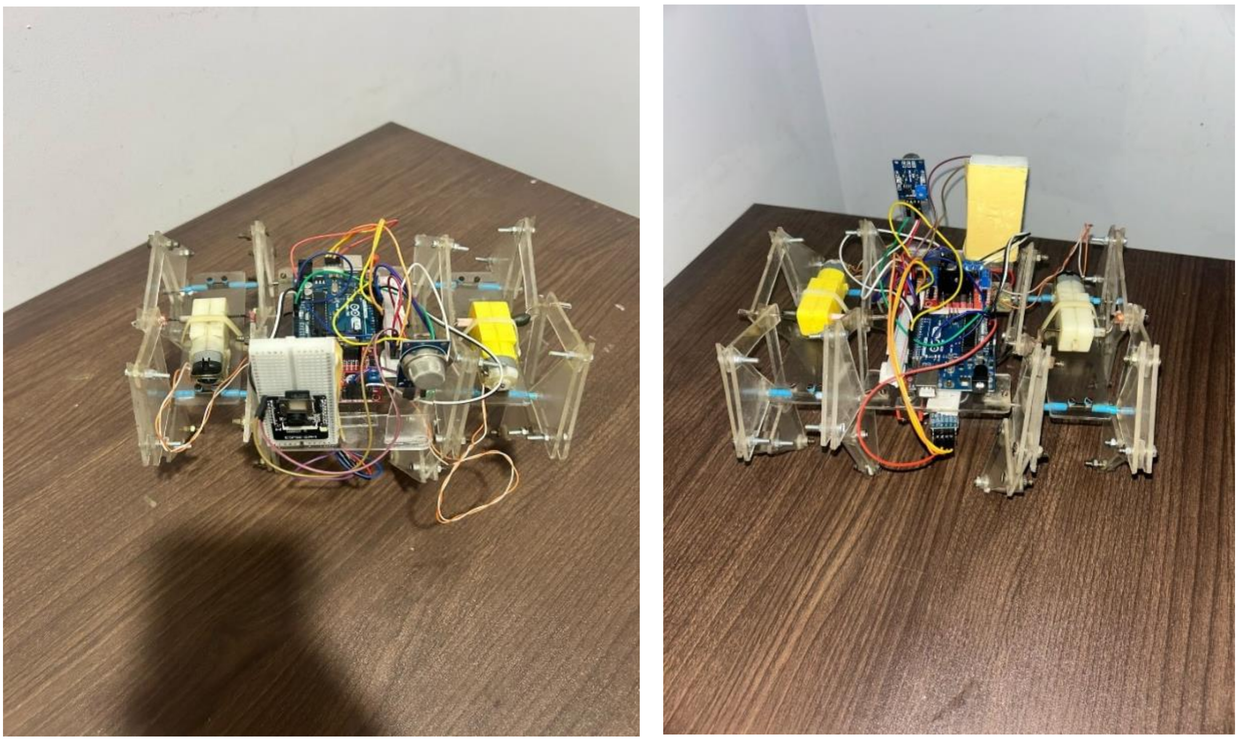


Figure 7.2 Strandbeest Robot

7.3 CODE FOR STRANDBEEST ROBOT

```
#include <SoftwareSerial.h>
#include <Servo.h>

#define IN1 6
#define IN2 7
#define IN3 8
#define IN4 9

#define TRIG_PIN 10
#define ECHO_PIN 11
#define MQ135_PIN A0

SoftwareSerial bt(0, 1); // RX, TX
Servo scanServo;

char data;

void setup() {
  Serial.begin(9600);
  bt.begin(9600);
```

```
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);

  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);

  scanServo.attach(5); // attach servo to pin 5
  scanServo.write(90); // center position

  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, LOW);
}

void loop() {
  if (bt.available()) {
    data = bt.read();
    Serial.println(data);

    switch (data) {
      case 'F': forward(); break;
      case 'B': reverse(); break;
      case 'L': left(); break;
      case 'R': right(); break;
      case 'S': stoprobot(); break;
      case 'U': obstacleScan(); break;
    }
  }

  // Always show MQ135 value
  int mq135_value = analogRead(MQ135_PIN);
  Serial.print("Air Quality (MQ135): ");
  Serial.println(mq135_value);

  delay(100);
}

void forward() {
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  delay(20);
}

void reverse() {
```

```
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  delay(20);
}

void left() {
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  delay(20);
}

void right() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  delay(20);
}

void stoprobot() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, LOW);
  delay(20);
}

void obstacleScan() {
  for (int angle = 60; angle <= 120; angle += 15) {
    scanServo.write(angle);
    delay(300);
    long distance = measureDistance();
    Serial.print("Angle: ");
    Serial.print(angle);
    Serial.print("°, Distance: ");
    Serial.print(distance);
    Serial.println(" cm");
  }
  scanServo.write(90); // Reset to center
}

long measureDistance() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
```

```
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  long duration = pulseIn(ECHO_PIN, HIGH);
  long distance = duration * 0.034 / 2;
  return distance;
}
```

CHAPTER 8
RESULTS

8.1 INTRODUCTION

- **Real-time gas detection:** Sensors detect the presence and concentration of harmful gases and trigger alerts (buzzer or LED) when thresholds are exceeded.
- **Obstacle detection:** Ultrasonic sensors detect objects or collapsed sections in tunnels and help navigate safely.
- **Live video feed or image capture:** The camera module provides visual feedback to operators monitoring the robot from a distance.
- **Mobility demonstration:** The Strandbeest mechanism allows the robot to walk smoothly across rough terrain, showcasing its adaptability in a mining environment.

8.2 GAS DETECTION OUTPUT

Digital Output (D0):

- Gives HIGH or LOW signal based on a set threshold.
- You can set the threshold using the onboard potentiometer.
- When gas concentration exceeds the threshold, D0 = LOW (trigger signal).
- This is used for alerts, like turning on a buzzer or LED.

Type	**Detection Range**	**Analog Output Behavior**
Carbon monoxide	10-1000ppm	Gradual rise with CO

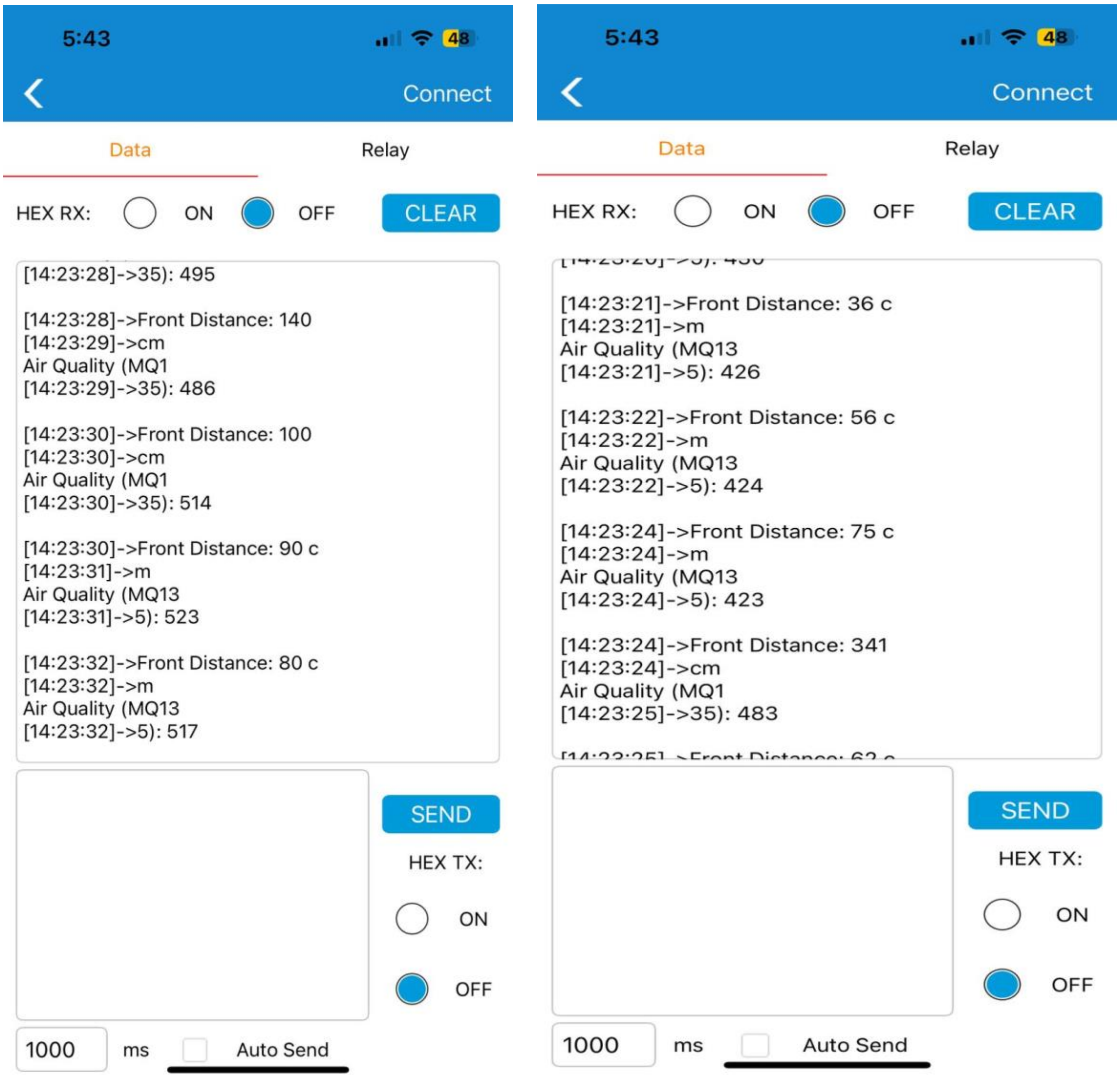


Figure 8.2 Detection of Hazardous Gases

8.3 DETECTION OUTPUT

The ESP32-CAM module plays a crucial role in the coal mine robot by providing real-time visual monitoring and object detection capabilities. It captures live video or images and helps identify obstacles, fallen debris, or human presence in underground environments.

The object detection process works in two possible ways:

Streaming & Processing via Wi-Fi

- The ESP32-CAM streams video to a remote server or mobile device.
- Object detection is done using AI models (like OpenCV or YOLO) on the receiving

device.

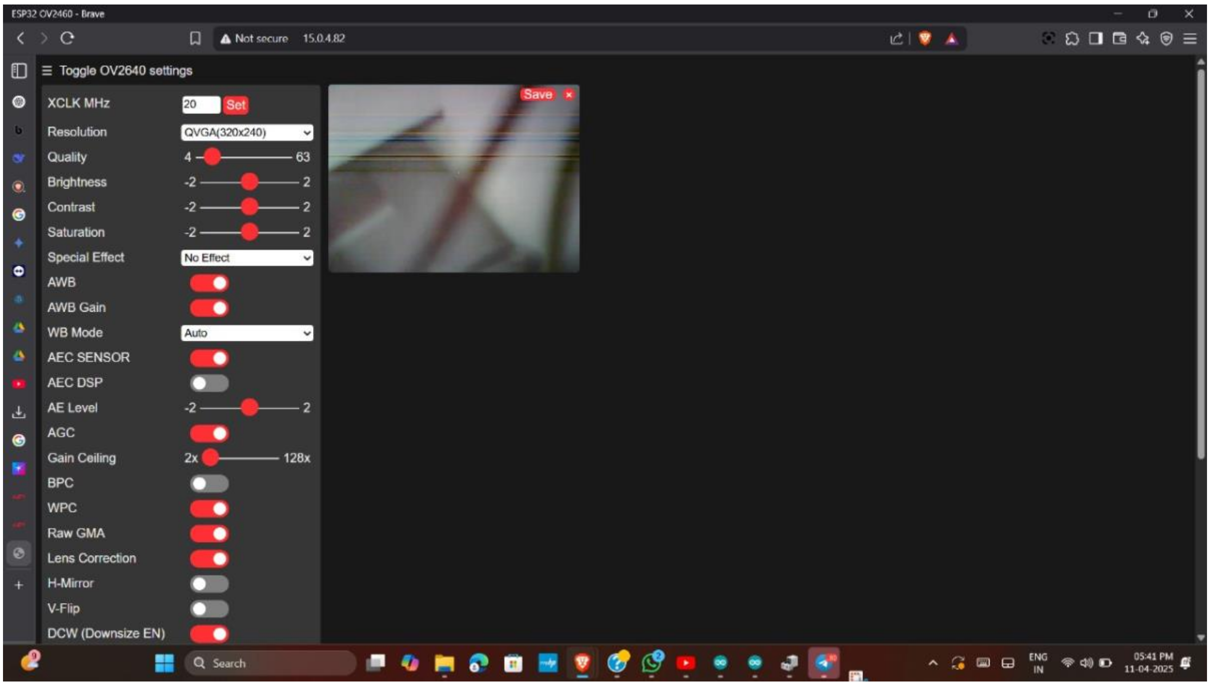
- Output: Alerts or visual identification of obstacles, enabling operators to take safety.
- 

Figure 11 Detection of Obastacles in Mine Environment

CHAPTER 9
CONCLUSION

CONCLUSION

9.1 CONCLUSION

The implementation of the Strandbeest-inspired coal mine safety robot marks an innovative advancement in the field of industrial safety and robotic mobility. Traditional mining operations expose workers to hazardous conditions, including toxic gases, unstable ground, and poor visibility. This robot has been specifically designed to mitigate such risks by providing early detection of harmful gases like methane (CH_4), carbon monoxide (CO), and hydrogen sulfide (H_2S), which are common in coal mines and can be fatal if undetected.

Built on the principles of Theo Jansen's Strandbeest mechanism, the robot uses a legged locomotion system that mimics natural walking. This allows it to traverse rough and uneven terrain where wheeled or tracked robots may fail. The lightweight, flexible design enables the robot to navigate narrow tunnels and confined spaces without disturbing the environment, reducing the likelihood of triggering collapses or explosions.

In addition to gas detection, the robot is equipped with sensors and cameras to detect objects or obstacles that may pose safety risks, such as loose rocks, tools, or unstable structures. By transmitting real-time data to operators on the surface, the robot allows for remote monitoring, reducing the need for human presence in dangerous areas. This not only protects lives but also increases the efficiency of mining operations by enabling preventive maintenance and hazard response.

Overall, this project demonstrates the potential of combining biomimicry, robotics, and sensor technology to create a versatile and reliable safety solution for the mining industry. With continued development, integration of autonomous navigation, and expanded sensor capabilities, the Strandbeest coal mine robot can serve as a vital tool in transforming coal mine safety standards and reducing the human cost of resource extraction.

CHAPTER 10

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REFERENCES

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CHAPTER 11
CERTIFICATES

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