RESEARCHERID
THOMSON REUTERS
[Rishika et al.,11 (5), May 2026]

ISSN:2455-9679
SJIF Impact Factor: 6.190

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"IMPLEMENTATION OF A FLEXIBLE SNAKE ROBOT FOR DISASTER MANAGEMENT USING ESP32 CAMERA MODULE"

Rishika Deshmukh [1], Yogesh Mewada [2], Pradeep Patel [3], Pranjali Wadurkar [4], Samrat Ghosh [5]

[1-5] *Department of Electronics & Communication Engineering, Sagar Institute of Science, Technology & Research (SISTec-R), Bhopal, Madhya Pradesh, India*

rishikadeshmukh79@gmail.com

ABSTRACT

The research work "Design and Implementation of ESP32 for Disaster Rescue Operation Using Snake Robot with ESP32 Web Cam" is an intelligent robotic surveillance and rescue system developed to assist disaster management teams in hazardous and inaccessible environments. The system is specifically designed to navigate through narrow pathways, collapsed structures, underground tunnels, and other dangerous locations where human rescue operations become difficult and risky. By integrating flexible robotic locomotion with wireless monitoring technology, the project directly supports UN Sustainable Development Goal (SDG) 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities) by promoting innovative disaster response solutions and improving emergency rescue infrastructure. The core architecture of the system is built around the ESP32 microcontroller and ESP32-CAM module, which together provide real-time wireless control, live video streaming, and intelligent monitoring capabilities. The snake robot consists of multiple servo motor-driven segments connected in a flexible structure that enables snake-like movement across uneven surfaces and confined spaces. A PCA9685 servo driver module is used for precise PWM-based control of multiple servo motors, ensuring smooth and coordinated locomotion. The integrated ESP32 Web Camera captures and transmits live video footage to the operator, allowing continuous remote surveillance in low-visibility and dangerous environments.

To enhance disaster detection capabilities, the system incorporates an MQ5 gas sensor for identifying hazardous gases and unsafe environmental conditions during rescue operations. The robot can be remotely operated through Wi-Fi communication, enabling users to monitor and control movement without direct physical interaction.

The embedded control system processes real-time commands and sensor inputs efficiently while maintaining low power consumption and compact hardware integration. The intelligent operational workflow of the robot includes obstacle navigation, remote visual inspection, environmental sensing, and real-time data transmission. During rescue missions, the robot enters confined spaces and continuously streams live video while monitoring gas levels. This helps rescue teams identify trapped victims, assess structural damage, and detect harmful gases before initiating human intervention. The flexible mechanical design significantly improves mobility in disaster-prone environments compared to traditional wheeled robots. The entire system is implemented using Embedded C programming on the Arduino IDE platform, with ESP32 serving as the central processing and communication unit.

Keywords: *Soil Fertility, Internet of Things (IoT), Arduino Uno, NPK Sensor, Precision Agriculture, Smart Farming*

I. INTRODUCTION

The snake robot is a flexible, multi-segmented robotic system specifically designed to operate in environments that are unsafe, inaccessible, or hazardous for humans. Inspired by the natural movement of real snakes, the robot is capable of navigating through narrow spaces, uneven surfaces, debris, and confined areas. These characteristics make it highly suitable

ISSN:2455-9679
SJIF Impact Factor: 6.190

for applications such as search and rescue missions, surveillance, and exploration of hazardous environments. In disaster situations like earthquakes, building collapses, underground tunnel accidents, or industrial failures, human access is often limited due to safety concerns. The snake robot provides an effective alternative by reaching these areas while minimizing risk to human life. The overall system architecture of the snake robot consists of multiple interconnected segments that enable smooth and continuous motion. Each segment is actuated using servo motors that allow controlled bending and turning of the robot body, producing snake-like locomotion. The robot is centrally controlled by the Arduino Uno, which acts as the brain of the system. The Arduino Uno coordinates movement, processes sensor data, and manages communication with the remote-control station. Its simple architecture, reliability, and compatibility with various sensors and modules make it suitable for mobile robotic applications operating in challenging environments.

Wireless connectivity is one of the important features of the system, achieved using a Wi-Fi communication module connected to the Arduino Uno. This wireless capability allows the robot to be operated remotely from a safe distance, eliminating the need for physical connections that could restrict movement or pose safety risks. Commands for movement and system control are transmitted wirelessly, while sensor data and visual feedback are sent back to the operator in real ti me. This ensures quick response and effective control during critical missions. To enhance situational awareness, a camera module is integrated into the snake robot to provide real-time visual feedback. The camera enables live video streaming,allowing operators to observe the surroundings through the robot's viewpoint. This feature is particularly important in low-light or dark environments such as underground tunnels, collapsed buildings, or nighttime surveillance areas. Visual information helps in identifying obstacles, structural damage, trapped victims, or potential threats, significantly improving the effectiveness and accuracy of rescue and inspection operations.

In addition to visual monitoring, the snake robot is equipped with a gas sensor to detect hazardous gases and monitor air quality levels. In many disaster zones and industrial environments, the presence of combustible or toxic gases can pose serious risks to human responders. The gas sensor continuously measures gas concentration in the surrounding environment and sends the data to the Arduino Uno for analysis. This information allows operators to assess environmental safety before deploying human rescue teams and helps prevent exposure to dangerous conditions. A GPS module is also incorporated into the system to enable precise location tracking of the snake robot. The GPS provides real-time position data, allowing operators to monitor the robot's movement path and current location during missions. This feature is particularly useful in large or complex environments where navigation and coordination are critical. Location tracking also assists in mapping explored areas and helps in retrieving the robot in case of signal loss or system malfunction. By combining flexible locomotion, wireless control, real-time video transmission, gas detection, and location tracking, the snake robot becomes a highly versatile tool for a wide range of applications. It can be effectively used in search and rescue operations, hazardous environment exploration, security surveillance, and environmental monitoring. The integration of multiple sensing and communication technologies significantly enhances operational efficiency while reducing risks to human life.

In conclusion, the proposed snake robot demonstrates how advanced embedded systems and robotic design can be used to address real-world challenges in disaster response and hazardous environment exploration. The use of the Arduino Uno alongwith a camera module, gas sensor, GPS system, and wireless communication module enables intelligent decision-making, remote monitoring, and safe operation in critical situations. With further improvements such as autonomous navigation and obstacle avoidance, the snake robot can become an even more efficient and reliable solution for future rescue and surveillance applications.

II. REVIEWOF LITERATURE

Biomimetic robotics, particularly snake-like locomotion, has been extensively researched to address complex mobility challenges.

- **Inoue et al. (2004)** explored neural oscillator network-based controllers to generate meandering locomotion patterns for snake-like robots, proving the efficacy of central pattern generators (CPGs) in undulating locomotion.
- **Kimura et al. (2004)** evaluated stuck-evasion mechanisms using active-wheel and passive-joint snake-like mobile platforms ("GENBU"), highlighting strategies to recover motion when navigating dense obstacles.
- **Ma et al. (2001)** introduced kinematic simulators to analyze creeping locomotion, establishing mathematical frameworks for body wave propagation across varied friction surfaces.
- **Wang et al. (2016)** developed modularized isomorphic joint structures, demonstrating that scalable, reconfigurable segments improve maintenance and control in multi-degree-of-freedom (DOF) systems.
- **Singh et al. (2018)** focused on path planning and obstacle negotiation strategies in cluttered environments, proving that articulated robots can maneuver through gaps where traditional platforms become trapped.
- **Su et al. (2012)** analyzed drive mechanisms using belt-driven multi-segment systems to distribute motor weight and torque across joints.

 ISSN:2455-9679
SJIF Impact Factor: 6.190

Existing literature emphasizes complex mechanical actuation, but often omits integrated, low-cost sensing, real-time visual feedback, and gas detection platforms designed for disaster rescue missions. This work addresses that gap through an integrated ESP32/PCA9685 framework.

III. PROBLEM IDENTIFICATION

During a disaster occurrence, rapid and accurate problem identification is essential for effective emergency response. The critical operational and systemic challenges that arise during an active disaster include:

- **Infrastructure & Lifeline Disruptions**
  - Failure of power grids, leading to blackouts in hospitals, shelters, and emergency operations centres.
  - Breakdown of municipal water supply networks, causing shortages of clean drinking water and increasing contamination risks.
  - Structural damage to transportation networks (roads, bridges, rail lines), preventing access for first responders.
- **Communication System Failures**
  - Overloading or collapse of cellular towers and landline networks, preventing victims from making emergency calls.
  - Loss of connectivity between field response teams, command centers, and government bodies.
- **Casualty Management & Health Crises**
  - High volumes of trauma injuries, mass casualties, or fatalities overwhelming local emergency rooms and healthcare staff.
  - Shortages of essential medical supplies, oxygen, blood products, and critical care pharmaceuticals.
  - Risk of secondary health hazards, such as disease outbreaks from standing water or unhygienic temporary shelters.
- **Search, Rescue, & Evacuation Obstacles**
  - Trapped survivors in collapsed structures or submerged zones requiring specialized heavy rescue equipment.
  - Hazardous environment conditions (e.g., active fires, gas leaks, toxic spills, ongoing landslides) putting rescue teams at immediate risk.
  - Bottlenecks and panic during mass evacuations due to blocked routes or insufficient public transit options.
- **Information Gap & Misinformation**
  - Difficulty in obtaining real-time, accurate ground-level data regarding the full geographical extent of the impact.
  - Unverified rumors or misinformation spreading rapidly, leading to public panic or misdirection of resources.
- **Logistical & Resource Shortages**
  - Immediate scarcity of basic survival provisions, including food, clean water, blankets, and temporary shelter kits.
  - Inefficient allocation and distribution bottlenecks at relief supply hubs.
- **Security & Governance Vulnerabilities**
  - Breakdowns in local law enforcement, risking looting, violence, or unsafe shelter environments.
  - Lack of a clear, unified command structure leading to duplicated efforts among different response agencies.

IV. SOLUTION

The principal idea of the proposed snake robot is based on developing a flexible, remotely operated robotic system capable of navigating through narrow, confined, and hazardous environments while continuously transmitting real-time data to a human operator. Traditional robotic platforms often face limitations when operating in cluttered or dangerous spaces due to rigid structures and restricted mobility. To overcome these challenges, the snake robot adopts a segmented and articulated design inspired by the natural movement of biological snakes. This structure allows the robot to bend, twist, and maneuver through tight gaps, debris, pipelines, and uneven terrain, making it highly effective for operations where human access is either difficult or unsafe. At the core of the snake robot lies the Arduino Uno, which serves as the central control and processing unit of the entire system. The Arduino Uno is responsible for coordinating the robot's movement, managing communication between various sensors and actuators, and handling wireless data transmission through an external Wi-Fi or Bluetooth module. Its reliable performance, ease of programming, and compatibility with multiple electronic components make it suitable for robotic applications.

By processing sensor inputs and control commands efficiently, the Arduino Uno ensures smooth locomotion and timely

ISSN:2455-9679
SJIF Impact Factor: 6.190

response, which is critical during search and rescue missions and hazardous environment inspections. The movement of the snake robot is achieved through a series of servo motors arranged along its segmented body. These motors allow precise control over each segment, enabling the robot to perform snake-like motions such as bending, crawling, and turning. This form of locomotion provides excellent adaptability to complex environments, including collapsed structures, underground tunnels, and industrial pipelines. The coordinated control of multiple segments allows the robot to maintain stability and direction while navigating through obstacles, further enhancing its operational effectiveness.

To provide visual feedback and enhance situational awareness, a camera module is mounted at the front of the snake robot. The camera captures live video footage and transmits it wirelessly to the operator's monitoring device. This real-time visual feed allows the operator to observe the surrounding environment directly and make informed decisions while controlling the robot. The camera is particularly useful in dark or low-light conditions such as underground passages, disaster sites, and nighttime surveillance areas. In addition to visual monitoring, the snake robot is equipped with a gas sensor to detect the presence of harmful or flammable gases. Many hazardous environments, such as disaster zones, chemical plants, underground mines, and industrial facilities, may contain dangerous gases that pose serious health risks.

The gas sensor continuously monitors air quality and detects abnormal gas concentrations. The sensed data is processed by the Arduino Uno and transmitted to the operator in real time, enabling early warning and risk assessment. This feature makes the robot highly suitable for safety inspections and environmental monitoring tasks. Another important component of the system is the GPS module, which provides realtime location tracking of the snake robot. The GPS allows the operator to monitor the robot's position, movement path, and coverage area during operation. This is especially useful in outdoor environments or large disaster sites where precise navigation and tracking are required. Location data helps in mapping explored areas, avoiding redundant paths, and coordinating rescue or inspection activities. In case of communication loss or system failure, the last known GPS location assists in recovering the robot, thereby improving reliability and mission success. The integration of wireless communication further enhances the functionality of the snake robot by enabling remote control and monitoring from a safe distance. Through Wi-Fi or Bluetooth modules connected to the Arduino Uno, control commands, video data, sensor readings, and location information are exchanged between the robot and the operator in real time. This wireless approach eliminates the need for physical connections, which could limit mobility or become hazardous in unstable environments. As a result, the operator can control the robot efficiently without being exposed to dangerous conditions. By combining flexible mechanical design, intelligent control, real-time sensing, and wireless communication, the snake robot becomes a powerful and versatile tool for a wide range of applications. Its ability to navigate confined spaces, detect environmental hazards, and provide visual and positional feedback makes it suitable for search and rescue operations, environmental monitoring, security surveillance, and exploration of dangerous or inaccessible areas. The system reduces risks to human life while improving operational efficiency and decision-making. In conclusion, the principal idea of the snake robot is centred on enhancing safety, adaptability, and real-time awareness in challenging environments. The use of the Arduino Uno along with a camera module, gas sensor, GPS system, and wireless communication module enables the robot to perform complex tasks autonomously or under remote control.

V. PROPOSED METHODOLOGY

The system uses an embedded architecture divided into processing, actuation, sensing, and communication sub-units:

Component	Main Specifications / Technical Parameters	Function in System
Arduino Uno (ATmega328P)	16 MHz, 14 Digital I/O, 6 Analog inputs, 32 KB Flash	Central locomotion coordinator and sensor evaluation unit
ESP32-CAM Module	32-bit dual-core, 160 MHz, OV2640 sensor, Wi-Fi/BT	Video streaming, Web Server host, wireless command interface
PCA9685 Motor Driver	16-channel, 12-bit PWM resolution, I2C bus interface	Offloaded PWM signal generator for smooth multi-servo control
Micro Servo Motors	Operating Voltage: 4.8V–7.4V, 50 Hz PWM control	Joint actuators driving body articulation and gait movement
MQ-5 Gas Sensor	Analog/Digital outputs, detects LPG, natural gas, methane	Continuous monitoring of hazardous and combustible gases
Power Management System	Regulated Li-ion battery pack with step-down regulators	Provides stable power supply to control boards and motors

 ISSN:2455-9679
SJIF Impact Factor: 6.190

The methodology is divided into block diagram, hardware specifications, software designand algorithm. The block diagram provides the conceptual idea of how each component is interrelated to the whole task. It defines the basic link of various blocks with each other while the hardware specification details the components involved in this design process. The software portion details the programming platform and its interface with multiple sensors, where the flow of system operation is elaborated. Since the system focuses on measurement accuracy, precision is emphasized throughout the design. The system has been designed with careful consideration of sensor calibration, data processing, and user interface requirements.

BlockDiagram:

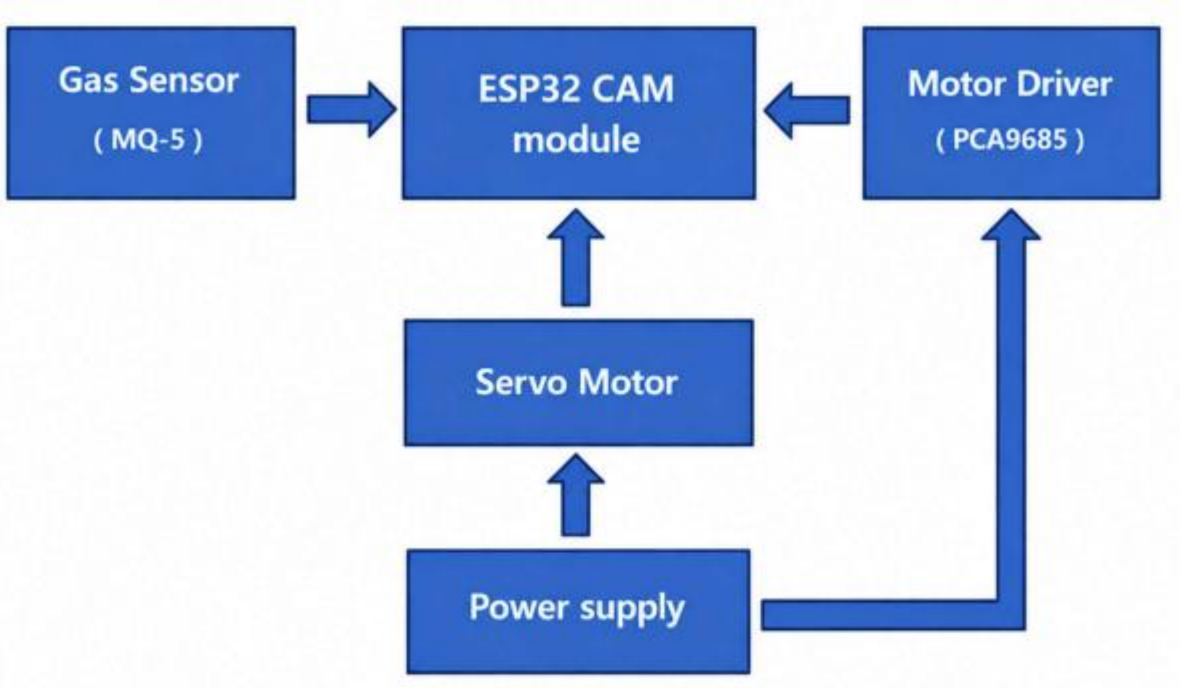


Figure1:**Block Diagram of Snake Robot**

Block Diagram Shown in Fig.1, demonstrate that, when the snake robot is poweredon, the Arduino Uno initializes all connected modules, including the PCA9685 servo driver, the gas sensor input, and the wireless communication system. The ESP32-CAM also initializes its camera module and begins preparing for video streaming. After initialization, the Arduino Uno continuously reads gas sensor values to check for any dangerous levels of gas in the surrounding environment. Based on the sensor readings, the controller makes decisions such as sending alerts or stopping the robot if gas levels exceed a predefined threshold. Simultaneously, the Arduino Uno calculates the required movement pattern and sends control signals through the PCA9685 to drive the servo motors, enabling snake-like locomotion. The ESP32-CAM streams live video to the operator for real-time monitoring, while the Arduino Uno transmits telemetry data such as gas readings and system status. The system continuously repeats this cycle to ensure coordinated movement, sensing, and video feedback throughout operation.
The block diagram and flow chart of the snake robot system illustrate the overall functional architecture and the sequence of operations performed during robot execution. These representations help in understanding how different hardware and software components interact with each other to achieve coordinated movement, sensing, communication, and monitoring. The system is designed around two main processing units: the Arduino Uno microcontroller, which acts as the primary controller, and the ESP32-CAM module, which is dedicated to visual data acquisition and streaming. Together, these components form a synchronized embedded system capable of operating efficiently in hazardous and confined environments. When the snake robot is powered on, the power supply unit provides regulated voltage to all electronic components, including the Arduino Uno microcontroller, ESP32-CAM, PCA9685 servo driver, gas sensor, and communication modules. The Arduino Uno is the first component to become active and begin system initialization. During this stage, the microcontroller configures its input/output pins, timers, serial communication interfaces, and I2C communication settings. This initialization phase ensures that the controller is ready to interact reliably with all peripheral devices connected to the system.

ISSN:2455-9679
SJIF Impact Factor: 6.190

Once the Arduino Uno completes its internal setup, it proceeds to initialize the external modules connected to it. The PCA9685 servo driver is initialized through the I2C communication interface. During this process, the Arduino Uno assigns the appropriate I2C address, configures the PWM frequency, and sets default pulse widths for all connected servo channels. This step is important because the PCA9685 acts as an intermediary between the microcontroller and the servo motors, allowing precise and synchronized control of multiple servos while reducing the processing load on the Arduino Uno. At the same time, the Arduino Uno initializes the gas sensor input system. The gas sensor is powered on and allowed to stabilize for a short period, which is necessary for accurate gas detection. The Arduino Uno configures its analog input pins to read the output of the gas sensor. Threshold values for gas concentration are predefined in the program to determine safe and unsafe conditions. These threshold values act as decision parameters during system operation.

Parallel to the Arduino Uno initialization, the ESP32-CAM module begins its own startup sequence. The ESP32-CAM initializes its internal processor, configures the camera sensor, and sets parameters such as resolution, frame rate, and image format. Once configured, the camera module establishes a wireless connection and prepares itself for real-time video streaming. This separation of control and visual processing helps reduce the computational burden on the Arduino Uno and improves overall system efficiency. After the initialization phase is completed, the system enters its main operational loop, which is represented in the flow chart as a continuous cycle. In this loop, the Arduino Uno continuously reads sensor inputs, processes control commands, and updates actuator outputs. The first major task in this loop is environmental sensing.

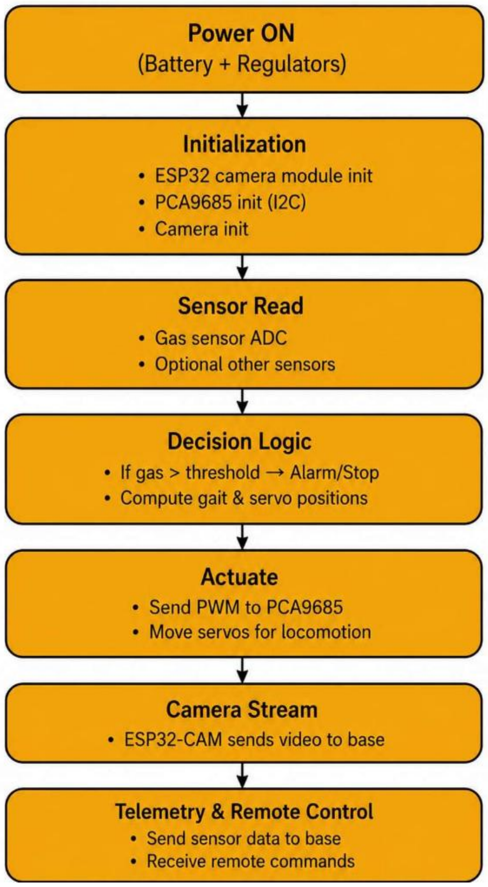
The gas sensor continuously monitors the surrounding air for the presence of hazardous or flammable gases. The analog signal generated by the sensor is processed by the Arduino Uno and compared with predefined threshold values. If the detected gas concentration remains within safe limits, the system continues normal operation. However, if the gas concentration exceeds the safe threshold, the Arduino Uno immediately triggers a safety response. This response may include stopping the movement of the robot, sending warning alerts to the operator, or changing the robot's direction to move away from the hazardous area. This decision-making process highlights the importance of the gas sensor in ensuring safe operation in dangerous environments. Simultaneously, the Arduino Uno processes movement control commands received from the operator through wireless communication. Based on these commands, the controller calculates the required movement pattern for the snake robot. This involves determining the angular positions and timing of each servo motor to produce smooth snake-like locomotion. The calculated PWM values are then transmitted to the PCA9685 servo driver through the I2C interface. The PCA9685 generates precise PWM signals for each connected servo motor. These signals control the rotation angle of the servo motors, enabling coordinated bending and movement of the robot's segmented body. By controlling multiple servos simultaneously, the system achieves flexible locomotion, allowing the robot to crawl, turn, and maneuver through narrow or uneven environments. This coordination between the Arduino Uno and PCA9685 is a key aspect highlighted in the block diagram.

While movement and sensing are ongoing, the ESP32-CAM continuously captures visual data from the environment. The camera streams live video footage wirelessly to the operator's monitoring device. This real-time video feedback allows the operator to observe obstacles, environmental conditions, and potential victims during search and rescue missions. The visual information complements sensor data and significantly improves situational awareness and control accuracy. In addition to video streaming, the Arduino Uno transmits telemetry data to the operator. This telemetry data includes gas sensor readings, system status, movement information, and alert messages. The continuous exchange of data between the robot and the operator ensures effective remote monitoring and control.

The wireless communication system plays a critical role in maintaining real-time interaction without exposing the operator to dangerous conditions. The flow chart emphasizes that all these processes occur simultaneously and repeatedly in a continuous loop. Sensor monitoring, decision-making, actuator control, video streaming, and data transmission are all synchronized to ensure smooth and reliable operation. This cyclic execution allows the system to adapt dynamically to changing environmental conditions and operator commands. In conclusion, the block diagram and flow chart provide a clear representation of the snake robot's functional workflow and system architecture. From power-on initialization to continuous sensing, movement control, and real-time monitoring, each component plays a vital role in achieving the overall system objective. The integration of the Arduino Uno microcontroller, PCA9685 servo driver, gas sensor, and ESP32-CAM ensures efficient coordination between sensing, actuation, and communication. This well-structured operational flow enables the snake robot to perform effectively in search and rescue operations, hazardous environment exploration, and surveillance tasks while maintaining safety, reliability, and real-time responsiveness.

ISSN:2455-9679
SJIF Impact Factor: 6.190

Process Flow Chart:



1. Power ON (Battery + Regulators)
The working process shown in Fig. 3.2, as the Arduino UNO, PCA9685 servo driver, sensors, and camera module. This ensures safe and reliable operation of the system.
2. Initialization
After powering ON, the controller initializes all connected modules and peripherals. Arduino UNO starts booting, the ESP32-CAM module is initialized for video transmission, the PCA9685 servo driver is initialized through I2C communication, and sensors and input/output pins are prepared for operation.
3. Sensor Read
The system continuously reads sensor data after initialization. The gas sensor sends analog values to the controller through ADC conversion. Optional sensors such as temperature or obstacle sensors may also provide environmental data for monitoring.
4. Decision Logic
The controller processes sensor data and performs decision-making operations. If gas concentration exceeds the threshold limit, the system generates an alarm or stops movement for safety. The controller also computes gait patterns and servo positions for snake-like locomotion.
5. Actuation
After processing the decision logic, the controller sends PWM signals to the PCA9685servo driver. The servo driver controls multiple servo motors simultaneously, enabling coordinated snake-like movement.
6. Camera Stream
The ESP32-CAM continuously captures and streams live video to the base station. This allows the operator to remotely monitor hazardous or narrow environments in real time.
7. Telemetry and Remote Control
The robot sends sensor data and system status information to the base station. It also receives remote control commands from the operator for wireless navigation and monitoring. Begins when the power supply is switched ON. The battery provides electrical energy to the entire snake robot system. Voltage regulators provide stable voltage levels to components.

ISSN:2455-9679
SJIF Impact Factor: 6.190

VI. RESULT

The prototype was subjected to functional testing across simulated disaster environments, assessing mobility, streaming reliability, and environmental sensing performance.

VII. CONCLUSION

The snake robot project successfully demonstrated how biomimetic design combined with modern sensing technologies can create an effective system for navigating and monitoring challenging environments. By integrating an ESP32 camera module, the robot was able to capture real-time visual data, enhancing its ability to inspect narrow or hazardous areas where human entry is difficult. Additionally, the inclusion of a gas sensor enabled the robot to detect harmful gases, making it useful for safety-critical applications such as industrial inspections, disaster response, and environmental monitoring.

The project achieved its key objectives, including the development of a flexible mechanical structure, implementation of efficient snake-like locomotion, and incorporation of sensory modules for environmental awareness. The collected results indicate that the robot can navigate confined spaces, provide live video streaming, and sense dangerous gas concentrations with reasonable accuracy. Looking ahead, future improvements may include enhancing the robot's mobility, improving autonomous navigation, adding more advanced sensors, and optimizing wireless communication. Overall, the project demonstrates a strong foundation for further research in bio-inspired robotics and highlights the practical usefulness of sensor-integrated snake robots in real-world scenarios.

VIII. FUTURE SCOPE

The global snake robot market was valued at USD 1.34 billion in 2023 and is projected to reachUSD 12.2 billion by 2032, growing at a CAGR of 27.86% (Market Research Future). Another report predicts a CAGR of 19.8% from 2025 to 2034. Key target users include emergency response teams (fire departments, EMS, search and rescue), disaster relief organizations (e.g., Red Cross), government agencies at all levels involved in disaster management, and construction or industrial companies operating in hazardous environments like mining, construction, and manufacturing. These sectors benefit from snake robots' mobility in confined and dangerous space.

IX. REFERENCES

[1]. K. Inoue, Shugen Ma and ChenghuaJin, "Neural oscillator network-based controller for meandering locomotion of snake-like robots," IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA '04. 2004, New Orleans, LA, USA, 2004, pp. 5064-5069.

[2]. H. Kimura, S. Hirose and K. Shimizu, "Stuck evasion control for active-wheel passive-joint snake-like mobile robot 'genbu'," IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA '04. 2004, New Orleans,LA, USA, 2004, pp. 5087-5092, doi: 10.1109/ROBOT.2004.1302524.

[3]. Shugen Ma, W. J. Li and Yuechao Wang, "A simulator to analyze creeping locomotion of a snake-like robot," Proceedings 2001 ICRA. IEEE International Conference on Robotics and Automation (Cat. No.01CH37164), Seoul, Korea (South), 2001, pp. 3656-3661 vol.4, doi: 10.1109/ROBOT.2001.933186.

[4]. Haomiao Wang, Hongtao Wang, Wenfu Xu and Zonggao Mu, "Developmentand experiment of a snake-like robot composed of modularized isomorphic joints," 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Budapest, 2016, pp. 003160-003165, doi: 10.1109/SMC.2016.7844720.

[5]. Singh, Anshul, C. Gong and H. Choset, "Modelling and Path Planning of SnakeRobot in cluttered environment," 2018 International Conference on Reconfigurable Mechanisms and Robots (ReMAR), Delft, Netherlands, 2018, pp. 1-6, doi: 10.1109/REMAR.2018.8449833.

[6]. X. Su, J. Gao, Z. Zhao, Q. Wu and C. Huang, "Structural analysis and design of round belt drive snake-like robot," IET International Conference on Information Science and Control Engineering 2012 (ICISCE 2012), Shenzhen, 2012, pp. 1-5, doi: 10.1049/cp.2012.2299. 64A