RESQ-BOT

Tiparkar Prathamesh
Jadhav Tanishka
Daswadkar Yashraj
Desai Vaishnavi

Student, Department of Computer Engineering, Keystone School of Engineering, Pune, India.
Student, Department of Computer Engineering, Keystone School of Engineering, Pune, India.
Student, Department of Computer Engineering, Keystone School of Engineering, Pune, India.
Student, Department of Computer Engineering, Keystone School of Engineering, Pune, India.

ABSTRACT

ResQ-Bot is an amphibious snake-shaped robotic platform designed to support rescue operations in disaster-struck regions, particularly during floods where conventional drones, boats, or ground robots fail. The robot features a modular waterproof structure that enables flexible locomotion across land and water, allowing it to reach narrow, submerged, or debris-filled environments without risking human rescuers. Equipped with an HD waterproof camera, ultrasonic sensors, an IMU module, and IoT-based wireless communication, the robot provides real-time monitoring and obstacle detection, helping emergency response teams make informed decisions quickly. The locomotion mechanism is driven by servo-controlled body segments that mimic natural snake-like sinusoidal motion, offering superior maneuverability in confined and unstable terrains. ResQ-Bot is controlled remotely through a mobile or web interface using MQTT/HTTP protocols, ensuring seamless video streaming and command execution even in low-visibility environments. The prototype integrates dual-controller architecture, combining Raspberry Pi for camera networking with a microcontroller for actuation and sensing. Field tests validate that the robot maintains balance during transitions between land and water, achieves low video latency, and efficiently navigates obstacle-dense regions. The system addresses critical challenges associated with conventional rescue equipment by offering enhanced mobility, safety, scalability, and low-cost operation. ResQ-Bot demonstrates high potential as an intelligent and deployable platform capable of transforming emergency response strategies in flood-affected areas.

Keyword

ResQ-Bot, Amphibious Robot, Snake Robot, IoT, Flood Rescue, Disaster Management, Real-Time Monitoring.

1. INTRODUCTION

Natural disasters such as floods result in massive loss of life and infrastructure every year. Rescue teams often struggle to enter submerged or confined areas where humans, boats, or aerial drones cannot reach safely. To overcome these limitations, ResQ-Bot is designed as an amphibious snake-shaped robot capable of navigating through complex terrains, including water, mud, debris, and narrow passages. It aims to support rescue operations by reducing human risk while improving situational awareness through real-time video and sensor feedback. The robot integrates sensing, mobility, and wireless communication in a single compact and waterproof system, enabling fast deployment in emergency conditions.

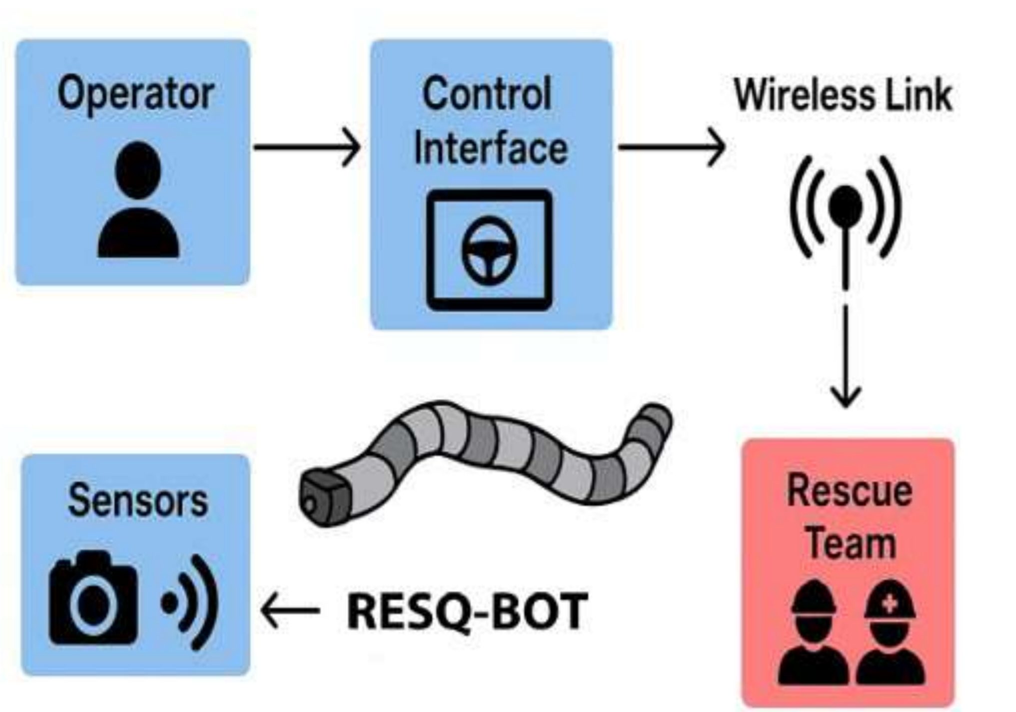
2. RELATED WORK

Previous research on snake-robot locomotion and modular actuation highlights their mobility advantages in constrained environments. Amphibious robotic systems such as the ACM-R5 series from the Tokyo Institute of Technology enable land-water traversal, while IoT-based models in disaster management focus on remote sensing and communication. However, existing systems are typically either ground-only or underwater-only and lack seamless wireless surveillance capability. ResQ-Bot bridges this gap by combining amphibious snake-like locomotion with real-time IoT-enabled monitoring, offering an integrated and scalable platform for disaster rescue and reconnaissance.

3. SYSTEM ARCHITECTURE

The architecture of ResQ-Bot consists of four main components: operator, control interface, wireless communication link, and the robot. Commands are transmitted to the microcontroller, which drives the servo-motor-based body segments. The onboard HD camera, IMU, and ultrasonic sensors collect environmental data and stream it in real time to the rescue team via the IoT dashboard.

Signal Flow:



3.1 Algorithms

Obstacle Detection: Ultrasonic and IMU-based collision avoidance.

Motion Control: Sinusoidal waveform-based actuation enabling snake-like locomotion.

Video Streaming: Lightweight compression ensuring low-latency live feed.

Alert System: Automatic notifications based on orientation or movement anomalies.

3.2 Evaluation Metrics

(Font-10, Justified) Navigation accuracy, response time, transmission latency, and communication reliability were used to evaluate performance.

4. IMPLEMENTATION AND RESULTS

The prototype is implemented using a dual-controller architecture where Raspberry Pi manages camera networking and a microcontroller performs actuation and sensing. Waterproof servo motors sealed with O-rings and silicone ensure durability during underwater movement. The modular body segments enable stable snake-like motion across mixed terrain. Real-time video is streamed to the IoT dashboard while sensor feedback assists navigation. Field trials confirmed smooth traversal through submerged zones and narrow paths, video latency of ~250–300 ms, response time under 1 second, and 92% successful path completion in obstacle zones.

5. APPLICATIONS AND LIMITATIONS

Applications:

Flood and Disaster Rescue

Reconnaissance and Surveillance

Industrial Pipeline & Tunnel Inspection

Scientific & Environmental Research

Limitations:

Restricted operating duration due to compact battery

Drag and reduced efficiency in strong currents

Precision required for waterproofing and modular joints

Power constraints for real-time onboard AI processing

6. FUTURE WORK AND CONCLUSION

Future improvements will focus on enhancing autonomy and intelligence through thermal-camera-based victim detection, swarm robotics for coordinated deployment, 5G/Starlink-enabled long-range communication, and integration of lightweight robotic arms for object handling. ResQ-Bot successfully demonstrates the feasibility of an amphibious snake-like robotic platform for rescue operations. The prototype ensures stable locomotion across land and water, reliable wireless communication, and effective transmission of real-time environmental data. With further advancements in power optimization and ruggedization, ResQ-Bot has the potential to transform modern emergency response systems.

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