DISASTER BOT: INTEGRATING ROBOTICS FOR EFFICIENT DISASTER RESPONSE AND MANAGEMENT

Project Reference No.: *47S_BE_4587*

College *: Christ Deemed To Be University, Kengeri Campus, Bengaluru*
Branch *: Department Of Robotics and Automation*
Guide(S) *: Prof. Amruta Rout*
Student(S) *: Mr. Rajveer Singh Sahni*
Dr. Tanishka Aggarwal
Mr. Kingshuk Maji

Keywords

Disaster response, Hybrid robotic system, Vine robot, Internal steering mechanism, Search and rescue

Introduction

In the face of increasing natural disasters, from earthquakes and tsunamis to hurricanes and wildfires, efficient and effective disaster response and management have become critical. Traditional methods of disaster response often involve significant risks to human responders, delays due to inaccessible areas, and limitations in reaching victims trapped in confined or hazardous spaces. As technology advances, integrating robotics into disaster management strategies offers a promising solution to overcome these challenges.

Robotic systems can operate in environments too dangerous for humans, providing real-time data, performing search and rescue operations, and delivering essential supplies. Among the various robotic innovations, the concept of a hybrid system that combines the robust mobility of a tank with the dexterity and reach of a vine-like robot stands out. This hybrid design aims to enhance the capabilities of robotic disaster responders, making them more versatile and effective in various scenarios.

The Disaster Bot, an innovative robotic system, embodies this hybrid approach. It integrates a sturdy robotic tank base with a flexible vine robot. This combination allows the Disaster Bot to navigate challenging terrains and confined spaces, thus addressing the limitations of traditional robotic responders. The tank base provides the necessary power and stability to move across debris-strewn environments, while the vine robot extends the reach into areas that are otherwise inaccessible, such as collapsed buildings or narrow crevices.

The internal steering mechanism within the vine robot enhances its manoeuvrability, enabling precise control and navigation through complex pathways. This capability is crucial for locating and rescuing individuals trapped in difficult-to-reach areas. Additionally, the Disaster Bot can be outfitted with various sensors and tools, further augmenting its functionality in search and rescue, damage assessment, and resource delivery missions.

Objectives

Our project aims to optimize disaster response through the development of a hybrid robotic system that integrates a robotic tank with a vine robot. Specifically:

- **Robust and versatile RC tank:** To design and develop a robust and versatile multi-terrain RC tank capable of navigating challenging environments encountered during rescue missions.
- **Integration of vine robot:** To integrate a vine robot with the RC tank to enhance mobility, agility, and reachability for accessing remote or inaccessible areas during rescue operations.
- **Advanced sensing and control:** To implement advanced sensing, perception, and control capabilities on both the vine robot and the RC tank to enable autonomous or semi-autonomous operation in dynamic and unpredictable environments.
- **Effectiveness demonstration:** To demonstrate the effectiveness and practicality of the integrated system through field trials and validation tests simulating real-world rescue scenarios, evaluating performance metrics such as speed, manoeuvrability, endurance, and mission success rate.
- **Collaboration and partnerships:** To establish collaboration and partnerships with relevant stakeholders, including emergency response agencies, disaster management organizations, and research institutions, to foster knowledge exchange, technology transfer, and adoption of the proposed solution for improving rescue capabilities and outcomes.

Methodology

1. Literature Review

Conduct an extensive review of existing research on robotic tank with a hybrid vine robot and their applications in Defence and Rescue Programs.

2. Understanding the Problems

- Comprehensive Review: Conduct an in-depth analysis of the Defence Program's objectives, challenges, and requirements. This includes studying existing rescue operations, technological constraints, and specific needs for remote control tanks and vine robots.
- Specification Development: Based on the review, develop detailed specifications for the remote-control tanks and vine robots that align with the Defence Program's goals, ensuring they meet the required performance and operational standards.

3. Design and Build

- **Mechanical Design**: Start with designing robust mechanical models and chassis for various remote-control tanks, using PLA (Polylactic Acid) as the primary material for its strength, durability, and ease of fabrication. Prioritize stability, adaptability, and durability to handle different terrains encountered during rescue missions.

- **Drive Systems and Suspensions**: Refine drive systems and suspension mechanisms to optimize performance across diverse environments. This includes iterative testing and adjustments to ensure reliability and efficiency.
- **Vine Robot Design:** Design a vine robot to complement the remote-control tank. Focus on maximizing utility and minimizing weight to ensure it can be easily deployed and maneuverer in tight or inaccessible areas.
- **Integration of Sensors and Actuators:** Equip both the remote-control tanks and vine robots with necessary sensors (e.g., ultrasonic, LIDAR) and actuators to enable precise movement and data collection. Communication devices are also integrated for seamless coordination.

4. Software Development

- **Control System:** Develop a real-time control system that facilitates smooth coordination between the remote-control tanks and vine robots. This system should allow for both autonomous and semi-autonomous operations.
- **Navigation and Computer Vision Algorithms:** Implement advanced navigation and computer vision algorithms to enable the robots to autonomously explore environments, avoid obstacles, perceive their surroundings, identify objects, and make real-time decisions based on visual data.

5. Testing and Validation

- **Component Testing:** Conduct rigorous testing of individual components (e.g., motors, sensors, actuators) to ensure functionality, reliability, and performance meet the required standards.
- **Simulated Rescue Scenarios:** Perform a series of tests simulating real-world rescue scenarios to evaluate the system's overall performance, mobility, and adaptability. Collect data on key performance indicators such as speed, manoeuvrability, and obstacle clearance.

6. Iteration and Improvement

- **Data Analysis:** Analyse the data collected during testing to identify areas for improvement. This includes assessing performance metrics and identifying any operational bottlenecks or failures.
- **Design and Algorithm Refinement:** Iterate on the mechanical design and software algorithms based on test results and feedback. Address any identified issues to enhance the system's reliability and effectiveness.
- **User Feedback Incorporation:** Engage with users (e.g., rescue operators) to gather feedback and incorporate their insights into the design and functionality enhancements.

7. Documentation and Sharing

- **Project Documentation:** Document all aspects of the project meticulously, including methodologies, design blueprints, software algorithms, and testing procedures.
- **Technical Reporting:** Prepare comprehensive technical reports and research papers summarizing the project's findings, outcomes, and lessons learned.

- **Knowledge Dissemination:** Present the project results at relevant conferences, workshops, and seminars to share knowledge and foster collaboration.
- **Stakeholder Engagement:** Engage with defence agencies, emergency response organizations, and research institutions to promote the adoption and further development of the integrated system for rescue missions. Establish partnerships to facilitate technology transfer and broader implementation.

Components

The components for the manufacturing of Dister robot are

1. Mechanical Components

- Chassis and Frame:
  Material: PLA (Polylactic Acid) for 3D printing
  Components: Base frame, side panels, mounting brackets

- Tracks and Wheels:
  Material: PLA (Polylactic Acid) for durability
  Components: Track links, wheels, and sprockets

- Vine Robot Body:
  Material: Flexible TPU for the main body
  Components: Segmented sections that can extend (inflate) and retract

- Enclosures and Housings:
  Material: PLA for all protective casings
  Components: Sensor housings, battery enclosures, electronics enclosures

2. Electronics and Sensors

- Microcontroller and Control Boards:
  Components: Arduino, and Esp32 for control and processing
- Motors and Actuators:
  Components: DC motors for movement, servo motors for precise control, stepper motors for vine robot extension/retraction
- Sensors:
  Components: Ultrasonic sensors for distance measurement,
- Power Supply:
  Components: Li-Po batteries, battery management system (BMS)

3. 3D Printing Considerations for Ender 3

- Printer Specifications:
  Printer Type: Ender 3 (FDM - Fused Deposition Modeling)
  Bed size: 235x235mm
  Nozzle Size: 0.4 mm (standard)

- Material Handling:
  PLA: Easy to print, strong and durable, suitable for most structural parts
  Finishing: Sanding, acetone smoothing for PLA, painting
  Assembly: Use screws, bolts, and adhesives for assembling printed parts with electronic components

Results And Conclusions

The development and testing of the robotic tank with a hybrid vine robot yielded several notable results:

- Enhanced Mobility: The hybrid system demonstrated superior mobility in constrained and complex environments compared to traditional robotic systems. The vine robot's ability to extend and navigate through tight spaces complemented the tank's robust traversal capabilities.
- Increased Reach: The vine robot's manual extension (inflation) and retraction allowed for significant reach extension along tortuous paths, enabling the system to access areas that were previously unreachable by rigid robotic arms or standard vine robots.
- Retraction Capability: The vine robot's ability to retract efficiently mitigated issues related to body buckling and facilitated easier manoeuvring and redeployment.
- Expanded Workspace: The hybrid configuration increased the operational workspace of the robotic tank. The vine robot could approach objects from multiple angles, enhancing the system's versatility in disaster response scenarios.
- Experimental Validation: The experimental tests confirmed the mathematical models' predictions. The hybrid system performed well in simulated disaster environments, including rubble and debris fields, showcasing improved navigation and object interaction capabilities.

The integration of a hybrid vine robot with a robotic tank has proven to be a significant advancement in disaster response and management robotics. The system's enhanced mobility, increased reach, efficient retraction, and expanded workspace provide clear advantages over existing robotic solutions.

- Improved Disaster Response: The hybrid system's ability to navigate and operate in challenging environments makes it a valuable tool for search and rescue missions, infrastructure inspection, and hazardous material handling.
- Future Work: Further research and development could focus on optimizing the vine robot's design and improving the control algorithms to enhance the system's autonomy and precision. Additionally, real-world field tests in diverse disaster scenarios would provide deeper insights into the system's performance and potential improvements.

- Broader Implications: The success of this hybrid system opens up possibilities for similar integrations in other robotic applications, such as medical surgery, industrial automation, and space exploration, where flexibility and precision are crucial.

Description of the Innovation in the Project

The project introduces a groundbreaking integration of a hybrid vine robot with a robotic tank, marking a significant advancement in disaster response and management robotics. This innovation is centred around merging the robust mobility of a tank with the flexible, adaptable capabilities of a vine robot.

Key aspects of this innovation include:

- **Hybrid Design:** This design seamlessly combines the flexibility of a vine robot with the stability and manoeuvrability of a remote-controlled tank, enhancing versatility and functionality across diverse environments.
- **Advanced Sensing and Perception:** The system implements cutting-edge ultrasonic sensors and computer vision algorithms to enhance environmental perception, identify objects, and navigate around obstacles effectively.
- **Enhanced Mobility and Reach:** By leveraging the combined capabilities of the tank and vine robot, the system can navigate complex terrains and access remote or difficult-to-reach areas, making it invaluable for search and rescue operations.
- **Expanded Workspace:** The hybrid design allows the system to approach targets from multiple angles, significantly increasing adaptability and operational efficiency in various rescue scenarios.
- **Optimized Control Systems**: Utilizing state-of-the-art navigation algorithms and a user-friendly interface, the system ensures coordinated and smooth operation even under dynamic and unpredictable conditions.
- **Experimental Validation:** Rigorous mathematical modelling and experimental tests validate the system's performance, ensuring reliability in real-world applications.

Future Work Scope

Based on the outlined objectives of the project, several potential future directions and expansions can be identified:

- **Enhanced Integration and Collaboration**: Explore opportunities for further integration of various robotic systems and technologies beyond the vine robot and RC tank. This could involve incorporating aerial drones, ground-based rovers, or even underwater vehicles to create a comprehensive multi-domain rescue system. Additionally, fostering collaboration with additional stakeholders such as technology companies, academia, and international organizations could bring diverse expertise and resources to further enhance the capabilities of the integrated system.
- **Adaptation for Specific Environments:** Tailor the integrated system for specific types of environments commonly encountered in disaster scenarios, such as urban settings, rugged terrain, or confined spaces. This could involve developing specialized attachments, sensors, or algorithms optimized for different environmental conditions to maximize effectiveness and adaptability.

- **Scalability and Modular Design:** Design the system with scalability and modularity in mind to allow for easy customization and expansion based on evolving requirements and emerging technologies. This could involve developing standardized interfaces and components that enable seamless integration of new features or upgrades without significant redesign or disruption to existing functionality.
- **Advanced Autonomy and AI:** Invest in research and development efforts aimed at enhancing the autonomy and artificial intelligence capabilities of the integrated system. This could include leveraging machine learning algorithms for improved decision-making, adaptive behaviour, and collaborative coordination between different robotic components. Additionally, exploring techniques for decentralized control and swarm robotics could further enhance the system's resilience and scalability in complex and dynamic environments.
- **Human-Robot Interaction and Communication:** Focus on improving the interface and communication mechanisms between human operators and the integrated robotic system. This could involve developing intuitive control interfaces, augmented reality visualization tools, or natural language processing capabilities to enable more seamless and efficient collaboration between humans and robots during rescue missions.
- **Global Deployment and Standardization:** Work towards standardizing the design, operation, and deployment protocols of the integrated rescue system to facilitate global adoption and interoperability across different regions and organizations. This could involve establishing industry standards, certification processes, and training programs to ensure consistency and compatibility between systems deployed by different agencies and jurisdictions.