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Original Paper

Multiple Symmetric Multi-link Search and Rescue Robot Based on a New Movable Structure

Yangyang Zhu, Luan Wang, Lizhen Chen, Yingfu Chen
Fuzhou University of International Studies and Trade, Fuzhou 350202, Fujian, China

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Abstract

In the event of disasters such as fires and earthquakes, the efficiency of rescue operations is often limited due to the difficulty for firefighters to enter narrow spaces. To address this issue, our team has innovated on traditional search and rescue robots by incorporating advanced sensing systems, obstacle-crossing capabilities, and autonomous return functions. This enables the robots to quickly reach disaster sites for personnel search and significantly improves rescue efficiency.

Keywords

Obstacle Ability, Autonomous Return System, Environment Perception

1. Introduction

In recent years, with the continuous growth of Chinas economy, it has been the world's second largest economy, the industrial capacity is expanding, the number of factories and industrial parks is increasing, and the fire safety risks have also increased. In order to cope with the increasingly severe security situation, China has issued a series of emergency management policies, such as the Regulations on Emergency Response to Production Safety Accidents and the Rating and Management Measures of National Demonstration Cities for Security Development, which have further improved the rescue system, improved the emergency response efficiency, and effectively reduced casualties and property losses.

2. Project Context

With the increasing complexity of fire rescue missions and the diversification of emergency situations, traditional artificial rescue methods face many challenges in certain high-risk environments. In order to solve the problem that firefighters can not directly approach the trapped people, and the rescue efficiency is low, this project introduces a new search and rescue robot. Through the application of this technology, it can not only effectively shorten the rescue time, improve the life safety of the trapped personnel, reduce the risk of search and rescue personnel, but also significantly improve the overall rescue efficiency, so as to better deal with the complex fire rescue tasks.

In the first half of 2024, various natural disasters caused 32.381,000 disasters, 322 deaths and missing, 856,000 emergency relocation, 23,000 collapsed houses, 279,000 damaged houses, crops affected 3172.1,000 hectares; and direct economic loss RMB 93.16 billion. In this case, the rescue robot shows great potential to quickly enter the dangerous areas for search and rescue, assess losses and ensure the safety of rescue workers, and improve the efficiency and precision of post-disaster recovery. The application of robotics not only effectively responds to complex disaster environments, but also accelerates post-disaster reconstruction and becomes a key tool for rescue work.

3. Problems Existing with Traditional Rescue Robots

3.1 Limitations of Technology and Environmental Adaptability

Movable structure multi-symmetrical multi-link search and rescue robot has some obvious limitations in the technical level. First, these robots have limited adaptability in complex and changeable disaster site environments, especially in narrow or rugged terrain, and their movement performance and propulsion speed are often difficult to meet the needs of actual search and rescue operations. In addition, the stability and anti-tipping ability of the robot in unstable surfaces are also the challenges to be overcome by the current technology, which is directly related to the safety and reliability of the robot.

3.2 Limitations of Environmental Perception and Positioning Technology

In the complex and unknown disaster scene, the search and rescue robots autonomous positioning and environmental perception ability are obviously limited. For example, GPS signals cannot be covered in closed environments such as indoor or ruins, making it difficult for robots to achieve accurate positioning. In addition, robots need to quickly draw accurate topographic maps when performing search and rescue missions, but existing technologies still have much room for improvement in real-time and accuracy. At the same time, the robots perception of the signs of life still needs to be further enhanced to ensure that it can accurately identify and locate the trapped people, thus improving the search and rescue efficiency.

3.3 Limitations of Autonomous Return

The robot cannot navigate independently according to environmental information or existing locations, which can easily lead to positioning difficulties. External factors such as obstacles or environmental changes may cause positioning errors or path deviations, so it is unable to safely return to the origin, increasing the uncertainty in the search and rescue task. At the same time, relying on external operations or predetermined path return reduces the flexibility of the search and rescue process, which may lead to the delay of the task completion time, and even interrupt the task due to the inability to return in time, which affects the search and rescue efficiency.

4. Innovation Point

4.1 Improve the Adaptability and Rescue Efficiency of Complex Terrain

The new search and rescue robot is designed with a variable mechanism and can be dynamically adjusted according to different environments to adapt to complex disaster scenarios such as nursing homes. Compared with traditional tracked robots, such robots show stronger adaptability in complex terrain, can maintain a stable movement speed, quickly complete the survey tasks, and reach the target area in time. In particular, the robot using the Bricard exhibition mechanism, whose structure can be folded or expanded according to the task requirements, so as to optimize the transport and storage space. The organization is small and easy to carry in non-working conditions, but it can quickly expand and adapt to various complex terrain in working conditions, which improves the rescue efficiency.

4.2 Ultrasonic Sensing and Positioning Methods

By using the ultrasonic echo signal to obtain multiple distance information, and combined with the wall as a reference mark, the system can realize the precise positioning of the search and rescue robot. The ultrasonic wave uses the vertical incident wall mode to ensure that the echo signal is strong, thus reducing the error caused by the low angular resolution. At the same time, the system combines the electronic compass information, which can accurately locate in the environment symmetry and reduce the dynamic object interference. When the disturbance is static, the series method is adopted to achieve accurate positioning, and when the disturbance is moving, multiple sampling points are collected by parallel method to optimize the position selection and ensure high precision positioning.

4.3 Autonomous Return System:

The new search and rescue robot autonomous return software consists of three main modules, namely communication interruption detection, execution instruction memory, storage instruction resolution and motion control. The main function of the communication interrupt detection module is to determine whether the communication between the console and the robot is interrupted. The execution instruction memory module is responsible for recording and rewriting the motor control instructions executed by the robot and their movement time between the nodes during the movement of the robot, especially at the nodes that receive the effective instructions. The order of data storage is: the movement time, the configuration before the node, the configuration after the node, the direction transfer at the node, and the movement speed after the node. The storage instruction resolution and motion control module parses the recorded data in the execution instruction memory module, and sends the corresponding motion control instruction to the robot according to the analysis results to ensure that the robot can return autonomously according to the predetermined path and instruction.

4.4 Visual Perception of — Infrared Detection

It is realized by installing infrared sensors and transmitters in the robot and the surrounding environment. When the sensor detects an infrared signal from the transmitter, the robot is able to determine its current position based on the received signal. This way can not only accurately carry out the location positioning, but also has strong environmental adaptability, can work effectively in different types of environments, to ensure that the robot can still operate stably in complex scenes *Figure 1*.

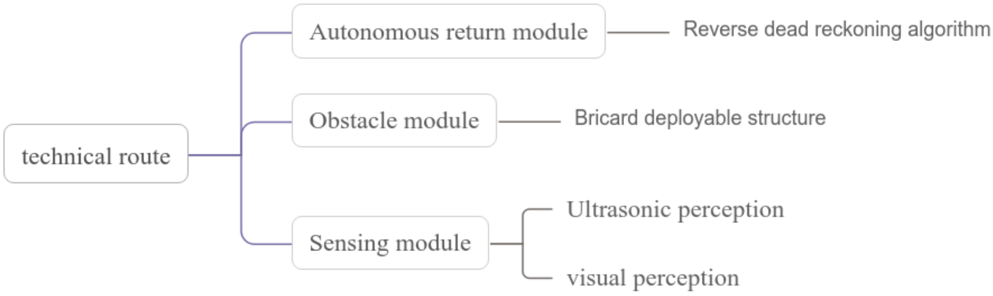

Figure 1. Flow Chart of the Technical Route

5. Conclusion

With its innovative mechanical design and exhibition mechanism technology, the new multi-link search and rescue robot can flexibly respond in a complex and narrow environment and carry out search and rescue tasks quickly. The robot is equipped with advanced environment sensing system and intelligent decision-making ability, which can identify surrounding obstacles in real time and automatically adjust the path to ensure accurate and efficient completion of rescue work. These technological breakthroughs improve the adaptability, flexibility and controllability, allowing robots to perform well in a variety of complex terrain and uncertain environments. Especially in emergency situations such as natural disasters and accident rescue, trapped people can quickly find and improve rescue efficiency. With the continuous progress of technology, the search and rescue robot will become a key tool in the future rescue work, making an important contribution to ensuring life safety and improving social well-being.

Fund Project

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