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Design of a Marine Emergency Search and Rescue System Based on Beidou

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Abstract. Under the guidance of the carbon peaking and carbon neutrality goals, the global energy structure is being reshaped, and offshore wind power has become an important means for China to promote energy transformation. "Communication lines are lifeline." In response to the high safety risks of offshore operations and the difficulty of ensuring communication for maritime rescue, a marine emergency search and rescue system integrating monitoring, positioning tracking, and emergency rescue based on Beidou has been designed. The system based on the high-quality services of Beidou, has independently developed the marine emergency search and rescue system (software) as well as supporting hardware products such as personal portable beacons, ship-borne beacons, and positioning navigation tracking terminals. It ensures smooth communication and positioning tracking during the search and rescue process, providing solid technical support for offshore operations related to offshore wind power. The marine search and rescue system provides the last line of technical support for the safety of offshore personnel and vessels, enhances the safety awareness of offshore personnel, reduces maritime accidents, and protects people's lives and property.

Keywords: Beidou, search and rescue system, offshore wind power, emergency response, communication guarantee

1. Introduction

In recent years, with the rapid development of the marine economy, maritime safety issues have become increasingly prominent, especially in offshore operations and navigation activities, where the ability to respond to emergencies is particularly important. The government, recognizing the importance of the lives of those in distress and offshore workers, established the National Marine Emergency Search and Rescue Plan in 2006 to build a national marine search and rescue emergency response mechanism [1]. This mechanism has led to active measures to strengthen maritime safety management and emergency response mechanisms. Against this backdrop, the marine emergency search and rescue system has emerged as an important means to enhance maritime security and has demonstrated broad application prospects.

However, current maritime emergency search and rescue technologies still have some shortcomings [2]. Existing systems rely heavily on manual operations, and delays in information

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transmission may affect rescue efficiency [3]. This means that offshore workers may face life-threatening situations in emergencies [4]. Moreover, complex maritime environments, signal interference, and equipment failures can lead to the failure of traditional search and rescue systems [5], posing a severe challenge to the safety rescue of offshore workers [6,7].

In response to these challenges, we have designed a marine emergency search and rescue system based on Beidou [8,9]. This system not only improves rescue efficiency but also provides strong support for the lives of offshore workers. By integrating Beidou positioning with the Internet of Things (IoT), big data analysis, and cloud computing, the system achieves intelligent scheduling of rescue resources and real-time monitoring, significantly enhancing the life safety of offshore workers and those in distress [10]. Users can register personal information through mobile terminal devices and generate identity markers. In emergencies, the system can automatically capture the user's location information and match it with the identity information in the database to quickly confirm the identity and location of trapped individuals [11].

Furthermore, the system features data encryption and transmission security functions to ensure the safety of information during transmission and prevent the leakage of sensitive information. During the rescue process, the system updates the rescue progress in real-time and uploads key data to the cloud for tracking and analysis by relevant departments.

In summary, the marine emergency search and rescue system based on Beidou integrates modern technological mean [12], effectively improving the efficiency and safety of maritime emergency rescue. It provides a more solid guarantee for marine operations and navigation activities, ensuring the life safety of those in distress and offshore workers.

2. Overview of Beidou System

The Beidou Satellite Navigation System (BDS) consists of three main parts: the space segment, the ground segment, and the user segment.

Space Segment: This includes multiple satellites distributed across different orbits, providing global navigation services.

Ground Segment: As the supporting part of the Beidou system, it is responsible for monitoring and maintaining the entire satellite navigation system.

User Segment: This includes various receivers and terminal devices that provide services to users.

The Beidou Satellite Navigation System can provide all-weather, wide-range, and high-precision location information for maritime search and rescue. It can also use short message communication functions to send information such as the preliminary location and type of distress to the search and rescue center. Additionally, the precise timing of the Beidou system can provide high-precision time synchronization services for the maritime search and rescue system, ensuring the accuracy of data transmission and the security of network management.

3. System architecture design

The system is divided into three layers: the data source layer, the platform layer, and the application layer. The system architecture diagram is shown in Figure 1.

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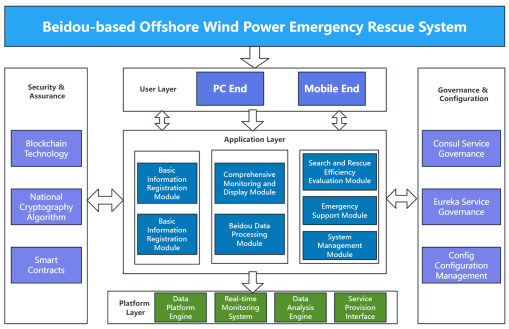


Figure 1. System architecture diagram

3.1. Data source layer

The data source layer is the foundation of the marine emergency search and rescue system, responsible for collecting, storing, and managing various data related to maritime emergency search and rescue. It mainly includes sensor devices, data collection systems, and data storage devices. This layer uses sensor devices such as the Global Positioning System (GPS), meteorological sensors, underwater sonar, and cameras to monitor maritime environments and equipment status, and transmits data in real-time through network interfaces. The data collection system collects data, preprocesses it, and converts its format to ensure compatibility. The collected data is stored in relational databases, time-series databases, and distributed storage systems, which must be highly reliable, available, and performant to meet the system's needs for data persistence and fast retrieval.

3.2. Platform layer

The platform layer is the core of the marine emergency search and rescue system, responsible for data processing, analysis, and service provision. Components of this layer include a data processing engine, real-time monitoring system, data analysis engine, and service provision interface.

The data processing engine is responsible for cleaning, transforming, calculating, and mining raw data to achieve real-time and batch processing.

The real-time monitoring system, based on the data processing engine, monitors maritime environments and equipment status in real-time. It can display the location, status, and trends of various monitored objects in real-time and supports real-time queries and control by users.

The data analysis engine analyzes and mines historical data from the maritime emergency search and rescue system. It can perform multi-dimensional data analysis, trend prediction, and anomaly detection to provide decision support and guidance for emergency search and rescue operations.

The service provision interface is the interface through which the platform layer provides services to the application layer. It includes data query interfaces, data push interfaces, and alarm notification interfaces. It can support multiple communication protocols and data formats to meet the needs of the application layer.

3.3. Application layer

The application layer is the top level of the marine emergency search and rescue system, providing users with core functions and services.Its central component, the user interface, displays system data and functions through web, mobile, or desktop platforms, supporting user interaction and operation.

The application layer mainly includes four aspects:

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Emergency search and rescue: enables distress calls, rescue response, command, and resource allocation, helping users track rescue progress and schedule resources.

Data visualization: presents maritime environment, equipment status, and rescue progress in real-time via charts and maps.

Emergency drills and training: offers interactive activities to improve emergency response capabilities and awareness.

System management and configuration: allows administrators to manage users, permissions, and parameters, ensuring security and stability.

4. System function design

The system's main functions are divided into seven modules: basic information registration, emergency search and rescue, comprehensive monitoring and display, Beidou data processing, search and rescue efficiency evaluation and visualization, emergency support, and system management.

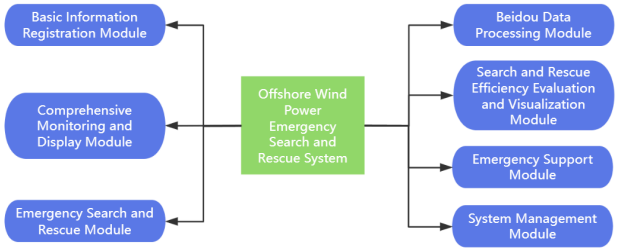


Figure 2. System function frame diagram

Basic Information Registration: Registers personnel, equipment, and emergency response data to form dynamic and static databases. Through a unified portal, rescuers can monitor offshore operations and equipment in real time, providing key information for missions.

Emergency Search and Rescue: Integrates weather and sea data to identify risks, issue alerts, and support emergency responses. It links to maintenance reminders and emergency plans to ensure timely, effective action.

Comprehensive Monitoring and Display: Enables layered monitoring and real-time management of maritime areas. Users can zoom from map overview to regional details to view equipment status, reports, and history, improving situational awareness.

Beidou Data Processing: Cleans, converts, and standardizes Beidou data for seamless integration with other modules, supporting diverse application scenarios.

Search and Rescue Efficiency Evaluation and Visualization: utomatically tracks rescue KPIs, generating visual reports on resource use and outcomes to support strategic adjustments and resource optimization.

Emergency Support: This module provides communication, personnel, and material support. An emergency contact database and backup plans ensure reliable communication. Training programs and equipment allocation enhance team readiness, while a material management mechanism ensures resources are sufficient and readily available.

System Management: Includes menu configuration, organizational management, and user permission control. Administrators can adjust menu structures, manage organizational hierarchies, and assign user rights, thereby maintaining system security and operational stability.

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5. System testing

The testing process is divided into three stages: functional testing, performance testing, and security testing.

In functional testing, the testing team simulates the actual operation scenarios of users, inputs various possible data and parameters, and then verifies whether the software's output and behavior meet expectations. This includes verification of the correctness of input data, correctness of functional logic, testing of boundary conditions, handling of exceptional situations, etc.

In performance testing, the testing team uses professional performance testing tools or writes automated scripts to simulate loads and collect key performance indicator data. This data can be used to analyze the performance bottlenecks, resource utilization, and bottleneck points of the software, and help the development team to optimize and improve performance.

In security testing, the testing team designs a series of test cases to try to break through the system's security confidentiality measures. These test cases can include attempts to bypass access control, input malicious data, conduct denial-of-service attacks, injection attacks, cross-site scripting attacks, etc. Through these test cases, the testing team can check whether the system has security vulnerabilities and whether it can resist various attacks and interference.

6. Conclusion

The Beidou-based marine emergency search and rescue system integrates advanced technologies such as Beidou positioning technology, the Internet of Things, big data analysis, and cloud computing to build a comprehensive and efficient marine emergency search and rescue system. The system can quickly locate emergencies and provide risk early warning, and it can also provide functions such as emergency response and search and rescue efficiency evaluation, effectively ensuring the safety of the lives of maritime workers.

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