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Design of Urban Waterlogging Emergency Rescue Boat from the Perspective of Human-Computer Interaction

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Abstract:
With the acceleration of the urbanization process, urban waterlogging occurs frequently and the demand for emergency rescue is increasing. However, the existing urban waterlogging emergency rescue boats have deficiencies in human-computer interaction design, such as poor operation convenience and low information visualization, which affect the rescue efficiency. This study aims to improve the rescue efficiency and ease of use. The Delphi method, Analytic Hierarchy Process (AHP), and Decision Making Trial and Evaluation Laboratory (DEMATEL) are used to construct the human-computer interaction design factor system and quantify the factor weights and relationships. The design factors are determined through discussions among experts in multiple fields. The relative weights are calculated by AHP, and the causal relationships are clarified by DEMATEL, and key factors such as safety protection and space layout are obtained. A mother-child rescue boat and auxiliary equipment are designed, including clear functional positioning, optimization of the shape structure and color matching, etc., which improves the comfort and rescue efficiency. This study provides a basis for the human-computer interaction design of rescue boats, improves the deficiencies in related research, provides ideas for similar designs, and can integrate advanced technologies and continue to be optimized in the future to deal with complex rescue scenarios.

Keywords: urban waterlogging; emergency rescue boat; human-computer interaction; user experience; rescue efficiency.

INTRODUCTION

Urban waterlogging, as a common natural disaster, has brought serious threats to the lives and property safety of urban residents. In recent years, with the acceleration of the urbanization process, the problem of urban waterlogging has become more and more frequent, and the high efficiency and timeliness of emergency rescue work are particularly important. Emergency rescue boats, as the key equipment for urban waterlogging rescue, their design and performance directly affect the rescue effect. Therefore, it is of great practical significance to optimize the design of urban waterlogging emergency rescue boats from the perspective of human-computer interaction.

Currently, scholars at home and abroad have carried out extensive and in-depth research in the design of urban waterlogging emergency rescue boats and related fields, and have achieved a series of important results.

In China, By combining theoretical analysis, simulation, and experimental verification methods, the overall scheme of the vehicle was determined1111[1]. Through the initial stability calculation, modal analysis, hydrodynamic analysis, and righting ability analysis of the vehicle, its reliable stability and high speed during the rescue process were ensured. [2] Cui Can proposed an improved GM-CKF target dynamic estimation method and a rescue ship distributed cooperative control method under the joint connected communication topology graph in view of the deficiencies in the dynamic estimation and tracking control technology of marine rescue targets under severe sea conditions. [3] Xu Shuo and others constructed a topological structure diagram, which reduced the dependence of marine rescue on ship communication, improved the cooperative operation ability of rescue ships in complex environments, and provided new ideas for marine rescue command and decision-making. [4] Wang Guoyong designed a new type of rudder steering structure in view of the problems such as easy water ingress of the rudder steering structure of the existing unmanned boat for water rescue. By installing the external rudder assembly and the sealed steering mechanism, optimizing the limit components and protective net boxes, etc., the water ingress into the cabin was effectively prevented, the stability and reliability of the rudder were improved, and the smooth progress of the rescue work was ensured. [5] Ren Wei and others carried out management innovation in the design and test of the mission system of a certain rescue and salvage ship, sorted out the design process, optimized the equipment layout, installation and test methods, and improved the test efficiency and installation reliability of the system equipment. [6] Wei Yongning and others designed an intelligent rapid rescue boat that uses double pumping jet pumps for propulsion, combined with the cooperative operation of drones, and utilizes visual image positioning and target detection technologies to achieve rapid and accurate rescue of drowning people. [7] Liang Hao, Liao

Xiaoju and others carried out research on the design of a compressed oxygen self-rescuer from the perspective of human-computer interaction, focusing on optimizing the interaction experience between the user and the self-rescuer. [8] Li Yang, Liu Guochuang and others used the Analytic Hierarchy Process (AHP) to determine the weights of user requirements and combined Quality Function Deployment (QFD) to transform user requirements into specific design elements. [9] Bu Jun, Zhou Tao and others determined the subjective weights of evaluation indicators through the Analytic Hierarchy Process, then analyzed the objective data using the entropy weight method to obtain the objective weights, and finally combined the two to obtain the revised weights. [10] Wu Yuanwei and Liu Guangjun studied the real-time estimation method of the dynamic RCS characteristics of non-cooperative targets, focusing on improving the accuracy and real-time performance of target detection and identification.

In foreign countries, although there is no direct mention of the relevant research on urban waterlogging emergency rescue boats for the time being, the research achievements in the fields of water rescue technology and ship design, such as advanced communication technology, navigation systems, intelligent control algorithms, etc., have provided certain technical references and inspiration for the development of urban waterlogging emergency rescue boats.

To sum up, the existing research has achieved remarkable results in the structural design, performance optimization, cooperative control, and new technology application of rescue boats. However, in the human-computer interaction design of urban waterlogging emergency rescue boats, there are still insufficient research situations. For example, some rescue boats need to be improved in terms of operation convenience, information visualization, and the interaction efficiency between personnel and equipment. The control systems of some rescue boats are complex, and it is difficult for operators to quickly get started, which affects the timeliness of rescue; the information feedback of some equipment is not intuitive enough, increasing the difficulty for operators to judge the situation. These problems may lead to low rescue efficiency in urban waterlogging emergency rescue and cannot fully play the role of rescue boats.

Based on the above research status, this study will use the Analytic Hierarchy Process (AHP) to analyze the relative importance of factors, and then use the Decision Making Trial and Evaluation Laboratory (DEMATEL) to identify the influence and being influenced relationships among factors. Deeply analyze the design factors of urban waterlogging emergency rescue boats, construct a design factor system, clarify the influence relationships among various factors, determine the key factors, and then propose an optimized design scheme. Through this method, the importance and mutual influence degree of each design factor can be systematically evaluated, providing a scientific basis for human-computer interaction design, thereby improving the ease of use, reliability, and rescue efficiency of rescue boats, and providing stronger support for urban waterlogging emergency rescue work.

METHODS

This study comprehensively uses a variety of research methods, with particular emphasis on the Analytic Hierarchy Process (AHP) and the Decision Making Trial and Evaluation Laboratory (DEMATEL), to deeply analyze the human-computer interaction design of urban waterlogging emergency rescue boats, aiming to provide scientific and accurate bases for the optimized design.

Delphi Method

Experts from multiple fields (including design scholars, emergency rescue experts, etc.) are invited to form an expert group to discuss and evaluate the human-computer interaction design factors of urban waterlogging emergency rescue boats[11]. Relying on their professional knowledge and rich experience, the experts screen and optimize the preliminarily proposed design factors, remove similar factors, and finally determine a design factor system that includes aspects such as functionality, safety, comfort, and maintainability, laying the foundation for subsequent precise analysis.

Analytic Hierarchy Process (AHP)

A hierarchical structure model is constructed, with the human-computer interaction design goal placed at the top layer, the first-level design factors (such as functional factors, safety factors, etc.) listed in the middle layer, and the second-level design factors (such as operation convenience, emergency response, etc.) as the bottom layer. Through the design of questionnaires, relevant personnel such as coal industry researchers, ship designers, emergency rescue personnel, and users are invited to conduct pairwise comparisons of factors at each level. The geometric mean method is used to aggregate expert opinions to construct a judgment matrix, and then the relative weights of each factor are calculated[12]. At the same time, the consistency verification index and the consistency ratio are calculated, and the consistency test is carried out according to the standard. If the test fails, communicate with the experts to adjust the judgment matrix until the consistency requirement is met to ensure the reliability of the weight calculation and provide a basis for clarifying the design focus.

Decision Making Trial and Evaluation Laboratory (DEMATEL)

Based on the results of the AHP analysis, the DEMATEL method is used to deeply explore the mutual influence relationships among the design factors. Designers, emergency rescue experts, users, etc. are invited to use a 0 - 5 scale to evaluate the influence degree among the factors and construct a direct influence relationship matrix. Through the calculation of the normalized direct influence matrix and the comprehensive influence matrix, the influence degree, influenced degree, centrality, and cause degree of each factor are obtained. The comprehensive weight is calculated with the goal of reducing subjectivity, and a causal relationship diagram is drawn to visually display the causal associations among the factors[13]. Through this method, key factors such as "safety protection" and "space layout" and their interaction mechanisms can be clearly identified, providing comprehensive and in-depth information for the optimization of the design scheme and effectively compensating for the deficiency of the AHP method in handling the relationships among factors.

PROCESS

Construction of Human-Computer Interaction Design Factor System

Table 1. Human-computer interaction design factors

Serial Number	Demand Information (Interview Content)	Content of Requirements	Requirement Level
01	The control buttons are ergonomic, and the icons and texts are helpful for identifying the functions.	The interface design is simple, the layout of buttons is reasonable, and the icons and texts are clear. A_{11}	Functional Factors A1
02	The high-resolution screen presents data in the form of charts and figures, helping rescue personnel obtain data quickly.	Accurately display all kinds of information. A_{12}	
03	Highlight life detection and the location of personnel during search and rescue, and display cargo and route information during transportation.	Optimize the interaction design according to different tasks. A_{13}	
04	Emergency braking buttons, communication buttons (for dealing with ship failures, personnel injuries, etc.)	Set up an effective mechanism (give alarms in time and provide solutions in case of emergencies) A_{21}	Safety Factors A2
05	Detection of collision and grounding risks and reminders on the interface	Use technology to monitor potential risks and give early warnings A_{22}	
06	Display of the status of life jackets and seat belts (to ensure correct usage)	Display the status of protective equipment (ensure the safety of personnel) A_{23}	
07	Adaptation to different body sizes (with comfortable and durable materials to improve work experience)	Seat comfort A_{31}	Factors for Comfort A3
08	Console convenient for observation and operation, wide passages preventing collisions	Interface adapting to different environmental conditions A_{32}	
09	Automatic brightness adjustment under strong light, normal operation in low-temperature environment	Interface adapting to different environmental conditions A_{33}	
10	Display of error codes, locations and troubleshooting methods when malfunctioning (to assist maintenance)	Equipped with functions of fault diagnosis and troubleshooting A_{41}	Safety Protection A4
11	Support for online and remote upgrade and maintenance functions	Consider the convenience of software upgrade A_{42}	
12	User manuals, operation videos (to help rescue personnel master the operation methods)	Provide training support (ensure the correct use of the system) A_{43}	

In order to comprehensively and scientifically determine the human-computer interaction design factors of urban waterlogging emergency rescue boats, this study adopted a combination of the Delphi method and the Analytic Hierarchy Process (AHP). First, a number of design scholars with rich experience in ship design, human-computer interaction, and emergency rescue were invited to form an expert group. Through multiple rounds of discussions and feedbacks, the expert group comprehensively sorted out and deeply analyzed the numerous factors that may affect the human-computer interaction of emergency rescue boats based on their own professional knowledge and practical experience[14]. During this process, full consideration was given to the particularity of the urban waterlogging rescue scene and the various situations that rescue personnel may face in actual operations. After careful screening and integration, a set of human-computer interaction design factor systems covering multiple aspects was finally determined. This system includes 3 first-level design factors, which are further refined into 12 second-level design factors. The specific content is shown in the following table (Table 1). These design factors will serve as an important basis for the subsequent analysis and optimization of the human-computer interaction design of emergency rescue boats, helping to deeply explore the relationships among various factors and providing strong support for improving the ease of use, reliability, and rescue efficiency of rescue boats. See Table 1.

After determining the human-computer interaction design factor system for urban waterlogging emergency rescue boats, in order to deeply quantify the relative importance of each design factor in the overall design, this study conducted a systematic analysis using the Analytic Hierarchy Process (AHP)[15]. By constructing a judgment matrix, evaluation opinions from various professionals, including coal mining industry researchers, ship designers, emergency rescue personnel, and users who actually use rescue boats, were widely collected through questionnaire surveys. These experts, relying on their rich industry experience and professional knowledge, carried out detailed pairwise comparisons of each design factor. Then, the geometric mean method was used to aggregate the experts' opinions, thereby constructing a judgment matrix, and further calculating the relative weights of each factor through the square root method[16]. Meanwhile, in order to ensure the consistency and reliability of the judgments, strict consistency verification was carried out, and the consistency index and consistency ratio were calculated. After a series of rigorous calculation and verification processes, the Analytic Hierarchy Process results of each design factor were finally obtained, as shown in the following table (Table 2). This result will provide crucial data support and a decision-making basis for clarifying the key directions of the human-computer interaction design of emergency rescue boats, reasonably allocating design resources, and optimizing the design scheme in the subsequent steps.

Table 2. Results of analytic hierarchy process (AHP)

item	eigenvector	weight coefficient(W_i)	he maximum eigenvalue	Consistency Index
Operational Convenience A_{11}	1.418	11.817%	13.16	0.105
Clarity of Information Display A_{12}	0.815	6.788%		
Task Adaptability A_{13}	0.712	5.934%		
Emergency Response A_{21}	1.429	11.904%		
Risk Early Warning A_{22}	0.784	6.537%		
Safety Protection A_{23}	2.456	20.465%		
Seat Design A_{31}	1.361	11.338%		
Space Layout A_{32}	1.597	13.311%		
Environmental Adaptability A_{33}	0.552	4.602%		
Fault Diagnosis and Troubleshooting A_{41}	0.331	2.756%		
Software Upgrade and Maintenance A_{42}	0.266	2.220%		
User Training and Support A_{43}	0.279	2.329%		

It is defined as the consistency verification index, and is the largest eigenvalue of matrix A. The relevant calculations are shown in Formulas (1) - (2)[17].

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} a_{ij} \times W_i}{4Wi} \tag{1}$$

$$C_I = (\lambda_{\max} - n)/(n-1) \tag{2}$$

The calculation of the consistency ratio is shown in Equation (3).

$$C_R = C_I / R_I \tag{3}$$

Quantification of Design Factor Relationships Based on DEMATEL to Increase the Objectivity of Weights and Make up for the Subjectivity of Methods, the Causal Relationships among Design Factors are further Clarified by Combining Survey Data and the DEMATEL Method

The calculation steps are as follows. Construction of the Direct Influence Relationship Matrix Ten designers, users, and rescue personnel were invited to evaluate the mutual influence relationships among all design factors using a 0 - 5 scale[18].The evaluation results of the expert matrix questionnaires were aggregated to obtain the direct influence relationship matrix B. The element bij represents the degree of influence of factor Bi on factor Bj. m is the number of design factors, as specifically shown in Equation (4).3.2 Quantification of Design Factor Relationships Based on DEMATEL

To increase the objectivity of weights and make up for the subjectivity of methods, the causal relationships among design factors are further clarified by combining survey data and the DEMATEL method. The calculation steps are as follows.

Construction of the direct influence relationship matrix

Ten designers, users, and rescue personnel were invited to evaluate the mutual influence relationships among all design factors using a 0 - 5 scale[18]. The evaluation results of the expert matrix questionnaires were aggregated to obtain the direct influence relationship matrix B. The element bij represents the degree of influence of factor Bi on factor Bj. m is the number of design factors, as specifically shown in Equation (4).

$$B = \begin{bmatrix} b_{11} & \cdots & b_{1m} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{bmatrix} \tag{4}$$

Matrix calculation

Define I as the identity matrix. Solve the normalized direct influence matrix C and the comprehensive influence matrix H through Equations (5) - (7), as shown in Equations (5) - (7).

$$\chi = \max_{1 \le i \le m} \sum_{j=1}^{m} b_{ij} \tag{5}$$

$$C = \frac{B}{\chi} \tag{6}$$

$$H = C(I - C)^{-1} \tag{7}$$

Calculation of the "four - degree" and comprehensive weights

The influence degree (D_i), influenced degree(E_i), centrality(F_i), and causal degree(G_i)of the design factors are the so - called "Four - Degree"[19]. The value of D_i is the sum of the elements in the i -th row of matrix H ; the value of E_i is the sum of the elements in the j -th column of matrix H ; F_i is the sum of D_i and E_i ; $G_i = D_i - E_i$.[20]

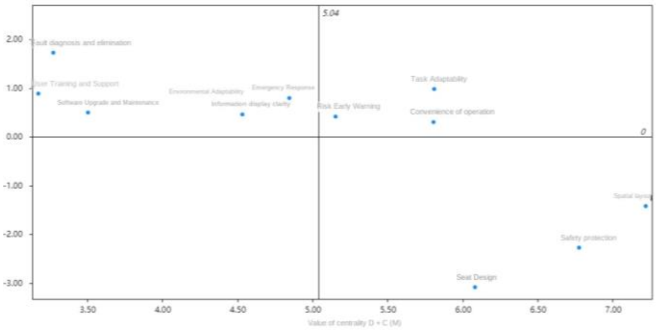

Figure 1. Centrality - causal degree diagram

By comparing the distribution of various factors in the figure, it can be seen that "Fault Diagnosis and Troubleshooting", "Emergency Response" and "Task Adaptability" all show relatively high values in terms of centrality and causal degree, indicating that their importance is rather prominent. However, "Safety Protection" and "Seat Design" have relatively low values in both centrality and causal degree, and their importance is relatively low. Among them, "Fault Diagnosis and Troubleshooting", "Emergency Response" and "Task Adaptability" are the three items with relatively outstanding comprehensive performance. While the comprehensive performance of "Safety Protection" and "Seat Design" is extremely low, and the figure also shows that their importance is low. Therefore, they may not be given key consideration in relevant practices. Centrality - Causal Degree Diagram is shown in Figure 1.

RESULTS

As shown in the following table (Table 3), based on the results of the AHP - DEMATEL analysis, the importance and interrelationships of each design factor have been clarified. Among them, the importance of factors such as safety protection and space layout is particularly prominent. Therefore, in the rescue boat design practice, special attention is paid to the optimization of these key factors.

Table 3. Functional positioning of mother - daughter rescue boats

Medium-sized Inflatable Mother Rescue Boat	Small Inflatable Son Rescue Boat
Rescue Trapped People in Water	Rescue Trapped People in Water Disasters in Narrow Areas
Transport Trapped People to Centralized Resettlement Points	Transfer Trapped People onto the Medium-sized Rescue Boat
Transport Relief Supplies After the Disaster	Transport Relief Supplies After the Disaster
Store Food, Drinking Water	Integrated Space
Store Food, Drinking Water	Inflatable Design
Mobile Rescue Boat	Manual Rescue Boat
Accommodate a Large Number of People	Small folding space

It is decided to adopt the design scheme of the mother-son rescue boat, which combines the medium-sized inflatable mother rescue boat with the small inflatable son rescue boat.

The medium-sized inflatable mother rescue boat mainly undertakes the tasks of rescuing the trapped people in the areas with large water disaster areas, transporting the rescued people to centralized resettlement points, transporting relief supplies after disasters, storing food and water sources, and carrying out night lighting rescue. Relying on its large capacity (which can accommodate 15 to 20 people), symmetrical hull design, lightweight inflatable seats, bow searchlights and internal ambient reflective light strips, it not only facilitates the movement, observation and operation of the personnel, but also effectively solves the problem of night search and rescue. Meanwhile, its multi-chamber and double-valve body structure ensures that it can still maintain a certain level of safety when the hull is damaged and continue to carry out the rescue mission.

The small inflatable son rescue boat focuses on the rescue in narrow areas. It can be launched into the water by the rescue auxiliary device and inflated. After carrying two people, it will be transported to the mother rescue boat. It is convenient to operate precisely. With the help of the infrared sight and the rear screen, it can achieve precise delivery and direction observation. The overall model of the rescue boat is shown in Figure 2.

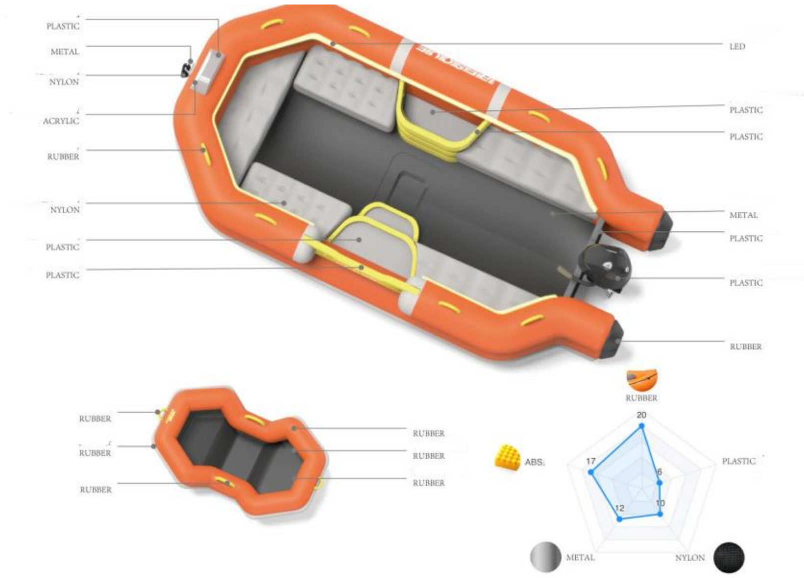

Figure 2. Display of the overall rescue boat model

The shape of the rescue auxiliary equipment adopts a multi-faceted form design that conforms to mechanical engineering, with harmonious proportions. It focuses on the design of contour lines, structural lines and parting lines. The color combination of dark gray and light gray echoes each other. A spraying effect is added on the large-area light gray surface to enhance the sense of detail. The auxiliary color of bright orange improves the safety of the product, as shown in Figure 3.

Figure 3. Display of the overall rescue auxiliary equipment model

In the design of the operation interface, full consideration has been given to the factor of operational convenience. The control buttons are designed in accordance with ergonomics to ensure a reasonable layout, and the icons and texts are clear and easy to understand, facilitating the rapid identification of functions by rescue personnel. The high-resolution screen accurately displays various types of information in the form of charts and figures. Moreover, it optimizes the information display content according to different tasks (such as search and rescue or transportation), highlighting key information (such as life detection and personnel location, cargo and route information), so that rescue personnel can quickly obtain data and make accurate decisions.

Regarding safety protection, emergency stop and communication buttons are set up to ensure that in emergency situations such as ship malfunctions and personnel injuries, timely alarms can be issued and response plans can be provided. Advanced technologies are utilized to monitor the risks of collisions and groundings, and reminders are clearly displayed on the interface to alert rescue personnel. Meanwhile, the states of life jackets and seat belts are displayed in real time to ensure the correct use of personal protective equipment by personnel.

The design for comfort is manifested in multiple aspects. For example, materials that are comfortable and durable and can adapt to different body types are adopted, and the internal layout is optimized to ensure wide and collision-proof passages, facilitating the operation and movement of rescue personnel. The interface also has functions to adapt to different environmental conditions, such as automatic dimming under strong light and normal operation in low-temperature environments.

In addition, the rescue boat also takes maintainability into account. It has the functions of fault diagnosis and troubleshooting. When a fault occurs, it can clearly display the error code, location and troubleshooting methods to assist in maintenance. It supports online and remote upgrade and maintenance functions, facilitating subsequent system updates. At the same time, materials such as user manuals and operation videos are provided to help rescue personnel quickly master the operation methods.

Through the above design practices, the concept of human-computer interaction has been fully integrated into the design of urban waterlogging emergency rescue boats, achieving the harmonious unity of humans, machines and the environment, improving the usability, comfort and rescue efficiency of the rescue boats, and providing stronger support for urban waterlogging emergency rescue work.

DISCUSSION

This research delves into the design of urban waterlogging emergency rescue boats from the human-computer interaction perspective to boost rescue efficiency and usability. By employing diverse research methods, a design factor system is constructed and quantified. Firstly, it meticulously combs through design factors, erects a multifaceted factor system integrating functionality, safety, comfort, and maintainability, and utilizes the AHP-DEMATEL method to work out objective weights and rankings, furnishing scientific guidance for the design. Secondly, the devised design path targets the harmonious unity of humans, machines, and the environment, ameliorating the current research deficiency. In practice, zeroing in on pivotal design aspects such as operational convenience and information clarity heightens the comfort of rescue boats and the operational experience of rescue personnel, thereby augmenting rescue efficiency and proffering valuable references.

Looking ahead, there's ample scope for enhancing the design research of these rescue boats. With technological advancements, more advanced technologies like intelligent and automated controls ought to be incorporated to grapple with intricate rescue scenarios. Concurrently, continuous heed should be paid to the actual requirements and feedback of rescue personnel to finetune the design, augment reliability and adaptability in extreme environments, and guarantee superior performance in urban waterlogging emergency rescue.

REFRENCES

[1] Zhang Z Q. Design and Performance Research of Surface Remote-controlled Rescue Vehicle. Harbin University of Commerce, 2024.

[2] Cui C. Research on Dynamic Estimation and Target Tracking Technology of Marine Rescue Targets under Severe Sea Conditions. Journal of Shaoxing University, 2023, 43(10): 95 - 100 + 120.

[3] Xu S, Wang Y. Research on Cooperative Control of Marine Fishery Vessels under Dynamic Communication Links for Rescue. Marine Fisheries, 2023, 45(6): 759 - 766.

[4] Wang G Y. Design and Optimization of a Rudder Steering Structure for an Unmanned Boat for Water Rescue. Technology and Market, 2023, 30(5): 55 - 57.

[5] Ren W, Xue L, Shi J. Management Innovation in the Design and Testing of the Mission System of a Certain Rescue and Salvage Ship. Guangzhou Shipbuilding Technology, 2024, (1): 77 - 78.

[6] Wei Y N, Wang Z F. Discussion on the Application of Intelligent Rapid Rescue Boats in the Field of Maritime Rescue. Pearl River Water Transport, 2023, (11): 65 - 66.

[7] Liang H, Liao X J, Huang S S, et al. Design of a Compressed Oxygen Self-rescuer from the Perspective of Human-computer Interaction. Packaging Engineering, 2023, 44(18): 35 - 41.

[8] Li Y, Liu G C, Liu S, et al. Human-computer Engineering Design of a Shared Elderly Scooter Based on AHP-QFD. Packaging Engineering, 2023, 44(18): 52 - 59.

[9] Bu J, Zhou T, Sun P X. Research on the Evaluation of Unmanned Helicopter Modeling Design Based on AHP-Entropy Weight Method. Machinery Design & Manufacture.

[10] Wu Y W, Liu G J. Real-time Estimation Method of Dynamic RCS Characteristics of Non-cooperative Targets. Shipboard Electronic Countermeasure, 2022, 45(2): 15 - 18.

[11] Wang S, Zhang Y, Zheng Y. Adaptive Understanding of Multi-Ship Encounter Situations Based on Individual Navigation Intention Reasoning. Ocean Engineering, 2021, 237: 109612.

[12] Sharma A, Nazir S, Ernstsen J. Information Requirements for Situation Awareness in Maritime Navigation: A Goal-Oriented Task Analysis. Safety Science, 2019, 120: 745-752.

[13] Chen X, Qi L, Yang Y, et al. Video-Based Detection Infrastructure Enhancement for Automatic Ship Identification and Behavior Analysis. Advanced Transportation Journal, 2020: 1-12.

[14] Lee W J, Roh M I, Lee H, et al. Detection and Tracking of the Ship's Surrounding Environment Based on Deep Learning. Computational Engineering Journal, 2021, 8: 1407-1430.

[15] Zhang Z X. Design of Visible - light Vision Target Tracking System for Unmanned Surface Vehicles. Ship Science and Technology, 2022, 44(13): 153-156.

[16] Thombres S, Zhao Z, Ramm-Schmidt H, et al. Sensors and artificial intelligence technologies for autonomous ship situation awareness: A review. IEEE Transactions on Intelligent Transportation Systems, 2022, 23: 64-83.

[17] Chen X, Qi L, Yang Y, et al. Video-Based Detection Infrastructure Enhancement for Automatic Ship Identification and Behavior Analysis. Advanced Transportation Journal, 2020: 1-12.

[18] Lee W J, Roh M I, Lee H, et al. Detection and Tracking of the Ship's Surrounding Environment Based on Deep Learning. Computational Engineering Journal, 2021, 8: 1407-1430.

[19] Yan J, Zhang S H, Guan X P, et al. A Bio-inspired Simultaneous Surface and Underwater Risk Assessment Method Based on Stereo Vision for USVs in Nearshore Clean Waters. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2022.

[20] Xue K W, Ma J L, Wu H F, et al. Design, Modeling and Implementation of a Projectile-based Mechanism for USVs Charging Tasks. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2022.