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Rapid navigation and deployment strategy of unmanned craft in maritime emergency response

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ABSTRACT
With the increasingly frequent Marine development activities and the increasingly complex maritime security situation, the demand for maritime emergency response is increasing. As a new type of Marine equipment, unmanned boat has great application potential in the field of maritime emergency response. This paper deeply analyzes the technical characteristics and advantages of unmanned boat, and discusses its various application scenarios in maritime emergency response. The key technologies involved in fast navigation are detailed, including environment awareness, path planning and navigation algorithms. For the deployment strategy, the content of task assignment, formation control and communication support is studied from the perspective of multi-boat cooperative deployment. Further enhancing the maritime emergency response capability provides a strong technical support and theoretical basis.

KEYWORDS
unmanned boat; offshore emergency response; fast navigation; deployment strategy

1 Introduction

The ocean plays an extremely important role in the global economy, trade, energy and other fields. However, the Marine environment is complex and changeable, natural disasters (such as typhoon, tsunami), Marine accidents (such as ship collision, oil leakage) and other emergencies occur frequently, causing serious threats to the safety of Marine life and property and Marine ecological environment. In the face of some complex situations, the traditional maritime emergency response means have some problems, such as slow response speed, high operation risk and high cost. As an intelligent and automatic maritime vehicle, unmanned vessel has many advantages such as small size, strong mobility, low cost, and remote control and so on. It can carry out tasks in the complex and dangerous maritime environment, without the direct exposure of personnel to the dangerous environment, providing a new solution for maritime emergency response.[1] Fast and effective navigation and reasonable deployment strategy are the key to the role of unmanned boats in maritime emergency response, and it is of great theoretical and practical significance for their in-depth research.

2 Technical characteristics and advantages of unmanned craft

2.1 Miniaturization and mobility

Unmanned boats are relatively small in size, which gives them excellent traffic capacity in narrow waters, nearshore zones and complex maritime obstacles. Its hydrodynamic design follows specific hydrodynamic principles, combined with a high-performance propulsion system, to achieve accurate and rapid steering, acceleration and deceleration operations. This allows unmanned boats to reach designated waters in a relatively short period of time.

For example, when dealing with small ship accidents inside the port, it can quickly approach the accident vessel; when carrying out search and rescue operations in the shallow area, it can effectively avoid the restrictions caused by large rescue vessels due to insufficient water depth, and carry out rescue operations quickly, which greatly improves the timeliness of emergency response.

2.2 Intelligence and autonomy

Unmanned craft is equipped with a variety of advanced sensors including radar, sonar, camera, GPS, etc., relying on intelligent algorithms to build a perfect environment perception and decision-making system. [2] The surrounding environment data is collected in real time through the sensors, the data is quickly processed and in-depth analyzed with the help of intelligent algorithm, and then the decision instructions are independently generated according to the task objectives. In maritime emergency scenarios, such as oil monitoring and cleaning tasks, unmanned boat can according to the sensor feedback information, accurately determine the oil area boundary and thickness, using the path planning algorithm to develop scientific and reasonable cleaning path, effectively reduce manual intervention link, significantly improve the efficiency and accuracy of emergency response, to ensure the consistency and stability of task execution.

2.3 Low cost and low risk

From the perspective of economic cost, unmanned boats show obvious cost advantages over manned ships in their construction, operation and maintenance. While the labor cost is greatly reduced, the simple and intelligent design of the equipment also reduce the complexity and cost input of hardware maintenance. From the perspective of risk prevention and control, without the need of personnel, the risk of casualties facing personnel at sea is completely eliminated[3]. Especially in the emergency task of high danger waters, such as bad sea conditions under the preliminary exploration and monitoring of toxic and harmful substances leakage area sampling task, unmanned boat can safely and stably into the dangerous area, obtain key data information, for subsequent rescue and treatment plan to provide strong support, guarantee the safety and feasibility of the emergency response action.

3 Application scenarios of unmanned craft in maritime emergency response

3.1 Maritime search and rescue

In the case of sea people falling into the water or ship crash, the unmanned boat can quickly reach the accident area and conduct a large-scale search with its thermal imager, optical cameras and other equipment. Through networking with the satellite communication system and the maritime rescue command center, the search screen can be transmitted back in real time. Once the target is found, life-saving equipment or rescue forces can be guided to rescue, so as to improve the success rate and efficiency of rescue. For example, in a fishing boat sinking accident in a sea area, many unmanned boats conducted grid search in the incident area from different directions, determined the position of the drowning crew in a short time and put the life raft, successfully rescuing many crew members.

3.2 Marine environment monitoring and pollution prevention and control

Unmanned boats can conduct real-time monitoring of Marine water quality, meteorology, ecology and other environmental parameters. In the event of Marine pollution events (such as oil leakage, chemical leakage), it can quickly reach the pollution area, monitor the pollution range, concentration and diffusion direction and other information, and cooperate with other cleaning equipment (such as skimmer, oil absorption felt delivery device, etc.) to carry out pollution control operations. For example, in a large oil tanker oil leakage accident, the unmanned boat carried multi-spectral sensors to accurately monitor the oil pollution, providing detailed data support for the subsequent oil fence layout and oil pollution cleaning operation, and effectively controlling the spread range of oil pollution.

3.3 Maritime security patrol and law enforcement

It is used for maritime border patrol, exclusive economic zone control, crackdown on illegal maritime activities (such as smuggling, illegal fishing) and other tasks. Unmanned boats can sail independently according to the preset patrol route, and use radar, AIS (automatic ship identification system) and other equipment to identify and monitor ships in the surrounding waters[4]. Once abnormal conditions are found, they can report and take corresponding measures in time, such as driving away illegal ships or tracking and monitoring suspicious targets.

4 Key technology of unmanned boat fast navigation

4.1 Environmental awareness technology

The environmental sensing technology of unmanned boats is crucial to their operations at sea. In terms of sensor fusion, the integrated use of laser radar, millimeter wave radar and camera, laser radar precision object distance and contour, millimeter wave radar performed well in bad weather, cameras provide visual information, with the help of kalman filter, particle filter data fusion algorithm integration data, enhance environmental perception reliability and accuracy, build a foundation for navigation decisions. In terms of target recognition and positioning, image recognition technology and deep learning algorithm are used to process camera images to achieve accurate identification and classification of ships, buoys, islands and other maritime targets, and then combine GPS and Beidou positioning system to determine the target position[5]. In terms of maritime emergency response, this helps the unmanned boats to quickly lock the accident scene or rescue targets, and improve the efficiency and accuracy of emergency response.

4.2 Path planning technology

The path planning technology of unmanned craft consists of two key parts: global and local path planning. Global path planning is based on the existing chart information and the location of the task target, using classical algorithms such as A * algorithm and Dijkstra algorithm. In the map model, they explore the optimal or close to the optimal path from the beginning to the target, and comprehensively consider many factors, such as the shortest range and the navigation safety area. For example, when planning the route from the port to the site of a maritime accident, it can skillfully avoid dangerous areas and busy waterways such as shoals and reefs, and select safe and efficient routes[6]. The local path planning aims at the dynamic changes of the environment during the unmanned boat voyage, such as the sudden appearance of other ships and wave impact, using common means such as artificial potential field method and dynamic window method. With the construction of gravitational field and repulsion field, the unmanned method can dynamically adjust the direction, and the dynamic window method can search the current speed and acceleration and the feasible speed combination in the speed space to achieve the purpose of safe obstacle avoidance and rapidly approaching the target point.

4.3 The navigation algorithm

The navigation algorithm of unmanned craft mainly includes model-based navigation algorithm and intelligent navigation algorithm. Model-based navigation algorithm such as extended Kalman filter (EKF) navigation algorithm, with unmanned kinematics model and sensor measurement data to carry out the state estimation and navigation calculation, through the nonlinear system linearized approximate processing, the prediction and update steps continuously correct unmanned position, speed, attitude, even if there are current, wind and other external interference, also can guarantee the accuracy and stability of the trajectory. Intelligent navigation algorithm uses neural network, reinforcement learning and other means to make navigation decisions. Neural network can be based on a large number of navigation data learning the optimal navigation strategy under different environment, reinforcement learning with unmanned boat and environment interaction constantly optimize their behavior strategy to get the biggest reward, like in complex islands waters, intelligent navigation algorithm can reference past experience data and real-time environmental feedback, flexible selected best navigation channel, effectively avoid excess detour and risk, greatly improve the efficiency and safety of navigation.

5 Multi-boat co-deployment strategy

5.1 Task assignment strategy

Match with the boat capability based on the mission requirements. According to the type of maritime emergency response tasks (such as search, rescue, monitoring, etc.), scale (such as search size, the number of rescue, etc.), and the degree of emergency, combined with the performance of unmanned load, endurance, navigation speed, using intelligent task allocation algorithm (such as genetic algorithm, ant algorithm, etc.) the task allocation to the unmanned boat. For example, for a large area maritime search task, the search area is divided into multiple sub-regions, and the number and types of unmanned boats are allocated to each sub-area according to the detection range and speed of the unmanned boat to ensure that the task can be completed efficiently.

Dynamic task adjustment. In the process of the mission, the task assignment scheme needs to be dynamically adjusted due to the change of the task progress (such as the increase of the difficulty of the original task with new goals) or the change of the status of the vehicle (such as power shortage, equipment failure, etc.). A dynamic model of task assignment is established to monitor the task performance and unmanned boat status information in real time, and the task is reasdistributed by online optimization algorithm (such as model prediction and control algorithm) is used to ensure the smooth progress of the whole emergency response task.

5.2 Formation control strategy

Formation design and maintenance. According to different maritime emergency mission requirements, the linear formation is suitable for large area search task, which expand the search range; the circular formation is beneficial to surround and monitor the target. Formation control methods such as pilot-following method and virtual structure method are adopted to maintain the relative position and attitude of unmanned boats. For example, in the pilot-follow method, an unmanned boat is designated as the pilot boat. Other unmanned boats maintain the formation formation by controlling their own navigation speed and direction according to the relative position and distance information with the pilot boat. When encountering obstacles or performing special tasks, the formation can flexibly change the formation.

Collaborative motion control. Realize the coordinated motion control of unmanned boat formation, including synchronous navigation, steering, acceleration and deceleration operations. Through the design of distributed collaborative control algorithm, each unmanned boat can achieve collaborative movement only by relying on local communication and its own sensor information. For example, when the maritime relief materials are launched, the unmanned boats in the formation need to slow down synchronously and adjust the position, so that the delivered materials can accurately fall in the target area. The cooperative motion control algorithm can ensure that the unmanned boats can still maintain a high degree of consistency and coordination under complex sea conditions.

5.3 Communication support strategy

Multi-communication mode convergence. Reliable communication links are required between and between the command center. The fusion of various communication modes, such as satellite communication, 4G / 5G mobile communication, AD hoc network communication, etc. Satellite communication has the advantage of wide coverage, which is suitable for long-distance communication and data transmission; 4G / 5G mobile communication can provide high-speed data transmission rate when the signal is good to meet the transmission demand of large image, video and other data; autonomous network communication can build network between drones without infrastructure to ensure the information interaction in the formation.

Communication protocol design and optimization. Design a special UAV communication protocol to standardize the data format, transmission rate, communication frequency and other parameters. The communication protocol is ptimized to improve the reliability and real-time of communication, and data encryption and error correction coding technologies are adopted to prevent data loss and tampering. For example, in offshore emergency response, the environmental monitoring data and mission implementation data transmitted by unmanned ship is crucial for command decision. Optimizing the communication protocol can ensure the accurate and timely transmission of data, and avoid mission failure or delay due to communication failure.

6 Conclusion

Unmanned boat has broad application prospects in maritime emergency response, and its rapid navigation and deployment strategy are the key link to play its role. Through in-depth study of unmanned boat environment perception, path planning, navigation algorithm of fast navigation technology and task allocation, formation control, communication support boat cooperative deployment strategy, and put forward the corresponding optimization method, it can be seen that unmanned boat can significantly improve the speed of maritime emergency response, efficiency and accuracy, reduce casualties and property losses, protect the Marine ecological environment. However, the current unmanned technology is still faces some challenges, such as the navigation accuracy under complex sea conditions, boat collaborative reliability and the cost of large-scale application, the future need to further strengthen technology research and development and innovation, constantly improve the unmanned boat in the maritime emergency response application system, to ensure the maritime security and sustainable development to provide more powerful technical support.

About the Author

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