

Research on the Application of Small UAVs in Maritime Search and Rescue Activities

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Abstract: In recent years, with the increasing frequency of global Marine activities, the occurrence probability of Marine accidents and emergencies has also increased. As a new technical means, small unmanned aerial vehicles (UAVs) have shown great application potential in Marine search and rescue activities. In Marine search and rescue activities, small UAVs can quickly arrive at the scene of the accident and carry out efficient information collection and monitoring under its simple and flexible operation. Compared with traditional search and rescue methods, small UAVs can cover a wider area, provide more detailed and accurate on-site information, provide strong support for search and rescue decision-making, and thus improve the quality and efficiency of maritime rescue. In this regard, this paper first describes the application advantages of small UAVs in Marine search and rescue activities and then puts forward effective application paths, to provide some references for relevant researchers.

Keywords: Small unmanned aerial vehicle; Maritime search and rescue; Application path

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1. Introduction

Currently, small UAVs cannot perform tasks independently and autonomously ^[1]. They must work together with a series of control systems and other related equipment to form a complete UAV system ^[1]. The system was designed with the relatively low fuel consumption requirements of small UAVs in mind, so the overall operating cost is also relatively low. This makes small UAVs respond to a variety of sudden disaster events, especially in maritime rescue operations, small UAVs have become an indispensable part, they can respond quickly in harsh environments and provide critical air support and real-time intelligence, greatly improving rescue efficiency and safety.

2. The application advantages of small UAVs in maritime search and rescue activities

2.1. Convenient operation and strong flexibility

Small UAVs have shown great advantages in maritime search and rescue activities because of their small size,

easy operation, and flexibility. For example, they can quickly detect areas and help personnel carry out rescue, especially in large maritime search and rescue missions. With their high mobility, small UAVs can maneuver flexibly in a variety of different environments. The speed and efficiency of search and rescue can be further improved. Additionally, when an emergency occurs, the small UAV can use the search-and-rescue personnel's palm as a springboard, autonomously adjust the route, and change the flight attitude in a certain area, so it has a huge application advantage in the absence of take-off and landing areas. In general, the use of small UAVs in maritime search and rescue can give full play to its advantages of flexibility, improve the efficiency of maritime search and rescue activities, and deal with various emergencies promptly ^[2].

2.2. Strong ability to obtain information

At present, in maritime search and rescue activities, small UAVs organize and analyze relevant information collected through the Beidou navigation satellite system, aerial photography system, navigator, information perception system, positioning system, etc., and collect environmental, meteorological, emergency, and other information in real-time, to facilitate rescuers to make accurate judgments and analysis. For example, for the offshore oil drilling platform explosion accident, rescue workers can use small UAVs to carry out local aerial observation and real-time monitoring, accurately judge the explosion scale and explosion time, real-time monitoring the duration of the fire, and model the fire transmission process. After receiving the early warning signal, the rescue personnel can obtain accurate forward projection and a three-dimensional model of the building according to the on-site photos and mapping information, and according to the observation and analysis of the accident site, determine the various details of the accident site to carry out subsequent rescue missions ^[3].

2.3. Strong safety and reliability

Small drones, due to their compact size, do not require large parking facilities and can perform emergency rescue missions even in harsh environments, offering enhanced safety. For instance, in situations like offshore oil drilling, hazardous chemical storage, fuel transportation sites, offshore ship capsizing, or sea crashes—where traditional search and rescue methods face significant challenges due to the marine environment—small UAVs excel. These drones can safely and reliably conduct rescue operations by leveraging their adaptability to the take-off environment, equipment safety features, and compact design. They can quickly assess the rescue situation, minimizing response time, and mitigating the risks posed to rescue workers by harsh sea conditions, thereby enhancing the overall safety and reliability of rescue missions ^[4].

3. Application path of small UAV in maritime search and rescue activities

3.1. Precise location of trapped people

In search and rescue missions across vast oceans, small drones play a crucial role by effectively locating and assisting trapped individuals. Traditional manual search and rescue methods or the use of ships alone often fail to achieve optimal results, as they may overlook critical areas during operations.

In contrast, small UAVs offer a significant advantage due to their ability to capture a wider range of video images from greater altitudes than ships. At the current stage of technological development, small drones can quickly identify a person's location in the early stages of a search and rescue mission. Once the target is located, helicopters or search and rescue ships can be dispatched for the specific rescue task.

This strategy not only saves valuable time but also reduces the demand for human and material resources,

ultimately improving the success rate of search and rescue missions ^[5]. In addition, small UAVs possess unique advantages, including the ability to achieve vertical take-off and landing, allowing them to complete flight missions even in extreme weather conditions. Beyond their efficient positioning capabilities, small UAVs are equipped with advanced thermal imaging and infrared imaging technology. These tools enable them to accurately detect the body heat signatures of trapped individuals, even at night or in adverse weather conditions, thereby enhancing the accuracy and efficiency of search and rescue operations.

Thermal imaging technology, in particular, is invaluable during nighttime rescue missions, as it can quickly detect heat emitted by the human body. This allows rescue teams to swiftly pinpoint the precise location of trapped individuals, significantly improving the scientific accuracy and overall effectiveness of search and rescue efforts.

3.2. Pay attention to extending the endurance time

The factors affecting the endurance of small UAVs in sea rescue operations are primarily as follows: the weight of the UAV (including its own mass and payload), flight speed, flight state, temperature, wind speed, and power system. The overall weight of a UAV includes components such as the frame, electronic speed controller, motor, blades, head, and flight controller.

In maritime rescue activities, the payload typically consists of cameras, life-saving equipment (such as life rings and manipulators), and other essential tools. The weight of the UAV directly impacts the thrust required to keep it airborne, which in turn affects its power output and limits battery life. Therefore, when utilizing UAVs for maritime search and rescue, rescue workers must prioritize minimizing the weight of the drone wherever possible. This ensures better endurance and efficiency during operations ^[6].

Secondly, the configuration and load selection of each component should be carefully planned. Components or configurations that do not meet the requirements of maritime search and rescue should be eliminated to reduce hardware redundancy ^[7].

Finally, while ensuring the endurance time as much as possible, factors such as the operating sea area should be taken into account. For example, in search and rescue activities conducted in waters with large waves and complex sea conditions, it may be necessary to choose a more durable UAV body and a more stable flight control system to ensure that the UAV can operate reliably in harsh environments.

For missions requiring long-distance flights, it might be necessary to equip the UAV with a larger-capacity battery or implement a more efficient energy management system to extend its flight time. Additionally, during the search and rescue process, the UAV's flight altitude, speed, and heading should be flexibly adjusted based on the specific situation to maximize the efficiency and accuracy of the operation ^[8].

3.3. Playing a vital role in providing warnings

In sea rescue activities, small UAVs must work closely with ground rescue teams by monitoring the rescue situation from above and promptly relaying information to the ground team. Upon receiving instructions, the UAV should immediately proceed to the accident site according to the pre-established plan and continue providing alerts to the ground rescue personnel.

For example, in the event of a marine explosion, small UAVs must quickly cool flammable materials to prevent further explosions. Additionally, they can assist environmental protection agencies in efficiently managing wastewater while supporting the rapid deployment of firefighting resources. This enables rescue forces to promptly reach the scene and ensures seamless coordination between aerial and ground operations. ^[9]

In the event of marine disasters, ground search and rescue teams may struggle to assess the situation at sea on time. Small drones can provide a comprehensive overview of the scene, identify suitable parking locations for rescue vehicles, and offer logistical support for maritime rescue operations.

Additionally, small drones can be equipped with high-decibel sirens or warning lights to fly over the accident site and alert nearby ships and personnel, preventing them from inadvertently entering hazardous areas. By carrying equipment such as loudspeakers, drones can also deliver rescue instructions to trapped individuals, helping them remain calm and wait for assistance.

Therefore, in marine search and rescue missions, fully utilizing the capabilities of small drones can help complete rescue tasks in the shortest possible time, reduce the risks associated with maritime rescue, minimize losses, and highlight the early warning and support functions of small drones ^[10].

3.4. Deliver materials and equipment

Firstly, long-distance transport by small UAVs in maritime rescue. Small unmanned aerial vehicles (UAVs) are highly effective in long-distance transport, especially in complex environments. Thanks to their strong carrying capacity, they can efficiently deliver relief supplies even in challenging conditions. With the ability to take off and land vertically, as well as fly at low altitudes, small UAVs can navigate through complex terrains and avoid obstacles on the ground.

Moreover, when equipped with a high-precision navigation system, small drones can plan their routes in real-time, ensuring that relief supplies reach their destinations accurately and efficiently. The advancement of battery technology has further improved the endurance of small UAVs, making them capable of completing long-distance transport missions. Additionally, the selection of different types of UAVs allows for the transport of varying loads; for example, larger UAVs can carry up to tens of kilograms of material, meeting the demands of rescue operations. By choosing the appropriate UAV model, these devices can adapt to the diverse needs of different rescue scenarios.

Secondly, the delivery of relief materials is a crucial function of small UAVs, particularly in maritime rescue operations. The delivery of basic survival materials, such as food and water, is especially critical in the aftermath of marine disasters. Stranded individuals often lack essential supplies, and the rapid delivery of these materials can make a significant difference in their survival. Small UAVs, with their strong carrying and transportation capacity, can deliver these materials quickly and efficiently to the scene. This ensures that trapped individuals receive the necessary provisions, allowing them to maintain confidence while awaiting rescue. Furthermore, small UAVs can transport urgently needed medical supplies, thereby safeguarding the health and safety of the stranded individuals.

Another important aspect of small UAVs in maritime rescue is their ability to deliver communication equipment. During maritime disasters, communication devices are often damaged or rendered inoperable due to sinking, water entry, or other causes. As a result, it becomes difficult for stranded individuals to communicate with rescue teams. Small UAVs can bridge this communication gap by delivering essential equipment such as satellite phones and mobile base stations. By establishing temporary communication networks, UAVs ensure that effective communication is maintained between the trapped individuals and search-and-rescue personnel, facilitating the smooth progress of rescue operations ^[11].

3.5. Conducting regular maritime safety inspections and information collection

Firstly, designate sea area safety inspections using small UAVs. Small UAVs play a key role in conducting safety inspections in designated sea areas. They take off and land to patrol and search for targets within specific waters,

ensuring the effectiveness of search and rescue operations. The operation process is as follows.

Based on weather conditions, small UAVs are prepared for takeoff, loaded with the designated patrol route, and then vertically lifted off from the launch platform. Once airborne at an altitude of 500 m to 3,000 m, the UAVs patrol the task area at a speed of 100 km/h to perform search and rescue tasks. After completing their mission, they return to base.

During flight, if additional targets are detected, rescue teams can use visual flight plans to connect the small UAV to the target's auxiliary equipment. After observing the target, the ground control operator directs the UAV back to its pre-determined orbit and initiates the return command. If an object of interest is discovered during the return journey, the UAV can deviate from its route, perform navigation or visual navigation, and then return to the original path to complete its return to base ^[12].

Secondly, collect information in specific sea areas. When a small UAV is deployed for mapping, photography, and other information collection tasks in a specific sea area, it will immediately take off for reconnaissance. The UAV targets specific areas or objects, performing remote mapping or capturing photos, videos, and other data. The high-definition image data is transmitted back to the shipping center, providing more detailed information on the target.

For example, small UAVs can remotely identify the appearance and side numbers of targets such as merchant ships and fishing boats, offering valuable decision-making support to users at a distance. In such cases, the UAV's pod locks onto the target and tracks it continuously, monitoring its movement patterns over time. Once the task is completed, the UAV can return to base at any time. It is important to note that information collection can be conducted in a single region or across multiple regions, with several small drones operating simultaneously ^[13].

4. Summary

All in all, small UAVs have gained widespread attention and application in future maritime rescue activities ^[15]. The search and rescue efficiency of small UAVs can be significantly improved by accurately locating trapped individuals, extending flight duration, serving as a special warning system, ensuring efficient material transportation and equipment delivery, and regularly conducting sea safety patrols and information collection. These capabilities can address key technological challenges and enhance the role of UAVs in sea rescue operations.

Therefore, in future maritime rescue missions, it is crucial to recognize the importance of small UAVs in these efforts and proactively adopt effective strategies to utilize them. This will help improve the quality of maritime rescue operations and maximize the preservation of lives and property.

Disclosure statement

The authors declare no conflict of interest.

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