

APPROACHES TO USING QUADCOPTERS FOR SHIP ESCORTING TO AVOID PROBABLE COLLISIONS

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Introduction. Navigation of maritime vessels is a complex process that demands high precision and reliability, especially in hazardous waters. Incorrectly determined coordinates can lead to serious consequences, such as collisions with other ships, grounding on reefs or shallow waters, which not only poses a threat to the life of the crew and passengers but can also lead to ecological disasters and significant financial losses [1, 2].

The problems with traditional navigation systems include:

1. Data ambiguity: Systems such as ECDIS (Electronic Chart Display and Information System) and marine radars are foundational for modern navigation, but they are not always capable of providing the necessary accuracy under complex conditions. Errors may arise due to many factors, including limitations in equipment accuracy, delays in data updates, and errors in operator data interpretation.

2. Dynamic changes in conditions: The marine environment is constantly changing, and static chart data can't always reflect the current situation, especially in waters with rapidly changing weather conditions or near coastlines where unforeseen obstacles may arise.

3. Technological limitations: While ECDIS provides comprehensive visualization of navigational information, the system may have technical limitations such as insufficient integration with other navigation systems or a lack of capability to promptly process changes in data about potential threats.

4. Human factor dependency: Despite automation, the final decision often depends on the captain and crew, who may not always be able to adequately assess all risks due to data representation deficiencies [3, 4].

These issues highlight the need to integrate cutting-edge technologies to enhance the accuracy and reliability of maritime navigation, especially in hard-to-access and dangerous waters, paving the way for innovative solutions like the use of quadcopters for high-precision monitoring and measurements.

Identifying potential hazards for maritime vessels

1. Shallow waters: The most common hazard for maritime vessels, especially in coastal areas and places with complex seabed topography. Shallow waters may not be adequately marked on marine charts or may change over time due to natural processes such as soil displacement or sediment accumulation.

2. Other vessels: The risk of collision with other vessels is high in popular trade routes or in areas of intensive fishing. This problem is exacerbated in conditions of poor visibility, such as in fog or heavy rain.

3. Artificial structures: Bridges, wind farms, oil and gas platforms pose serious hazards for navigation. These objects are often located in areas that are difficult to navigate and require vessels to pay special attention and precision when passing nearby.

Limitations of existing navigation systems

1. Outdated data: The navigation charts used by ECDIS may not be updated or may contain errors. This becomes critical when a vessel relies on this data while planning a route in unknown or complex waters [5].

2. Equipment technical limitations: Radars and other navigation devices may have limited range or may not be able to accurately detect small or distant objects. This can complicate the identification of potential threats with enough lead time to maneuver safely.

3. Weather condition dependence: Navigation systems can be highly vulnerable to weather conditions. For example, poor visibility can significantly reduce the effectiveness of radars and optical systems, and strong winds and waves can affect GPS accuracy.

4. Human factor: Errors in interpreting the data provided by ECDIS and other systems can lead to incorrect decisions. Even with modern technologies, human error remains a significant risk.

Technological solution proposals for configuring quadcopters

Quadcopters [6], proposed for use in maritime navigation will be equipped with several key technological components

1. Infrared camera: Provides high-quality imaging at night or in conditions of poor visibility. This allows the identification and tracking of dangerous objects or vessels at significant distances, even in the absence of visible light.

2. Laser distance measurement (LIDAR): Used for precise distance measurements between the quadcopter and objects in the water or on its surface. Laser scanning allows creating a three-dimensional map of the object, providing accurate data for analysis.

Interaction of quadcopters and integration with ECDIS

1. Autonomous coordination: Quadcopters will be able to autonomously coordinate their flights according to set safety parameters and optimal trajectories. They will be positioned at strategically important points around the vessel to ensure complete coverage of the surrounding space.

2. Application of artificial intelligence for data analysis: Artificial intelligence (AI) on each drone will process the collected data in real-time, detecting potential threats and calculating possible collision scenarios. This allows the system to quickly respond to changing conditions and relay important information to the ship's captain.

3. Communication with ECDIS: Data from quadcopters will be transmitted to the onboard computer of the vessel and integrated with ECDIS. This will allow for dynamic updating of navigation charts and information, enhancing their accuracy and relevance. The captain will receive a visual representation of the situation around the vessel, including distances to potential hazards and their movement.

Practical implementation and monitoring of quadcopter operations

During critical maneuvers or in conditions of poor visibility, quadcopters will be deployed from a base station located on the vessel and will accompany it, sending data to the onboard computer of the vessel in real-time. This will provide the captain and crew of the vessel with high-precision information, allowing them to take appropriate measures to avoid collisions and other dangers.

Development and testing of the prototype

1. Design: Development of the technical design of quadcopters, with a special focus on maritime durability, waterproofing, and the ability to withstand strong winds and salty air. It is important to consider the need for long flight time and quick charging.

2. Manufacture of the prototype: Ordering components and assembling the first prototype taking into account all necessary sensors and communication systems.

3. Laboratory tests: Testing of the main functions in a controlled environment, including piloting, stability, data transmission, and sensor accuracy.

4. Field tests: Conducting field tests at sea to evaluate the system's performance in real conditions. This includes testing the interaction with maritime navigation systems, battery endurance, and the quadcopter's ability to perform tasks in various weather conditions.

Scenarios for using quadcopters in different maritime conditions

1. In hazardous waters: Using drones to monitor shallow waters, mooring operations, and passage through narrow straits.

2. In conditions of poor visibility: Drones can provide critically important visual information in fog or heavy rain, where traditional navigation systems may be limited.

3. In interactions with other vessels: Providing additional safety during maneuvering or mooring in port, especially for large vessels that are difficult to maneuver.

Plan for integrating the system with existing ship navigation systems

1. Collaboration with ECDIS manufacturers: Work with leading navigation system manufacturers to ensure compatibility and integration of drone data in real-time.

2. Development of a management interface: Creating an intuitive interface for captains that integrates with existing navigation consoles, providing easy access to data from drones.

3. Training operators and crew: Developing training programs for captains and ship crews to teach them to effectively use the new system and understand the data it provides.

Improving safety, accuracy, and timeliness of navigation

1. Increased safety: Using quadcopters to monitor the environment around the vessel significantly enhances the level of safety, reducing the risk of collision with other objects and navigation errors. Additional sensors, such as the infrared camera and LIDAR, allow for more accurate data about the environment, even in conditions of poor visibility.

2. Increased accuracy: Laser distance measurement provides high-precision data, allowing the ship's captain to make decisions about maneuvering with greater confidence. This is particularly important in complex navigation conditions, such as narrow channels or crowded maritime routes.

3. Increased timeliness: The rapid transmission of data from drones to the vessel and their integration with the ECDIS system allows for prompt responses to changes in conditions and potential threats. This enables the crew to adapt to the situation more quickly and take corrective actions if necessary.

Economic aspects of implementation

1. Reduced insurance costs: With fewer incidents and increased overall safety, insurance companies may review the insurance rates for vessels using this technology. Reducing risk can lead to a significant decrease in premiums.

2. Reduced costs for ship repairs: With fewer collisions and other accidents, the costs for ship repairs are significantly reduced. This not only saves money but also preserves the company's resources that can be directed towards other needs.

3. Operational efficiency: Reducing downtime due to technical and emergency repairs increases the overall productivity of the fleet. More reliable and accurate navigation systems help avoid delays associated with unexpected navigation errors, positively impacting departure and arrival schedules.

Technical and operational challenges

1. Endurance and reliability: Quadcopters must be designed to withstand the harsh conditions of the marine environment, including high humidity, salt, and wind. This requires the use of specialized materials and technologies, which may increase production costs.

2. Limited range and flight time: The flight time and range of quadcopters are limited by their battery. For effective operation in maritime conditions, sufficient flight time must be ensured so that drones can monitor at significant distances from the vessel.

3. Drone management: Coordination and control of multiple drones in a dynamic and often changing marine environment require complex management algorithms and communication. Ensuring stable and reliable communication between drones and the vessel is critically important.

Legal and regulatory aspects

1. Regulatory requirements: Introducing drones into the maritime industry may face regulatory hurdles related to flight safety, privacy, and the use of airspace. It is necessary to determine what rules and standards will regulate the use of drones over water.

2. International legislation: Maritime transport often takes place in international waters or through the territorial waters of several countries. The introduction of drones may require consent or coordination with various international bodies and authorities.

3. Standardization: To ensure compatibility and integration with existing systems, such as ECDIS, standards for the technical specifications and data formats of drones need to be developed. This requires international cooperation and the establishment of universally accepted norms.

These challenges require careful planning and coordination with many stakeholders, including equipment manufacturers, maritime regulatory agencies, and international organizations. It is also important to consider the potential for ongoing innovation and improvement of the technology so that it can adapt to changing conditions and requirements of the maritime industry.

Conclusions. The use of quadcopters in maritime navigation is an innovative way to monitor the surrounding marine environment and traffic [7,8]. This technology offers a significant increase in safety by providing accurate and timely information about potential hazards, allowing ship captains to make more informed and balanced decisions [9]. The precision with which distances to objects and other parameters can be measured can significantly reduce the number of navigation errors and, accordingly, accidents in maritime transport.

It should be noted that the proposed approach requires the development of advanced management algorithms for coordinating the work of multiple drones, ensuring their effective interaction with ship systems, and analyzing the data obtained.

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