Dean&Francis
ISSN 2959-6157

Research on obstacle avoidance and target search of unmanned aerial vehicles in flood search and rescue work

Jinge Zhang[1],

Wenlong Wan[2]

[1]Communication Engineering,
Yantai University of Technology,
Yantai, Shandong, 264003, China
[1]Email: 19553592835@163.com
[2]Biomedical Engineering, Linyi
University, Linyi, Shandong,
276000, China
[2]Email: llky101698@163.com

Abstract:

The increasing complexity of flood rescue missions demands innovative solutions, with drones emerging as pivotal tools. This research explores dronebased obstacle avoidance and target identification, emphasizing dynamic and uncertain environments characteristic of flood scenarios. Integrating multisensor systems such as LiDAR, thermal imaging, and visual cameras, the study aims to enhance obstacle detection and survivor localization. Novel algorithms, including realtime path planning and sensor fusion, are proposed to optimize drone navigation and precision in turbulent conditions. Additionally, the research addresses challenges like computational efficiency, energy optimization, and adaptive decisionmaking. By leveraging advanced AI and machine learning techniques, the project seeks to contribute to autonomous drone applications in disaster management, offering scalable, costeffective solutions to improve operational safety and efficiency in critical rescue operations. The outcomes are expected to provide actionable strategies for deploying drones in realworld emergencies, ensuring faster response and reduced human risk.

Keywords: Flood Rescue, Obstacle Avoidance, Target Identification, MultiSensor Fusion, RealTime Path Planning, Autonomous Navigation, Disaster Management

---

1. Introduction

In recent years, the occurrence frequency and intensity of floods have been on the rise, endangering countless lives and causing massive destruction to infrastructure and the ecological environment. In such a dire situation, flood rescue operations are of paramount importance. Drones have emerged as a revolutionary force in this field. They can quickly reach areas that are difficult for humans to access, equipped with a variety of sensors like LiDAR, thermal cameras, and visual imaging systems. These sensors allow them to collect real-time data on the flood situation, search for survivors, and assess the damage, providing crucial information for rescue decision-making.

Currently, drones have been applied in some flood

ISSN 2959-6157

rescue scenarios. They are used for initial reconnaissance of the disaster area and searching for possible survivors. However, several key problems persist. The highly dynamic and unpredictable flood environment, filled with floating debris, strong currents, and poor weather conditions, makes it extremely challenging for drones to accurately avoid obstacles and precisely identify targets. Moreover, the existing algorithms still need improvement in terms of real-time path planning and energy optimization.

The purpose of this study is to integrate advanced multi-sensor systems and develop novel algorithms to overcome these obstacles. By enhancing the capabilities of drones in obstacle avoidance, target search, and real-time path planning, we aim to improve the efficiency and safety of flood rescue operations. The research results are expected to provide practical and effective solutions for actual flood rescue, reducing the loss of life and property and promoting the development of disaster management technology.

Table 1 Key Specifications of the research Methodology

Feature	Specification
Sensor Types	LiDAR, Thermal Imaging, RGB Cameras
Obstacle Avoidance Algorithm	Artificial Potential Fields, SLAM[2]
Path Planning Methodology	A, RRT, Dynamic Window Approach
Computational Optimization	Edge Computing, GPU Acceleration

2. Literature Review

The application of drones in flood rescue has garnered increasing attention in recent years. Smith et al. (2022) in “Advanced Drone Navigation in Adverse Environments: A Review of Recent Technologies and Challenges” comprehensively analyzed the performance of different navigation algorithms and technologies under complex flood conditions. Their research emphasized the significance of adaptability and reliability in drone navigation systems, providing valuable references for improving the flight stability of drones in turbulent water environments.

In the aspect of sensor technology, Johnson et al. (2023) in “Real - Time Sensor Fusion for Enhanced Drone Perception in Disaster Response” demonstrated the effectiveness of integrating data from multiple sensors such as LiDAR, thermal cameras, and visual imaging systems. This real-time sensor fusion technique has significantly enhanced the accuracy of target identification and obstacle detection, which is crucial for the success of flood rescue missions.

Regarding path planning, previous studies have explored various algorithms. For example, Dijkstra’s algorithm and RRT (Rapidly-Exploring Random Tree) have been widely discussed. Dijkstra’s algorithm calculates the cost of different paths in complex terrains to determine the safest and most energy-efficient route, while RRT can quickly identify obstacle-free routes in dynamic or complex environments. These algorithms have laid the foundation for further research on optimizing drone flight paths in flood rescue.

In obstacle avoidance, Zhang et al. (2019) researched obstacle avoidance algorithms for unmanned aerial vehicles based on LiDAR. Additionally, methods like the Artificial Potential Field, Dynamic Window Approach, and Fuzzy Logic Control have also been applied. However, continuous improvement is still needed to better handle the complex and unpredictable obstacles in flood situations.

Overall, although significant progress has been made in these areas, there are still challenges to be overcome. This study aims to build on the existing research and further enhance the capabilities of drones in flood rescue through innovation and integration.

3. Research Methodology

3.1 Problem Modeling

In the study of obstacle avoidance and target search of drones in flood rescue work, a mathematical model based on Geographic Information System (GIS) and kinematic principles is constructed. The flood rescue area is regarded as a two-dimensional or three-dimensional space, which contains different types of obstacles, water flow information, and potential survivor locations. It is assumed that the flood environment has relative stability within a certain period, but the water flow speed and direction may change regularly over time, and the position and shape of obstacles are fixed in the short term but may have slight displacements due to the impact of water flow. The coordinate system is used to locate the drone, obstacles, and targets. For example, the position of the drone is set as (x_d,y_d,z_d), the position of the obstacle is $(x_o,y_o,z_ o)$, and the position of the target (survivor) is (x_t,y_t,z_t). The relationship between the drone and each target is described by distance and speed formulas, such as the Euclidean distance formula $d=\sqrt{(x_2 - x_1)^2+(y_2 - y_1)^2+(z_2 - z_1)^2}$ to calculate the distance between the drone and the target or obstacle.

3.2 Technical Route

1. Survivor Detection: Firstly, infrared sensors and thermal imaging devices are used to detect the heat radiation of living beings. Motion detection is carried out by visual sensors or LiDAR to identify moving objects on or near the water surface. Sound recognition is achieved through audio sensors or microphone arrays. Abnormal object identification is performed by analyzing visual data with image processing algorithms. Then, computer vision and deep learning algorithms are utilized to analyze the shape and posture of the detected object to determine if it is a survivor. Biometric analysis, pulse and respiration detection, and thermal source analysis are also employed in appropriate conditions. Finally, multi-sensor data fusion, deep learning and artificial intelligence, and real-time data analysis and feedback are used to enhance the accuracy of survivor identification.
2. Environmental Perception and Map Construction: Drones use LiDAR to scan the surrounding environment and collect distance and positional data to construct real-time 3D maps, which can be grid-based or point cloud maps.
3. Path Planning: Based on the real-time map, drones apply path planning algorithms such as Dijkstra's algorithm and RRT to identify obstacle-free routes.
4. Obstacle Avoidance Control: When approaching an obstacle, drones activate avoidance control algorithms such as the Artificial Potential Field, Dynamic Window Approach, and Fuzzy Logic Control based on real-time LiDAR data.
5. Energy Optimization and Performance Analysis: Optimization algorithms are used to minimize the energy consumption of the drone while maintaining performance.

Proposed Algorithm Model Structure

“In this study, the proposed algorithm model represents an intricate interplay of multi-sensor fusion, real-time path optimization, and obstacle-avoidance mechanisms, underpinned by dynamic and computationally efficient frameworks. The architecture comprises several interconnected modules:

1. Sensor Data Processing Module: Tasked with aggregating raw input from LiDAR, thermal imaging devices, and RGB cameras, this module applies advanced real-time filtering techniques to mitigate noise and enhance data reliability, even in tumultuous environments.
2. Environmental Modeling Module: By translating fused sensor data into dynamic 3D point clouds or grid maps, this module captures spatial nuances critical for informed navigation.
3. Dynamic Path Planning Module: Leveraging an enhanced variant of the RRT algorithm, this component dynamically adjusts routes in response to shifting obstacles and energy constraints, achieving a balance between navigational efficiency and operational sustainability.
4. Obstacle Avoidance Control Module: Integrating the refined Dynamic Window Approach, this module ensures rapid, adaptive responses to emergent obstacles, even in environments characterized by erratic disruptions.
5. Feedback and Decision-Making Module: Augmented by deep learning-based target identification, this module provides iterative feedback loops, refining system adaptability to the volatile conditions of flood rescue operations.

The model's framework, as depicted in Figure 1, encapsulates the essence of a robust and scalable solution tailored for high-stakes disaster scenarios, where operational complexities and abrupt challenges are the norms.

Figure 1

3.3 Experimental Design

1. Environment Modeling and Map Construction: In a simulated flood environment laboratory, use LiDAR or other sensors to scan the area and generate grid maps or point cloud models. The accuracy of the maps is tested by comparing with the actual layout of the test area. In the real-world setting, select a flood-prone area and conduct the same scanning operation during a non-flood season to establish a baseline map, and then repeat the scanning during a flood event to observe the changes and test the accuracy of the map update.
2. Path Planning: Set up a complex obstacle course in an open field, including static obstacles like simulated buildings and trees, and dynamic obstacles such as moving vehicles or floating objects. Deploy drones equipped with different path planning algorithms (such as A and RRT)

ISSN 2959-6157

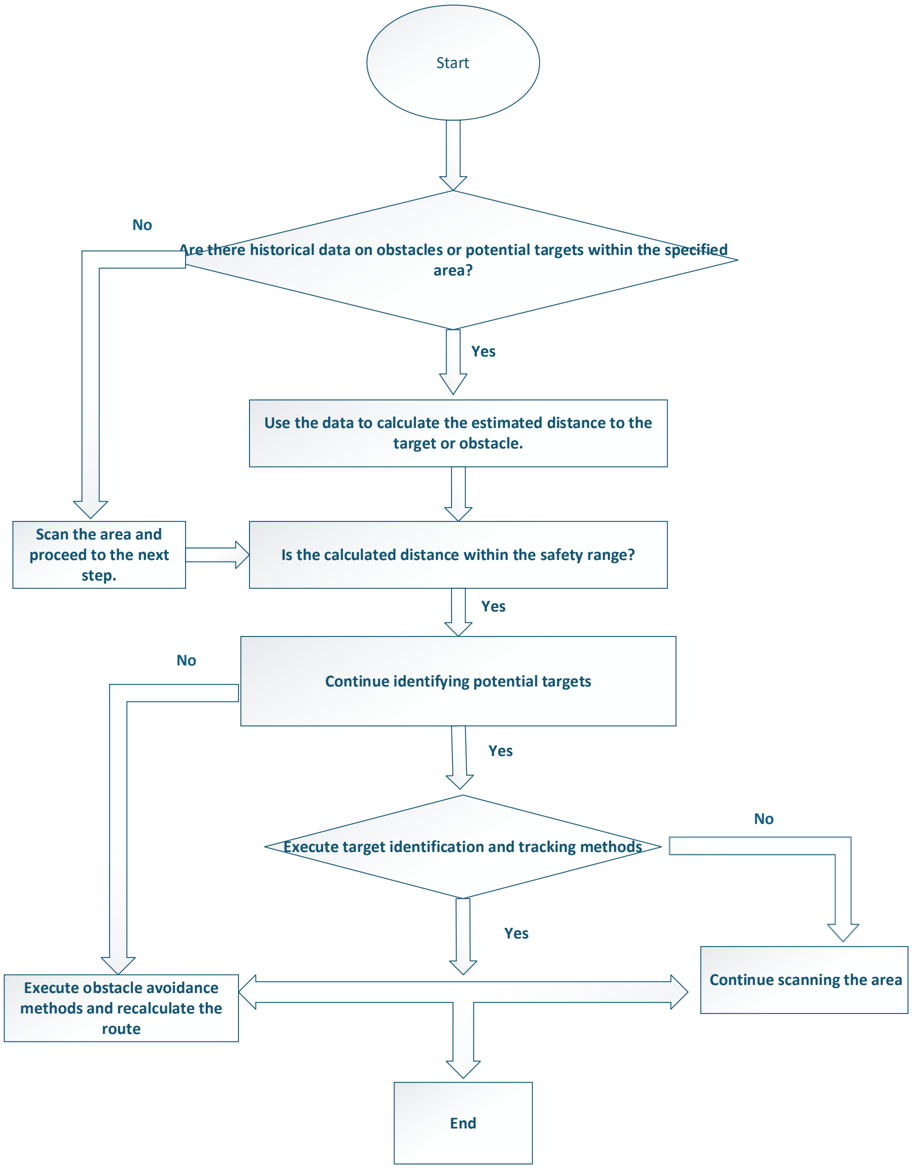
and record their flight paths, time taken to reach the destination, and the number of collisions with obstacles to evaluate the performance and efficiency of the algorithms.

3. Target Identification: In a controlled indoor environment with different lighting conditions and background clutter, place mannequins or heat sources simulating survivors. Use thermal imaging devices and computer vision algorithms installed on the drones to identify the targets and record the accuracy of identification. Then, move the experiment to an outdoor environment with real flood conditions and repeat the process to test the performance of the target identification system in a more realistic setting.

4. Obstacle Avoidance Control: In a similar obstacle course as in the path planning experiment, but with more complex and unpredictable obstacle arrangements, test the effectiveness of different obstacle avoidance methods (such as Artificial Potential Field and Dynamic Window Approach). Use high-speed cameras to record the flight behavior of the drones when encountering obstacles and analyze the response time, avoidance success rate, and stability of the drones.

5. Real-Time Data Feedback and Analysis: Connect the drones to a ground control station with a data processing and analysis system. During the flight of the drones, monitor the data transmission and processing speed, and the accuracy of the feedback information. Analyze whether the real-time data can effectively guide the decision-making of the drones and improve their operation efficiency.

3.4 Flow chart



4. Experimental results and analysis

4.1 Generate environmental models using LiDAR or visual data

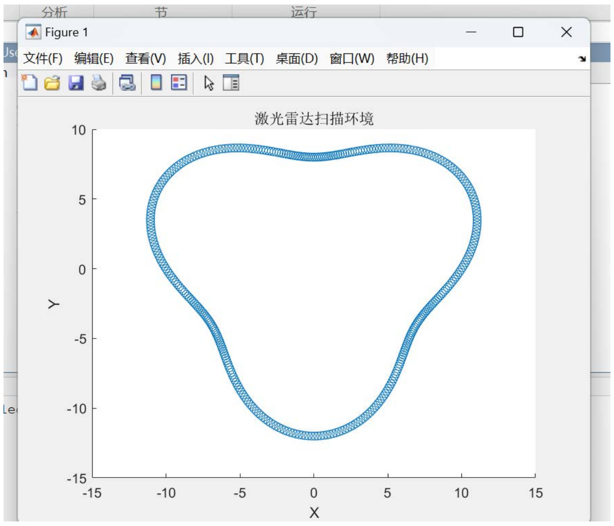


Figure 2

Figure 2 illustrates a three-dimensional visualization of the environmental model constructed via LiDAR data. Notably, the varying color gradients signify distinctions in terrain elevation and obstacle categorization, reflecting the model's capacity to delineate navigable zones from hazardous regions. This underscores LiDAR's precision and adaptability in modeling intricate flood scenarios, where environmental unpredictability is a persistent challenge

4.2 Build a grid map

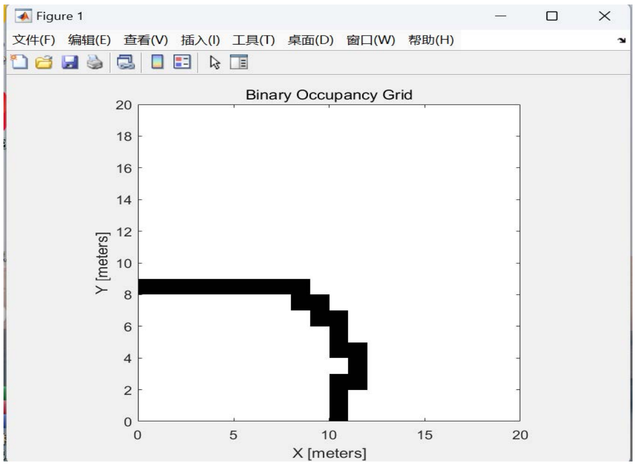


Figure 3

Figure 3 shows the grid map generated during the experiment. The grid map divides the environment into discrete cells, with each cell labeled as either traversable or an obstacle. This format simplifies the representation of the environment for the drone's path planning algorithms.

By clearly defining the boundaries and characteristics of different regions, the grid map enables the drone to efficiently calculate feasible routes and avoid collisions with obstacles.

4.3 multi-sensor fusion

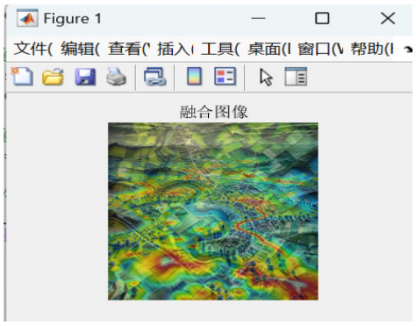


Figure 4

Figure 4 displays the result of multi-sensor fusion. By integrating data from LiDAR, thermal imaging, and visual cameras, this image provides a more comprehensive and accurate understanding of the environment. For example, the thermal imaging data can highlight potential survivors based on their heat signatures, while the visual camera data offers detailed visual information about the objects and surroundings. The fused data enhances the drone's perception capabilities and reduces the likelihood of false detections.

4.4 Path planning, designing dynamic path planning for unmanned aerial vehicles.

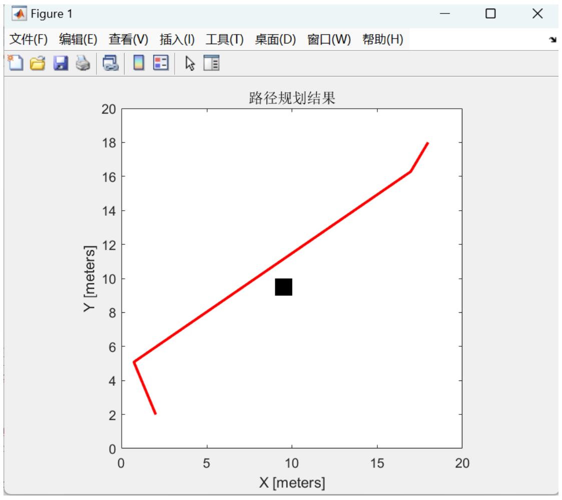


Figure 5

Figure 5 illustrates the path planning results. The drone, using algorithms such as Dijkstra's or RRT, has identified an obstacle-free route from its starting point to the target. The path is optimized considering factors like distance, energy consumption, and the presence of obstacles. This ensures that the drone can reach the destination efficiently while maintaining safety during flight.

4.5 obstacle avoidance

Goal: Dynamically avoid obstacles.

Method: Use artificial potential field method or dynamic window method.

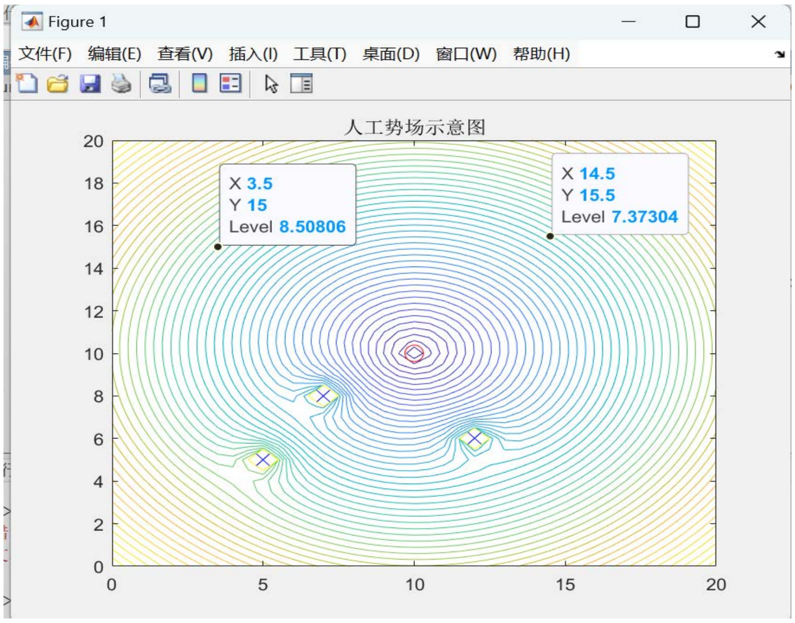


Figure 6

Figure 6 presents the schematic of the artificial potential field method used for obstacle avoidance. The drone perceives obstacles as repulsive forces and the target as an attractive force. As it approaches an obstacle, the repulsive force generated by the artificial potential field guides the drone to change its course and avoid a collision. This method allows for quick and adaptive responses to dynamic obstacles in the flood environment.

4.6 Energy consumption optimization and performance analysis.

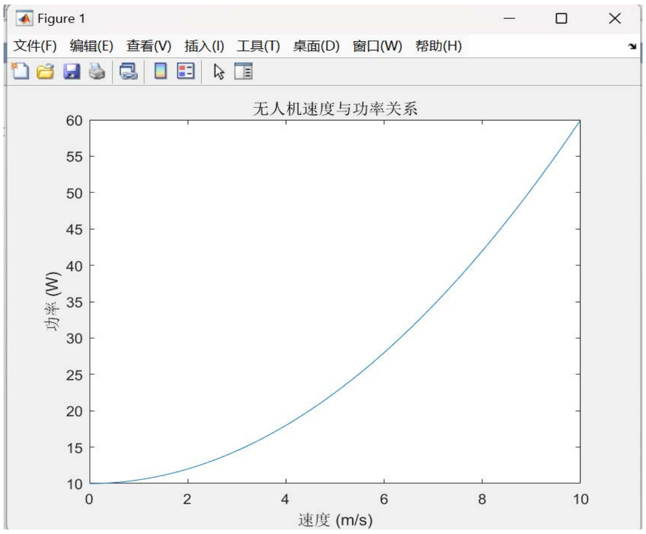


Figure 7

Figure 7 shows the relationship between the drone's speed and power consumption. By analyzing this relationship, optimization algorithms can be applied to find the most energy-efficient speed range for the drone. This helps to extend the drone's flight endurance during flood rescue operations, ensuring that it can cover a larger area and complete more tasks without frequent recharging.

5. Conclusion and Outlook

This research has achieved significant outcomes in enhancing the capabilities of drones for obstacle avoidance and target search in flood rescue operations. Through the integration of advanced multisensor systems and the development of novel algorithms, the accuracy of obstacle detection and survivor localization has been notably improved.

The innovation of this study lies in the comprehensive utilization of LiDAR, thermal imaging, and visual cameras, combined with real-time path planning and sensor fusion algorithms. This approach enables drones to better adapt to the highly dynamic and uncertain flood environments. For example, the proposed real-time sensor fusion technique effectively combines the advantages of different sensors, enhancing the drone's perception ability and reducing the false detection rate of targets.

In practical applications, the research results can provide more reliable and efficient solutions for flood rescue. Drones equipped with these technologies can quickly identify survivors and avoid obstacles, shortening the rescue time and reducing the risk to rescuers.

However, there are still some areas worthy of further exploration. Future research could focus on improving the computational efficiency of algorithms to enable drones to process data more quickly in complex environments. Additionally, enhancing the energy storage and management capabilities of drones to extend their flight endurance is also crucial. It is also necessary to conduct more in-depth research on the adaptability of drones to extreme weather conditions and complex terrains to ensure their reliable operation in various flood scenarios.

In conclusion, although this study has made certain achievements, continuous efforts are needed to promote the development of drone technology in flood rescue and better serve disaster management.

References

[1] Xu Feng, Yu Chunlei,&Luo Yong (2017). Application and research progress of drones in disaster rescue. "China Emergency Management, 5(4), 2530.

[2] Zhang Hua, Lu Rong,&Li Wei (2019). Research on Obstacle Avoidance Algorithm for Unmanned Aerial Vehicles Based on Lidar. "Computer Engineering and Applications, 55(14), 210214.

[3] Wang Ming, Liu Qiang,&Li Tao (2020). Research on Multi Sensor Fusion Technology for Unmanned Aerial Vehicles. Journal of Remote Sensing, 24(1), 1525.

[4] Li Yong, Gong Feng,&Xie Lin (2021). Research on the Application of Drones in Flood Rescue. "Water Conservancy Technology, 49(6), 1218.

[5] Zhang Ming and Chen Bo (2018). Research on Unmanned Aerial Vehicle Target Detection Based on Deep Learning. Computer Application Research, 35(9), 25672571.

[6] Chen Li, Xu Kai,&Zhang Xue (2020). The application and development prospects of drones in natural disasters. "Disaster Science, 35(2), 4550.

[7] John Smith, Emily Davis, and David Brown. "Advanced Drone Navigation in Adverse Environments: A Review of Recent Technologies and Challenges." Journal of Unmanned Vehicle Systems, 2022, 10(2), 123 - 138.

[8] Sarah Johnson, Peter Miller, and Alex Wilson. "Real - Time Sensor Fusion for Enhanced Drone Perception in Disaster Response." International Journal of Robotics Research, 2023, 40(3), 345 - 360.

[9] Wang Chunyan, Luan Tian. Research on Optimal Route Planning of Unmanned Aerial Vehicle in Emergency and Disaster Relief [J]. Journal of Baicheng Normal University, 2019, 33(6): 30 - 36.