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Original Research Article

Research and construction of UAV intelligent flight control and inspection system integrating geographic information system in the context of digital communication

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Abstract: With the rapid development of digital communication technology, the integration of UAV flight control and various positioning means is a hot research topic. Especially with the widespread use of digital maps and other technologies, integrating GIS into UAV flight control is of great significance. This paper reviews the research status of UAV flight control and GIS applications, discusses the significance of optimizing UAV flight control through GIS fusion, and analyzes its application scenarios in many fields. Research shows that integrating GIS significantly improves UAV flight control performance, meets the requirements of intelligent inspection tasks, effectively controls costs, and enhances safety. Finally, the paper looks forward to the prospect of optimizing UAV intelligent inspection based on GIS and believes it has broad application and development space in the future.
Keywords: digital communication; geographic information system; UAV flight control; inspection

1. Overview of drone flight control and geographic information system

As an important part of modern aviation technology, drone flight control technology has achieved remarkable results. Relevant flight control systems can precisely control key parameters like drone attitude, position and speed, applicable to basic maneuvers (takeoff, landing, hovering, straight - line flight) and complex tasks (low - altitude traversing, high - speed cruise, autonomous obstacle avoidance). With the development of sensor technology, accuracy and stability have improved, providing more accurate data for flight control systems. Meanwhile, the improved processor performance enables faster sensor data processing and more complex control algorithms, enhancing response speed and accuracy. Additionally, the new - generation flight control systems use INS and GPS. Through multi - source data fusion and intelligent algorithm optimization, they can achieve more precise navigation and positioning, supporting intelligent drone inspection.

Geographic Information System (GIS) combines geography, cartography, remote sensing, and computer science. It's mainly used for inputting, storing, querying, analyzing, and displaying geographic data. Supported by computer systems, it's a technical system for collecting, storing, managing, analyzing, and displaying geographic distribution data on the Earth's surface. GIS has basic and advanced functions like data collection and editing, graphic display, and map production, and can enrich its functions using various technologies to meet social and user needs.

Leveraging GIS's powerful spatial data processing and analysis capabilities can support intelligent flight control inspection by drones. Current research on their integration focuses on data sharing, path planning, and target positioning. Through digital communication, drones can get real - time data from GIS for precise positioning and efficient operations.

2. Significance of the study

By combining digital communication technology and integrating data from geographic information systems, drones can avoid exploring while flying during inspection missions, thereby improving recognition ccuracy, effectively avoiding obstacles, and achieving safe flight. The introduction of this technology greatly enhances the autonomous flight capabilities of drones, promotes the intelligence of drone flight control and inspection, and

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provides strong support for their application in various complex environments.

2.1. Enhance the positioning accuracy and navigation capabilities of drones

Geographic information systems can provide rich spatial data like topography, building distribution, and road networks. Drones can access these data to obtain real - time detailed information of the flight area and precisely identify the flight environment, including both static obstacles and dynamically changing objects such as vehicles and pedestrians.

The drone intelligent inspection system integrated with GIS data can calculate flight trajectories and obstacle - avoidance paths in real - time. During flight, it collects environmental information via sensors and digital communication signals, compares and analyzes it with GIS data. When a potential obstacle is detected, the flight control system activates the obstacle - avoidance mechanism to adjust the flight direction or altitude for safe bypass.

Moreover, this system has predictive and planning capabilities. It can predict future flight risks based on historical and real - time GIS information and plan safe flight paths in advance. This enables drones to be highly autonomous and flexible in complex and changing environments, improving flight safety and efficiency.

2.2. Optimize the system to reduce the operational costs of drones

Digital communication technology equips drones with efficient and stable data transmission and communication capabilities. By establishing real - time communication links with ground stations or other drones, drones can quickly get flight instructions, transmit real - time data, and receive monitoring and scheduling info from ground stations. This efficient mechanism reduces information delay and misoperations during flight, improves flight efficiency, and cuts the rise in operating costs due to poor communication.

The introduction of Geographic Information Systems (GIS) offers drones precise spatial data and geographic info support. Via the GIS system, drones can obtain accurate info on the terrain, obstacle distribution, and meteorological conditions of the flight area, enabling them to design more reasonable flight plans and obstacle avoidance strategies. This precise data support helps drones avoid unnecessary detours and altitude adjustments during flight, reducing energy consumption and flight time, and thus lowering operational costs.

2.3. The intelligent operation of drones saves labor costs

Geographic information systems provide drones with precise and comprehensive spatial data and geographic information support, enabling drones to accurately identify inspection targets, plan reasonable flight paths, and obtain and process inspection data in real time. By integrating advanced image recognition and data processing technologies, drones can autonomously complete inspection tasks such as equipment status detection, anomaly identification, and data recording, without manual intervention or with only minimal human assistance.

The implementation of intelligent inspection means that drones can automatically perform

inspection tasks, reducing the need for extensive manual involvement in traditional inspection methods. Through intelligent inspection, drones can transmit inspection data in real-time, enabling real-time data exchange and analysis with ground stations or remote monitoring centers. Ground personnel can quickly grasp the equipment status and abnormalities in the inspection area through data analysis and take corresponding measures to address them. This not only greatly reduces the workload of inspection also minimizes inspection errors and omissions caused by human factors time, the efficient and rapid flight capabilities of drones enable them to cover large inspection areas in a short time, improving inspection efficiency and quality, and significantly saving labor costs.

3. Research findings

Backed by geographic information systems and based on digital communication technology, we designed intelligent scheduling algorithms, route planning technology, and flight matching control modes for multiple emergency scenarios. This ensures precise collaboration among drone fleets in complex scenarios, leading to the development of an intelligent drone flight control and inspection system.

This system is the central hub for automated airports and drones, enabling unified fleet management. Users can issue tasks via the control system, and the drone fleet will execute flights automatically. Staff can control

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drones and monitor on - site status centrally from their offices. The system includes modules such as system management, route management, plan management, inspection data management, data tagging, real - time monitoring, and data reporting.

3.1. Implementation plan for intelligent drone inspection

3.1.1. Preliminary hardware preparation

Before conducting aerial inspection operations, it is necessary to complete the deployment of equipment for fixed airports and the layout of related equipment for fixed airports. The operation mainly includes the following steps:(1) first step: equipment deployment; (2) second step: installing drone remote control; (3) third step: equipment power-on; (4) fourth step: opening fixed airport; (5) fifth step: placing drone; (6) sixth step: airport reset and switching to remote control mode.

(1) Equipment deployment. Before use, confirm that there is at least one set of batteries and up to three sets of batteries in the battery slot inside the fixed airport. Install the drone shoe cover provided by the fixed airport and add an on-board control box.

(2) Install the drone remote controller. If you need to replace the drone remote control, you need to fix the drone remote control on the upper back of the mast. The fixing steps are as follows:

Step 1: Remove the remote control placement plate

Step 2: Fix the remote control to the remote control placement board

Step 3: Install the remote control board onto the mast. Place the remote control board placement plate with the installed remote control board onto the mast and secure it firmly with four M4 screws on each end. Then, insert the remote control board charging port and data port into the charging interface and data port of the remote controller, respectively.

Finally, attach the remote control holder tightly to the remote control and tighten the screws beneath the holder. The remote control is now installed.

(3) Power on the device. The fixed airport is equipped with an uninterrupted power supply and a battery, which can ensure the normal operation of the fixed airport in case of external power supply abnormalities.

(4) Open fixed airport. Open the airport using the HMI control panel on the fixed airport.

(5) Placement of Unmanned Aerial Vehicles (UAVs). The airport is currently open. Please place the drone on the airport's takeoff and landing platform. Once completed, reset the airport.

(6) Reset the airport and switch to remote control mode. Press the emergency stop button above the fixed airport, observe that the three-color status lights of the airport turn red, and the airport stops all mechanical movements and enters an emergency stop state; click the switch to enable remote control mode.

3.1.2. Remote execution of inspection tasks.

After completing the relevant hardware deployment and configuration, the intelligent inspection control platform can be used to remotely issue tasks and assign fixed airports to perform inspection tasks. It mainly includes the following five steps: 1. Log in to the intelligent inspection control platform --> 2. Create inspection data --> 3. Create and issue inspection plans --> 4. Execute inspection plans and monitor status --> 5. View and download inspection results.

(1) Log in to the intelligent inspection control platform. The primary step in executing a drone inspection mission is for the operator to log into the intelligent inspection control platform through a secure network connection. This platform serves as the command center for the entire inspection mission, responsible for task issuance, monitoring, and data management. Operators must authenticate using an authorized username and password to ensure operational security and traceability.

(2) Create Inspection Data. The process of creating inspection data involves entering and confirming all required parameters for the drone inspection task, such as the geographical information of the inspection area, expected flight height, speed, camera parameter settings and other inspection - related details. Also, it's necessary to accurately calibrate the drone's onboard sensors and the Beidou positioning system to facilitate precise data collection in subsequent steps.

(3) Create and issue inspection plans. Operators define the time, path, and parameters of the inspection task on the platform and generate an inspection plan. The plan includes flight - route planning, expected flight time,

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and key inspection points. After formulation, the plan is issued to the drone system at the fixed airport via the platform. Upon receiving the task instructions, the drone readies to perform the inspection task.

(4) Implementation and status monitoring of inspection plan. After the drone starts inspection tasks, the intelligent inspection control platform monitors its status and progress in real - time. Operators can receive real - time image data and sensor information via the platform interface and monitor key parameters like flight path, speed, altitude, and battery status. During inspection, if abnormal situations like signal loss or emergencies occur, the platform will promptly alarm and offer corresponding emergency handling options.

(5) Viewing and downloading inspection results. After completing the inspection task, the drone will automatically return to the fixed airport and land safely. At this time, the intelligent inspection control platform will synchronize all the data collected by the drone during the inspection process, including high-definition images, sensor detection results, and flight logs. Operators can view the inspection results on the platform, conduct preliminary analysis, and download relevant data for further detailed analysis and report preparation as needed.

3.2. Future improvement plan

3.2.1. Technological iteration and equipment upgrade

BeiDou high-precision positioning integration: Integrate the BeiDou high-precision positioning system into drones to provide accurate geographical location data for on-board detection equipment, supporting precise flight navigation and operation positioning, especially in complex railway environments.

Multi-sensor synchronization: Using Beidou positioning to accurately synchronize radar, infrared sensors, electromagnetic induction, and other devices to improve the accuracy and practicality of sensor data, ensuring high-quality data collection.

Intelligent scheduling algorithm: Adopt an intelligent scheduling algorithm based on Beidou data to achieve efficient operation planning and task allocation for machine groups, enhancing emergency response capabilities in complex scenarios.

Real-time data exchange and location synchronization in the cloud: Using the Beidou system to achieve real-time data exchange and location synchronization services between drone fleets and with ground control centers in the cloud, ensuring collaboration and precise synchronization during task execution.

3.2.2. Application value and scalability of intelligent drone inspection technology

(1) Application value. Intelligent drone railway inspection technology can improve railway line monitoring efficiency and quality, reduce labor costs and safety risks. The high maneuverability of drones and their high - precision sensors allow them to quickly cover large areas, inspect railway lines, and detect potential problems. Also, drones' rapid response in emergencies supports railway accident response. Through intelligent analysis systems, drone - collected data can become decision support, optimizing maintenance plans and service levels. Thus, this technology is significant for railway transportation safety, reliability, and economic benefits.

(2) Scalability. Intelligent drone railway inspection technology is suitable for the railway industry and other transportation infrastructure monitoring, like urban rail transit, highways, bridges, and tunnels. Drones have strong geographical adaptability, can work in various terrains and climates, and are globally applicable. Moreover, the technology can be customized for different scenarios, meeting diverse needs in urban planning, agricultural monitoring, and environmental protection.

As smart city construction advances, drone applications in urban surveillance, traffic management, and public safety will expand. In international cooperation, this technology is expected to be a bridge for cross - border exchanges, promoting global railway and infrastructure monitoring. In summary, due to its efficiency, safety, and cost - effectiveness, intelligent drone railway inspection technology has high promotion potential in multiple industries and regions.

4. Conclusion

With the advancement of digital communication technology and the maturity of drone technology, drone inspection integrated with geographic information systems and flight control optimization will have broader development prospects. Combining the advantages of these technologies, new application scenarios and solutions

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can be developed. For example, in environmental monitoring, sensor - equipped drones can collect data, analyze it spatially via geographic information systems, and transmit results in real - time through digital communication technology.

In summary, UAV inspection and flight control optimization integrated with GIS in digital communication have significant research value and broad application prospects. Through research and application, we aim to improve UAV flight control performance, reduce costs, and enhance safety, supporting the widespread use and industrial development of UAV technology.

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