UAV Remote Sensing Technology Driven by Low-Altitude Economy for Smart City Governance

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Abstract. Against the background of the large-scale development of the low-altitude economy, unmanned aerial vehicle (UAV) remote sensing is a key technical means for building a city-wide spatial perception system and promoting refined governance of smart cities. This paper selects Shanghai as the research area, combining the cutting-edge technologies of the low-altitude industry with on-site monitoring data, to outline the application scenarios of UAV remote sensing in four major fields: urban construction supervision, ecological protection, smart transportation, and emergency security. The study identifies five practical shortcomings in the UAV remote sensing operations of government affairs in high-density urban areas: insufficient efficiency in airspace approval and scheduling, limited accuracy of remote sensing data collection in complex urban areas, barriers in the interdepartmental exchange of spatial data, blind spots in low-altitude flight supervision, and a shortage of comprehensive low-altitude governance talents. Drawing on international experiences in airspace control and drone networking operations, this study proposes feasible optimization paths from five dimensions: airspace scheduling, technology adaptation, data coordination, overall supervision, and talent cultivation. The research conclusions can provide practical references for the construction of low-altitude smart governance in Shanghai and also offer theoretical support and practical inspiration for similar drone remote sensing government applications in other large cities in China.

Keywords: Low-altitude economy; UAV remote sensing; geospatial data; smart city; Shanghai.

1. Introduction

Low-altitude economy combined with integrated sensing technologies for air, space, and ground is an important direction for the transformation of urban digital governance [1]. Satellite remote sensing is slow in updating, manual inspections have limited coverage and are costly, while UAVs are flexible, have clear imaging, and have now become the main force for regular spatial monitoring in cities [2]. Domestic airspace policies have been continuously optimized, the low-altitude industry has gradually been standardized and scaled up, and various regions have implemented a unified management platform for one network. Traditional manual inspections are transforming towards intelligent monitoring of air, space, and ground [3]. Relying on 5G-A, BeiDou, intelligent remote sensing interpretation and digital twin technology, UAVs can autonomously identify ground objects, detect hazards and build three-dimensional models, supporting urban precision management [4].

Existing research mostly focuses on the hardware of UAVs or single-scenario experiments, lacking systematic implementation research that is suitable for high-density urban areas of megacities. In government affairs work, there are common problems such as inconsistent data standards, poor model adaptation, and difficulties in data intercommunication across departments [5]. This paper combines the practical operation case of low-altitude inspection in Shanghai, sorts out operational pain points, analyzes causes, builds an optimization system, and makes up for the shortcomings of existing research that focuses on theory and lacks empirical evidence.

2. Development Trends of the Low-Altitude Economy and Advanced Remote Sensing Technologies

2.1. Large-Scale Implementation of the Low-Altitude Economy Industry

With the gradual relaxation of China's airspace control policies, the civilian unmanned aircraft industry has maintained a stable development trend. Low-altitude remote sensing technology has been widely applied in various government scenarios such as national mapping, ecological inspection, and urban security [6]. Various regions have successively established integrated low-altitude control systems, completely connecting the entire business process of unmanned aircraft data collection, transmission, and processing [1]. As a core pilot city of China's low-altitude economy, Shanghai has built a full-area low-altitude remote sensing perception network. After the regular automatic inspection mode was officially put into use, the speed and coverage of various hazard inspections in the city have been significantly improved, and the inspection pressure on field personnel and the operating costs of vehicles have decreased accordingly. This has continuously contributed to the steady improvement of the city's digital governance level [7].

International researchers have established optimization models for key issues such as dynamic airspace allocation and flight conflict avoidance and have now formed a complete set of theories on the refined management of airspace [8]. The related research has enriched the theoretical system for the safe operation of unmanned aircraft networks, which can not only provide theoretical support for practical operations in the industry, but also offer effective references for the low-altitude governance work in large cities in China [7].

2.2. Iterative Upgrade of Frontier Remote Sensing Technology System

Currently, UAV remote sensing is no longer limited to simply capturing images. It has gradually integrated positioning, information interpretation, 3D modeling, and simulation capabilities, forming an integrated, comprehensive technical solution that is suitable for complex urban operation scenarios. The BeiDou system combined with 5G-A can achieve centimeter-level positioning, alleviating the positioning deviation caused by obstructions from high-rise buildings [3].

The sub-meter tilt aerial photography of UAVs has a better recognition effect than traditional satellite remote sensing methods [7]. The remote sensing intelligent algorithms adapted to urban scenarios have significantly improved the accuracy of identifying various governance elements [4]. Laser radar modeling can restore the detailed urban space [9]. Combined with the automatic flight scheme of UAV networking, it can complete continuous and regular patrols throughout the day [10]. The complete technical solution lays a solid technical foundation for the implementation of low-altitude remote sensing in urban government affairs.

3. Core Application Scenarios of UAV Remote Sensing in Shanghai

3.1. Intelligent Supervision of Urban Planning and Construction

Shanghai integrates aerial photography images with laser point cloud data to build a city-wide universal geographic spatial database. The spatial information that was originally updated quarterly can now be updated weekly [4]. By comparing images taken at different times, the system can automatically detect potential hazards such as illegal constructions on rooftops, dust from construction sites, and wall deformations, reducing the number of on-site inspections by staff and making up for the shortcomings of manual high-altitude inspections, significantly improving the efficiency of urban construction supervision [7].

This article selects the long-term drone supervision pilot project in Pudong New Area as a case for analysis. In the local area, 16 sets of automated machine nests were deployed in 8 core townships, covering 80% of the flyable built-up areas within the jurisdiction. The autonomous cruise of the drones can quickly locate illegal construction at night and illegal structures on building rooftops, and

the system generates corresponding law enforcement documents through intelligent recognition, achieving online off-site supervision. This effectively reduces the workload of manual inspections and solves the problem of difficult control of high-altitude areas in large urban areas [11].

3.2. Dynamic Intelligent Management of Ecological Environment

The urban green spaces are scattered, and manual inspections are not only difficult to cover all the blind spots but also often time-consuming. Therefore, multiple functional departments in Shanghai have equipped themselves with multispectral infrared drones for daily patrol. These devices can monitor water pollution and abnormal growth of vegetation, thereby forming a complete closed-loop supervision process [7].

The Dianshan Lake project vividly demonstrates the advantages of this technology. In the lake area, there are thick reeds and numerous shallow banks, which seriously obstruct the view of the vessel inspections. The local has built a drone inspection platform with a supporting 5G network, using the intelligent recognition function to quickly locate various pollution sources, which not only shortens the inspection time but also eliminates the blind spots in water area supervision [12].

3.3. Smart Transportation Operations and Low-Altitude Innovative Applications

Drones can quickly collect traffic-related information such as traffic volume, road damage, and illegal parking by vehicles. Combined with GIS tools, they can analyze the causes of traffic congestion and identify potential safety hazards on the roads. The time required for traffic emergency response has been reduced from several hours to several minutes [13]. During the morning rush hour in the inner ring of Shanghai, drones can cover areas that fixed monitoring equipment cannot reach and quickly handle accidents involving vehicle scratches on ramps. During the inspection of the main roads in the Fengxian urban area, the system records the locations of road damage simultaneously and automatically generates repair documents based on geographic information. The local area plans low-altitude emergency flight routes based on the airspace model and improves the integrated air-ground-space transportation management model [14]. Renji Hospital uses drones to transport test samples, avoiding traffic congestion on the ground. Ground transportation takes 19 minutes, while drone transportation only takes 8 minutes, significantly improving the efficiency of emergency sample transportation [15].

3.4. Public Safety and Disaster Emergency Response

Daily inspections by drones can identify potential risks at high altitudes and monitor the movement of people. Shopping districts rely on drones to promptly warn of crowded situations among people, compensating for the shortcomings of manual inspections. After a typhoon or flood disaster, drones can complete aerial photography modeling within half an hour, mark the waterlogged sections, and increase the accuracy by 60%, providing real-time data for disaster relief dispatch and post-disaster reconstruction, and enhancing the city's disaster prevention capabilities [13].

Fengxian District once used drones to handle typhoon disasters. There were concerns about damaged trees on the roofs of over 200 buildings in Leikangyuan [16]. Manual climbing inspections were time-consuming and dangerous. Drones' aerial photography quickly identified the damaged areas, generated coordinated information, and transferred it to the rescue personnel, simplifying the handling steps and shortening the emergency response time [16].

4. Bottlenecks and Internal Causes of Low-altitude Remote Sensing Applications

There are still many practical challenges in using UAV remote sensing for urban governance. Governmental UAV operations require separate reporting, and each inspection takes four to eight hours, making it impossible for them to conduct autonomous cluster flights. The airspace supervision is handled by multiple entities, and the execution standards are not unified. The existing regulations

only apply to short-term single-aircraft flights, and policy updates lag behind technological development [6]. Urban buildings can reduce data quality. In the central area of Shanghai, 20% of the aerial photos have occlusion and positioning deviations. High-rise buildings interfere with the BeiDou signal, and general models are difficult to adapt to rainy and densely built-up urban areas. The image restoration technology is insufficient, and the data is difficult to use directly [10].

The data standards of various departments are inconsistent, making it difficult to exchange information among planning, ecology, and transportation. Repeated data collection is common. Geographical data is classified as confidential, and each unit independently builds its database. The municipal level lacks shared norms, resulting in data islands. Cross-departmental collaboration is hindered [5]. There are shortcomings in low-altitude safety control. It is difficult to trace the origin of illegal flights, and aerial photography is prone to revealing residents' privacy. Buildings block radars, and small UAVs have difficulty tracking. The existing regulations are not complete in terms of controlling civilian aircraft and encryption mechanisms [17]. There is a shortage of multi-disciplinary specialized talent. University teaching focuses more on theory and lacks practical training for government affairs. Technicians do not understand airspace declarations, and public officials have difficulty interpreting images. The mismatch of talents slows down the implementation of technology [18].

5. Systematic Optimization Countermeasures for Low-altitude Remote Sensing Governance in Large Cities

5.1. Build a Hierarchical Intelligent Airspace Scheduling Platform

Relying on the existing unified flight management system in Shanghai, the urban airspace can be flexibly divided according to the usage scenarios. The main areas covered include daily inspection, emergency rescue, low-altitude logistics, and permanent no-fly zones. Different scenarios will be managed with corresponding practical control methods. By connecting the approval channels of military aviation, civil aviation, and local government affairs, the unified flight reporting norms for the entire city can be established. A fast approval channel can be opened for routine inspections. In case of sudden situations like typhoons, the system will automatically open emergency flight channels, significantly reducing the waiting time for approval. At the same time, digital twin technology can be used to predict flight conflicts in advance and dynamically adjust flight routes. As a result, the urban airspace resources can be more fully exploited, and the utilization efficiency will also be improved [8].

5.2. Upgrade Iteratively Localized Remote Sensing Technology

In order to better adapt remote sensing technology to the urban environment with numerous tall buildings in Shanghai, the data collection effect can be optimized from three aspects: hardware, algorithms, and recognition models. For instance, by replacing with anti-interference positioning equipment and high-definition shooting equipment, the signal deviation and image blurriness caused by building obstructions can be alleviated. For the shooting blind areas blocked by buildings, the system will incorporate image restoration functions to fill in the missing parts. By adjusting the parameters of the recognition model based on local real-scene data in Shanghai, the recognition accuracy for complex scenes such as elevated roads, streets, and old residential areas can be improved. Combined with an unmanned aircraft automatic storage facility, continuous round-the-clock inspections can be carried out, and the urban three-dimensional data can be improved by using tilt photography technology. Thus, the quality of remote sensing data can be comprehensively enhanced [9].

5.3. Unify Spatial Data Standards at the Municipal Level

In response to the problem of chaotic data and difficulty in data interoperability among various departments, the municipal level can introduce unified low-altitude remote sensing data management regulations. The entire city will uniformly adopt the 2000 National Geodetic Coordinate System, standardizing the data collection and storage formats. Based on the degree of confidentiality, the data will be classified and categorized, and corresponding de-identification processing and authority allocation mechanisms will be established to ensure data security while facilitating the sharing and invocation among various departments. All remote sensing data from various industries will be uniformly aggregated to the municipal GIS basic platform, effectively avoiding duplicate data collection and improving the overall utilization efficiency of the data [5].

5.4. Improve the Digital Twin Low-Altitude Supervision System

By leveraging digital twin technology to establish a visualized, grid-based low-altitude supervision system, combined with low-altitude radar, flight trajectory traceability, and other technologies, the monitoring gap around high-rise buildings can be filled. The real-name registration system for drones is strictly implemented, and automatic warning and handling procedures are established for unauthorized flights and border-crossing flights, etc. [7]. In terms of data management, the entire process of aerial photography of real-scene data is encrypted, and sensitive information in the images is automatically de-identified, minimizing the risk of leakage of urban public space and residents' privacy, and improving the low-altitude security control system [17].

5.5. Establish a Joint Talent Training Model for Enterprises, Universities, and Government Departments

To address the shortage of professionals in low-altitude governance, it is advisable to promote joint training among universities, industry enterprises, and government departments. Based on the existing curriculum, additional practical teaching contents such as airspace management, government affairs application, and confidential data processing should be added. Through a two-way rotation training method, students can be sent to the front line to participate in urban low-altitude inspection work, and regular practical training on remote sensing technology for grassroots public officials should also be provided. In conjunction with local low-altitude talent introduction policies and training base construction, it should continuously cultivate comprehensive talents with both technical capabilities and government thinking, to facilitate the implementation and application of low-altitude remote sensing technology [18].

6. Conclusion

This article takes Shanghai as the empirical case and explores the application value of UAV remote sensing in four scenarios: urban construction supervision, ecological protection, smart transportation, and emergency security. By combining grassroots cases, it verifies its advantages in eliminating regulatory blind spots, shortening response cycles, and improving inspection efficiency. From five dimensions management mechanism, technical hardware, data system, regulatory system, and talent supply - this article analyzes the pain points and causes of low-altitude remote sensing implementation and identifies five core obstacles: cumbersome airspace approval procedures, insufficient image accuracy, cross-departmental data barriers, low-altitude regulatory security loopholes, and a shortage of multi-disciplinary talents. Based on this, five types of countermeasures are proposed: intelligent airspace scheduling, local remote sensing technology upgrade, unified municipal data standards, digital twin low-altitude supervision, and joint government-enterprise-university talent training. These measures aim to solve the problems of remote sensing implementation in high-density urban areas.

This article innovatively integrates remote sensing, airspace management, and governance perspectives, constructing an analytical framework suitable for high-density urban areas, and

compensating for the deficiency of emphasizing theory while neglecting empirical evidence. The article believes that the integration of low-altitude intelligence and AI technologies will promote the deep integration of UAV remote sensing into urban digital governance and proposes that subsequent comparisons can be made with different-sized cities to formulate differentiated plans and continuously improve this research system.

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