Potentials of UAV Remote Sensing Data Carrier – A Case of Application in UAV Low Altitude Route—planning

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Abstract. Unmanned aerial vehicles (UAVs) are commonly applied for low-altitude remote sensing, and their effective flights generate a large amount of remote sensing data in centimeter-level resolution every day. UAV remote sensing has become an important new source for generating geographic big data. However, UAV remote sensing data is multi-source heterogeneous and disordered in management. To scientifically manage and maximize the utilization of UAV remote sensing data, the "UAV remote sensing data carrier" has been proposed. It features distribution of remote sensing tasks and exchange of rich datasets for various UAVs owned by individuals or organizations and thus has great application potential in low altitude with complex artificial and natural environments. The UAV low-altitude public air route is a commonly recognized solution to enable safe flights of UAVs in low altitude, which requires a variety of precise geographic data. Therefore, the UAV remote sensing data carrier can contribute to the construction of low-altitude public air routes. It can realize the three-dimensional geospatial data acquisition and dynamic information updates on routes, the service to route construction in various industries, and the support of real-time optimal path selection. Construction of low-altitude public air routes based on the carrier have already been applied in the UAV cloud regulation system "SkyGrid", which is currently inadequately studied. Besides route construction, the carrier has great potential for further development of low-altitude airspace resources and reasonable use applications.

Key words: UAV remote sensing, UAV remote sensing data carrier, Low altitude public air route, Cloud regulation system.
1. Introduction

In recent years, unmanned aerial vehicles (UAVs), or drones, have become increasingly popular. A large number of UAVs, classified as low, slow, and small, are active in low-altitude airspace below 500 m. With unmanned aircraft characteristics, UAVs have replaced people in performing a variety of ‘4D’ (Dull, Dirty, Dangerous, and Deep) tasks [1] because of their strong maneuverability, high adaptability and viability, no risk of casualties, and low manufacturing and maintenance costs [2]. With the development of UAV sensor and platform technology, the spatial, temporal, spectral, and radiometric resolutions have increased [3]. In addition, the data types and amounts are dramatically increasing. UAV remote sensing data are now considered big data. Among the remote sensing methods, UAVs are the primary method for obtaining centimeter-level, ultra-high resolution and near real-time response data at present and in the future [4]. Recently, it has become an important part of the space-earth observation infrastructure in China. UAV remote sensing big data technology will considerably enhance the efficiency and precision of geographic information services, improving traditional remote sensing data processing modes and further expanding remote sensing applications. The author proposes the UAV remote sensing data carrier which could plan tasks, store data, process images, and generate and output products [5]. It has great potential in various civil applications.

There are safety and efficiency problems in several UAV operations which require low altitude flight routes. Most light and small UAVs mainly operate below 120 m [6]. UAV flights are characterized by low velocity, low height, and limited area which distinguishes them from general and civil aviation. Specific, but not too strict, regulations are necessary to manage and encourage sales of UAVs, so as to invigorate the national economy. The low-altitude air route network is a prerequisite and a necessity [7]. At present, no systematic research, only key technologies on UAV air routes, are available both at home and abroad, such as the UAV Traffic Management (UTM) technology proposed by the U.S. Federal Administration Aviation (FAA) and the urban low-altitude traffic Management technology proposed by the Singapore team [8].

Remote sensing big data acquired by UAVs can be applied in the flight safety management of UAVs in real time. At present, UAVs are mainly regulated by policy and technology. At the national level, they are regulated through the establishment of a multi-department joint mechanism to coordinate and implement responsibilities. Through the formulation of relevant government laws and regulations, there exists real name registration for UAV drivers, a limit on the operational height and weight of UAVs, and research on a UAV traffic management system [9]. Technically, the electronic “geo-fence” is used to restrict drones from entering the no-fly zone [10]. Major drone manufacturers, such as Shenzhen Dajiang Innovation Co., have begun to display regulatory and security hazard information in the map of management software. Based on local aeronautical charts and regulatory requirements, the flight cloud management system uses GPS and other satellite navigation signals to limit the flight altitude of the flyable area [11]. Vendors and legislators need to work closely together to increase the availability of such data. At present, the design and management policies for low-altitude airspace cannot meet the needs of the growing number of drone users, and the ability to regulate services is low, which may lead to a serious waste of airspace resources, inadequate supervision, and increased pressure on air traffic management (ATM) services. These technical means only achieve the purpose of restricting the drone, but do not fully achieve the scientific management of regulation.
With the increasing number of UAVs and remote sensing data, UAV remote sensing big data provides unique advantages in route application. This paper introduces the UAV remote sensing data carrier and studies the application of geographic big data in the low altitude public air route using the UAV cloud regulation system developed by Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS). The UAV flying route data and cloud management system provide the basic data support for safeguarding public safety and privacy, which is conducive to the further development of low resource and reasonable use applications (Figure 1).

![Figure 1. Relationship between data carrier, air route and management system of UAVs](image)

2. The proposed UAV remote sensing data carrier application potential in low altitude

Civil UAVs have been rapidly developed and popularized, as has the application of remote sensing for UAVs. Every day, massive remote sensing data of UAVs with centimeter-level resolution are generated, and it is becoming an important new big data source [12]. The UAV remote sensing data carrier is registered with UAVs nationwide, supporting data resource sharing, remote-sensing task dispatching, flight management, large data processing, etc. The characteristics of UAV low-altitude remote sensing data include high resolution; scattered, heterogeneous sources; lack of unified benchmark; and standardized data processing flow of space and time. The UAV remote sensing data carrier is a specific data gathering, processing, and exchanging platform, which can connect the national distributed UAV stock with the incremental heterogeneous, multi-source remote sensing data. And it can simultaneously realize value-added services through data cleaning, splicing, fusion, mining, and other technologies (Figure 2). The measurement tasks can be distributed for all kinds of matched UAVs, so that the carrier platform could cover the whole country through seamless docking within the UAV remote sensing network, dynamically obtaining the high-resolution remote sensing images, and building a national geographic information UAV big data system. In practice, the UAV remote sensing catalogue retrieval system has been developed, which can provide the network retrieval and download services for UAV remote sensing data. At present, most UAV technologies and platforms are traditionally remote sensing data processing. With the development of Internet technology, UAV remote sensing will become the perception node of the Internet, and the acquisition of data will be faster and more standardized. In addition, the acquisition of outcome information will also be faster and more intelligent.
To meet the application requirements of UAV remote sensing big data, the data processing platform requires compatibility, dynamics, high performance computing, scalability, fault tolerance, and deep mining. At present, new UAV remote sensing big data processing technologies keep emerging, including large-scale spatial data processing technology based on GPU cluster, remote sensing data processing technology based on distributed computing, and massive remote sensing data processing technology based on cloud computing platforms. Remote sensing big data have made breakthroughs in research on key technologies, such as distributed clustering storage, high-performance computing oriented to data-intensive applications, association analysis of multi-source and heterogeneous data, and geographic visualization of remote sensing big data. This is relevant as UAV remote sensing big data are multi-source heterogeneous. However, the research leaves many problems still to be investigated, including multi-source heterogeneous UAV spatio-temporal data storage technology, multi-source heterogeneous UAV remote sensing big data management and service technology, UAV big data computing and services technology, UAV big data visualization and map service technology, and so forth. We propose developing a cloud service platform of UAV remote sensing image big data, which can store mass observation data of UAV networking, mass UAV product data, and background data. This will support the operation of a national UAV traffic management system, construction of a 3D air route network, and further industrial and commercial applications.

3. Low-altitude public air route of UAVs based on massive geographic data

The low-altitude public air route network is the infrastructure of UAV commercial application. Its overall planning, construction, and operation is a large project and requires the active and joint participation of scientific research institutes and enterprises under the leadership of the national military and civilian airspace management departments and departments, which can truly instigate the development of civil UAVs. Recently, the CAAC (Civil Aviation administration of China) issued the “Guidance to promoting the development of civil unmanned aviation (draft)” [7], explicitly proposing to explore key technologies and demonstrating the typical application of low-altitude public air routes of UAVs. With the positive leadership of military and civilian administration, the cohesion of industries and research institutes, and policy support of the key techniques and pilot works of the low-
altitude public air route, China will certainly advance internationally in the innovation of science and technology for UAV management, just as it has in civil UAV manufacturing.

UAV flights and other activities (e.g. take-off and landing) are concentrated in very low level (VLL) airspace, thus they are closely related to the ground geographic information. Therefore, the planning of the UAV low-altitude public air route needs the support of highly integrated geographic information technology and aviation technology, especially the support of massive geographic big data. The key techniques include: acquiring sensitive geographic elements of UAV flights by rapid identification and extraction technology on remote sensing images. Building a gridding database that is convenient for storage and fast retrieval of the UAV public route by uniform gridding subdivision technology, a fine dividing and structuring technology for the low-altitude airspace, the quick search and optimization technology of the three-dimensional path, multilevel road network construction and the rules of design, risk assessment of UAV operation, simulated and actual flight tests, and so forth (Figure 3). It is notable that a variety of practical tests aiming to quantify the clear boundary using function, and the spatial risk distribution for each element are necessary for constructing a UAV flight restriction element database. For example, the actual distance of the UAVs from tall buildings in a school that does not interfere with normal activities, or the safe distance from obstacles such as a lighthouse, pole, or wire (Table 1) [13]. In addition, to ensure the standard and legal operation of UAVs in air routes, the precise regulation technology of UAVs is equally important.

**Figure 3.** Schematic of key technologies for low-altitude air route construction of UAVs.

**Table 1.** Key natural or artificial elements and their safe distance and flying rules for UAVs.

| Natural or artificial elements                  | Rules          | Suggested distance |
|------------------------------------------------|----------------|-------------------|
| Military and civil airports                    | Keep away      | 2 km              |
| Temporary landing ports for manned piloted aircrafts | Keep away      | 2 km              |
| Civil plane air routes                         | Keep away      | 20 km for both ends, 10 km for two sides |
| National boundary line and borderlines         | Keep away      | 5 km on our side  |
### 4. Related work of the carrier in low-altitude public route construction

The UAV cloud regulation system combines high-tech such as the Internet, cloud computing, artificial intelligence, communication navigation, remote sensing, and so forth, by registering the owner of the drone, managing flight plans, implementing electronic geo-fencing map warning, monitoring flights, and other drone conduct management functions. The advancement of technology, the evolution of system framework, plus the consideration that the drones fly at a low altitude near the ground are all important factors in utilizing the UAV remote sensing data. Fully utilizing the UAV remote sensing data to construct a complex and accurate UAV flight geodetic underlying surface environment using the UAV remote sensing data carrier as data support, embedded in the low-altitude public route of the drone, supports the intelligent decision-making function of the next-generation of cloud management systems. These intelligent decision-making functions include rapid approval of a custom flight plan, reasonable dispatching, safe operation of conventional drones, efficient use of airspace resources, and remote sensing applications. Considering the "SkyGrid" system architecture proposed by the research team of the IGSNRR, CAS, as an example, the system is designed and constructed based on the holographic earth and cloud computing technology for the integrated management of UAVs. Under the unified space-time benchmark, the space and sky data are highly integrated, which can effectively monitor and group the UAVs in various industries. Network operation provides the technical basis for effectively supporting and serving the unified UAV operation management system in China and also takes an important step towards the construction and operation of UAV remote sensing network observation, low altitude public air route construction and operation, and the construction of a UAV remote sensing big data aircraft carrier. It mainly includes six subsystems: Skynet monitoring, holographic mapping, pilot training, remote sensing application, flight approval, and Skyway design.

| Location                                                                 | Distance       | Action        |
|--------------------------------------------------------------------------|----------------|--------------|
| Forbidden military zone or military management zone, government offices, nuclear power plant | Keep away       | 100-1000 m   |
| Mountainous terrain                                                      | Climb/detour   |              |
| Radio Astronomy Observatory, Satellite Ground Station, Meteorological radar observation station | detour          | 500-5000 m   |
| Warehouse or enterprise with inflammable and explosive objects or dangerous goods, electric power facilities, petrol station | detour          | 50-200 m     |
| Buildings, tall towers, power grid, wind generating tower                | detour          | 1 km         |
| Wind shear                                                               | Keep away       | 1 km         |
| Noises                                                                   | Keep away       | 1 km         |
| High-speed railway, road                                                 | Translation     | 500 m        |
| Rivers and lakes                                                         | Utilization     | 200 m        |
| Mountains                                                                | Utilization     | 200 m        |
subsystems, as shown below (Figure 4).

**SkyGrid**

![SkyGrid diagram](image)

**Figure 4.** UAV cloud regulation system (SkyGrid) architecture

Low-altitude public routes, with remote sensing data and GIS technology provided by the carrier, play an important role in the following aspects of the cloud regulation system:

1. Flight regulation scheduling

The multi-level low-altitude public route network based on remote sensing data proposed in Section 3 is embedded in the cloud management system as a normalized route to manage the UAVs. Commercialized drones, such as logistics drones, operate in accordance with established routes and are supervised and managed by the regulation center. The scheduling and management of anti-collision flights of UAVs at fairway intersections is based on a genetic algorithm and other artificial intelligence algorithms [14].

2. Flight plan approval

Another important function of the cloud management system is the on-site flight plan approval. For drones that do not operate on the established public route and need to meet the temporary operation requirements, the flight route needs to be generated through on-site route planning [15]. The geo-constrained elements extracted by the UAV remote sensing data are identified, and a high-precision grid constrained map is formed after evaluation and grading; the planned route is verified by safety simulation for flight approval decision.

3. UAV remote sensing application

The cloud remote sensing application module integrates the remote sensing data of multi-source UAVs and extracts the fusion analysis of each data feature, such as calculating NDVI index, video dynamic target tracking detection, etc., to assist the needs of ecology, environmental protection,
emergency, and other industries.

5. Summary and prospects

The UAV remote sensing data carrier shows great prospect in route planning, but there are still some problems to be solved. To provide technical support for the orderly and legal flight of UAVs, it is still necessary to further study the general rules of flight route construction, basic database construction, the path search and optimization core algorithm, route network traffic rules, and other aspects, to form a complete set of technical processes of low-altitude flight route construction. A national UAV regulation infrastructure platform can be built to realize UAV status supervision, UAV observation resource scheduling, UAV flight regulation, real-time monitoring of UAV operations, and other UAV regulations and operations. Through the development of the UAV cloud regulation system, the UAV remote sensing data carrier is used as data support, and the flight network designed for the low-altitude public route of the UAV is used to transmit information to the UAV pilot, operator, and bureau through the Internet. Sharing between the governments ensures that the drone flights "have a route" and achieves reasonable regulation through scientific dispatch.

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