A review: UAV-based Remote Sensing

Ninghao Yin¹*, Ruian Liu¹, Beibei Zeng¹, Nan Liu¹

¹College of Electronic and Communication Engineering of Tianjin Normal University, Tianjin, China

*Corresponding author e-mail: y54795664@163.com

Abstract. In recent years, rapid development of drone technology, information technology, and sensor technology has enabled drone remote sensing to gradually emerge in various industries, especially in agro-forestry. This paper analyzes the three levels of the UAV-RS system's space infrastructure system, ground infrastructure system, and remote sensing data storage system to analyze the development history and current status of UAV-RS systems at various levels and their application status in various fields. It has been found that with the development of related technologies, UAV-RS technology has continuously reached a new level of technology, and looks forward to the future development trend of intelligent UAV-RS, hoping to provide a reference for researchers in this field.

1. Introduction

From the advent of the first drone to various types of drones in various countries, there have been 101 years [1]. The subjective factor in the development of drones is that it has the advantages of miniaturization, high maneuverability, and ability to perform difficult tasks compared to manned aircraft. The objective factors are the rapid development of microelectronic technology, intelligent technology, radio technology and sensors. And another potential factor is the superiority of drones in the war, prompting many countries to strengthen the research and development efforts in the field of drones. The drones can be divided into military and civilian fields according to the application areas. Civil drones can be divided into consumer-class UAVs, commercial UAVs, and experimental research machines. As the market for civilian drones continues to expand, more and more industries are gradually discovering the new prospects with UAVs. Among them, the remote sensing technology based on UAVs has many applications in the civil field.

This paper analyzes the UAV remote sensing(UAV-RS) from the three layers of the spatial foundation system, the ground infrastructure system and the remote sensing data storage system of the RS system and explains each layer from the local to the whole. It has been found that UAV-RS technology is constantly becoming more and more complex with requirements. However, most of these complications simply superimpose multiple sensors and reduce the efficiency to some extent.
Then, shows the author's development outlook for UAV-RS.

2. Remote Sensing (RS) Systems
Remote sensing system is based on RS technology, including data acquisition, transmission, processing and storage system. It mainly consists of five parts: carrier platform, remote sensor, control and positioning system, data transmission and data preprocessing. Also, scientists divide this system into three parts, namely, spatial foundation system, ground base system and remote sensing data storage system, such as Fig.1.

Fig.1

2.1. Space Infrastructure System
2.1.1. Carrier Platform and Remote Sensors
The traditional carrier platforms include satellites, spacecraft, aircraft, and ground overheads. Among them, satellite remote sensing is one of the most important components and methods of RS technology. Satellite remote sensing technology is the most mature technology in the development of RS technology, because it is usually a national-level technology. The national government has sufficient human, material and financial resources to develop it vigorously. However, some industries also need RS technology to assist their development. At this time, the use of satellite remote sensing technology may not be practical. First, satellites have time cycle when obtaining information such as images. Second, the cost is large. Third, the resolution of image is low, and detailed features are difficult to obtain. This gave birth to some emerging delivery platforms, such as UAVs, unmanned airships, etc.

UAVs will inevitably overcome some of the shortcomings of traditional RS platforms. 1) Compared with manned aircraft, UAVs need not worry about operating heights and dangers; 2) UAVs have low flying costs; 3) UAVs have a wide range of flying heights. 4) High flexibility, no strong demand for take-off and landing sites; 5) High work efficiency, UAVs less affected by the external environment, can make secondary measurements at any time.

2.1.2. Data Acquisition and Pre-processing
UAV-RS technology like a coin having two sides. There is also a lack of it. For example, its volume is small, has limited power, and limited payload. But these deficiencies can be compensated by other means and can also continue to promote the development of related technologies. As remote sensing technology and science developed further, some high-level remote sensors, such as multi-spectrum, hyper-spectrum, and a series of high-resolution imaging sensors tend to be lightweight, high quality. This allows UAV-RS to be applied in more fields.

Niethammer, James et al. [2] used a mini-quadrotor UAV with digital camera to quickly acquire high-resolution images of landslides at low altitudes to further detect landslide velocity and trends. This method makes up the problem of low resolution and low real time of satellite remote sensing.
Using high resolution image and photogrammetry for orthophoto correction, the texture of geographical environment can be obtained and modeled accurately. With the need of development, UAV-RS provides the possibility for the application of various fields. Herwitz, Johnson et al. [3] used the UAV platform to carry high-resolution cameras and multi-spectral cameras to obtain RS data for monitoring and management of crops. However, these multi-spectral images can only be used to distinguish different categories or extracting edge feature. To further know the growth status of the vegetation, Hunt, Hively et al. [4] proposed a method to get color digital images from the infrared channel to the near infrared photosensitive sensitivity without post-processing using UAV with the near infrared-green-blue digital camera. In this method, we can know relationship of some parameters from the sensor, and more accurate decisions can be made. RS technology applied to agriculture can not only detect the growth status of crops, but also can be used to estimate crop yields. Honkavaara, Saari et al. [5] Using a novel camera system based on FPI (Fabry Perot Interferometer) technology to acquire data, which can effectively improve the accuracy of the data results. The obtained FPI spectral images can be processed completely, and the biomass can be estimated in line. Besides agriculture, RS applications in the other civil field. With the continuous expansion of the application field, there is a higher demand for data acquisition by UAV remote sensing, and some more intelligent systems have been gradually developed.

2.2. Ground Foundation System

2.2.1. Flight Control and Data Transfer

The flight control system is important. Because the movement of UAV depends entirely on its control system. To obtain effective remote sensing information, the high performance of the control system must be required. To meet the continuously complex UAV remote sensing requirements, simple linear-control cannot meet the current application environment. Some control systems based on nonlinear control methods have gradually become relatively better alternative methods. It can basically solve the problems of classical control methods for multivariable input and output conditions. Studies shown that these nonlinear control methods solve a certain problem, but they will have other deficiencies. Then, some methods combining expert system and neural network emerged, for improve the nonlinear control method further. Due to the importance of flight control in UAV-RS systems, there must be more researches. But, the current UAV flight control system has not yet emerged from a fundamental technological change, mostly based on the current technology to further improve, and the development of intelligent networks, such as deep learning, provides more effective means for flight control.

Limited by payload of UAVs, the data storage device and other devices should be reduced as much as possible. Due to the large amount of data in remote sensing information, high data transmission speed and anti-jamming performance are required to ensure data integrity. In other words, UAV remote sensing must select multiple highly efficient and stable data transmission links to transmit the data real-time and uninterruptedly, also consider data preprocessing and storage to ensure that effective and complete data.

2.2.2. Remote Sensing Data Processing

At present, remote sensing image processing of UAVs is mainly in the ground system after acquiring images. Since the UAVs carry a wide range of sensors, the data obtained by different sensors is not the same, and the purpose is not the same. Although a single piece of image information acquires useful data, the amount of data in the image information is large and the correlation is poor. To solve this
problem, some scholars combine a single vision sensor with a UAV attitude control sensor to obtain image data containing the real-time attitude information of the UAVs. This can reduce the difficulty of further processing the image.

Sugiura, Noguchi et al. [6] used an unmanned helicopter equipped with an INS (inertial sensor) and a GDS (geomagnetic direction sensor) to obtain data with the pitch angle and rotation angle of the flight platform. Moreover, GPS (Global Positioning System) receiver also installed IMU (Inertial measurement unit) to measure roll and yaw data. Based on the above hardware basis, the authors propose a method that uses rotation conversion to convert the coordinate data on the image to the geodetic coordinates, thereby correcting the error reduction error in measurement. This method compensates for the error of acquiring data from the bottom layer and is more accurate than a single image mosaic method. Now, for different applications, the benchmark for RS image processing is generally divided into pixel-based and object-based. KAN Youxun. [7] Uses data from multiple sources to perform real-time 3D modeling. The surface of the modeled object is usually not smooth. To accurately model it, it is necessary to analyze the image based on pixels and handle the texture features of the image. This 3D modeling can also be applied to the three-dimensional reproduction of the cultural relics, and texture analysis is an important part of it. Pixel-based image analysis can play an important role in some scenarios, but it does not appear to be sufficient in object-based environments. Literature [8], [9] are all object-based image analysis applications; the former uses object-based analysis to estimate the number of trees in the forest by obtaining high resolution images, and the use of point cloud sets can accurately separate the small seedlings. The latter uses object-based layered image analysis to classify images of plots that are simultaneously measured on the ground by standard grassland monitoring procedures and can accurately monitor pastures. In view of the continuous expansion of UAV-RS applications, a single method does not fully meet the requirements of the mission. Therefore, the analysis of UAV-RS image content can also combine multiple methods to meet the maximum demand.

The above analysis of the image content is the local processing of the image. Mancini, Dubbini et al. [10] is committed to the reconstruction of the bank based or sand dune shape measurement, using the GPS, the total station, the ground laser scanning and so on, with the SfM method to generate the dense set point cloud to construct the digital surface model of the coast so that changes in coastal landforms can be detected. These literatures [11], [12], [13] describes the use of SfM and creates a corresponding 3D point cloud to get more detailed data to restore the overall information of the image. Recent years, to meet the market demand, some data processing methods combined with expert system or intelligent network begin to develop continuously. Pekel, Cottam et al. [14] proposed that the amount of data acquired in the process of surface water variation mapping is large, and these data have more unstable variation factors. The author proposes to use an expert system to explain the data in the Certainty, incorporating image interpretation expertise into the classification process and can be used for multiple data sources. Eliminating the destabilizing factors through three different methods to achieve correct water monitoring.

2.3. RS Data Storage System
The storage of RS data is related to the effectiveness of all previous work. Along with the expansion of UAV remote sensing applications, the amount of RS data has surged to TB (Terabyte) level, even exceeding PB (petabytes) level, and the source of these data are more complex. In addition, there are features such as heterogeneous and distributed storage of RS data. Due to the characteristics of current
RS data and the need for data sharing, traditional relational databases based on document management are not conducive to the management and distribution of massive amounts of RS data, and their security is low. The citation [15] analyzes the characteristics of the long-term sequence of satellite RS data and the difficulties in processing analysis due to storage problems. The article shows that the current storage of RS images is based on a 3D cube model and proposes a SPATS (SPAtial-Temporal-Spectral) data structure which integrates the four dimensions of remote sensing data, time, space, spectrum. According to the way of data storage, it can be divided into 5 multidimensional data formats, corresponding to different scenarios. The citation [16] is to improve the traditional data storage irregularities and complex shortcomings by processing the data itself. Although this method can improve the efficiency of data storage to some extent, the effect is limited. The citation [17] proposed an object-oriented distributed RS data storage model. The model uses direct addressing to access massive multi-source RS data and uses object-relational database to abstract transform and characterize the data, then, combined with consistent hashing algorithms and virtualized storage technologies to propose a dynamic allocation strategy. It can distribute the data as evenly as possible to each storage node, solves the problem of data migration caused by node changes.

Using consistent hashing algorithm can theoretically solve the problem of uniform storage. But the premise is that all storage nodes have the same performance, which is difficult to achieve. The citation [17] proposed a combination of cloud computing and memory cloud technology. The model RD-Cloud provides security for building a high-performance storage integration platform. Both the citation [16] and [17], not only improves from the storage model, but also proposes suitable data management algorithms for the model, which can be improved from two aspects, which can greatly improve the processing speed of data.

3. Conclusion
This paper aims at the three major components of RS system and analyzes the UAV-RS from the space foundation system, ground infrastructure system and remote sensing data storage system. With the continuous development of various technologies, UAVs have become more and more powerful. In the space infrastructure system, especially the current means of data acquisition are mostly based on the needs of the purchase of RS systems equipped with appropriate sensors. Because of the UAV's payload, if faced with a variety of different needs, it may require multiple different UAV-RS systems, thereby increasing the cost of use. Now, the researches on the unification of UAV-RS system module structure are finite. However, the two parts of the RS data processing and flight control in the ground base system and RS data storage system largely determine the efficiency of the UAV-RS system. As the artificial intelligence continues to mature, and further improve the efficiency and precision of UAV-RS, the application of artificial intelligence to drone flight control and data processing will have significant results. At present, the research on integrating artificial intelligence with RS systems is not mature enough, especially in data processing.

References
[1] QIN Bo, WANG Lei. An Overview of UAV Development [J]. Aerodynamic Missile Journal, 2002(8): 4-10. (in Chinese)
[2] Niethammer U,James MR, Rothmund S, et al. Uav-based Remote Sensing of the Super-sauze Landslide: Evaluation and Results[J]. Engineering Geology, 2012, 128: 2-11.
[3] Herwitz SR, Johnson LF, Dunagan SE, et al. Imaging From an Unmanned Aerial Vehicle: Agricultural Surveillance and Decision Support [J]. Computers and Electronics in Agriculture, 2004, 44(1): 49-61.

[4] Hunt ER, Hively WD, Fujikawa SJ, et al. Acquisition of Nir-green-blue Digital Photographs From Unmanned Aircraft for Crop Monitoring [J]. Remote Sensing, 2010, 2(1): 290-305.

[5] Honkavaara E, Saari H, Kaivosoja J, et al. Processing and Assessment of Spectrometric, Stereoscopic Imagery Collected Using a Lightweight Uav Spectral Camera for Precision Agriculture [J]. Remote Sensing, 2013, 5(10): 5006-5039.

[6] Sugiura R, Noguchi N, Ishii K. Remote Sensing Technology for Vegetation Monitoring Using an Unmanned Helicopter [J]. Biosystems Engineering, 2005, 90(4): 369-379.

[7] KAN Youxun. Research on 3D Real Reconstruction Technology Based on Multi-source Measurement Data Fusion [D]. China University of Geosciences, 2017. (in Chinese)

[8] Jaakkola A, Hyypa J, Kukko A, et al. A Low-cost Multi-sensoral Mobile Mapping System and Its Feasibility for Tree Measurements [J]. Isprs Journal of Photogrammetry and Remote Sensing, 2010, 65(6): 514-522.

[9] Laliberte AS, Herrick JE, Rango A, et al. Acquisition, Orthorectification, and Object-based Classification of Unmanned Aerial Vehicle (uav) Imagery for Rangeland Monitoring [J]. Photogrammetric Engineering and Remote Sensing, 2010, 76(6): 661-672.

[10] Mancini F, Dubbini M, Gattelli M, et al. Using Unmanned Aerial Vehicles (uav) for High-resolution Reconstruction of Topography: the Structure From Motion Approach on Coastal Environments [J]. Remote Sensing, 2013, 5(12): 6880-6898.

[11] Mathews AJ, Jensen JLR. Visualizing and Quantifying Vineyard Canopy Lai Using an Unmanned Aerial Vehicle (uav) Collected High Density Structure From Motion Point Cloud [J]. Remote Sensing, 2013, 5(5): 2164-2183.

[12] Lucieer A, Turner D, King DH, et al. Using an Unmanned Aerial Vehicle (uav) to Capture Micro-topography of Antarctic Moss Beds [J]. International Journal of Applied Earth Observation and Geoinformation, 2014, 27: 53-62.

[13] Tonkin TN, Midgley NG, et al. The Potential of Small Unmanned Aircraft Systems and Structure-from-motion for Topographic Surveys: a Test of Emerging Integrated Approaches at Cwm Idwal, North Wales [J]. Geomorphology, 2014, 226: 35-43.

[14] Pekel J, Cottam A, Gorelick N, et al. High-resolution Mapping of Global Surface Water and Its Long-term Changes [J]. Nature, 2016, 540(7633): 0-418.

[15] ZHANG Lifu, CHEN Hao, SUN Xuejian, etc. Spatial and Temporal Spectrum Integrated Storage Structure Design of Multidimensional Remote Sensing Data [J]. Journal of Remote Sensing, 2017, 21(1): 62-73. (in Chinese)

[16] MA Jun, CHEN Yulin. Research on RS Data Distributed Storage Model Based on Object-Oriented [J]. Journal of Henan University. 2017, 47(2): 185-193. (in Chinese)

[17] LI Rongyang. A RAM-Drive Cloud-based Strategy for the High-resolution RS Data Storage and Computation Integration [D]. Zhejiang University, 2014. (in Chinese)