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Multi-Scenario Application of UAV Remote Sensing Technology in Environmental Protection

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Abstract. Unmanned Aerial Vehicle (UAV) remote sensing, as an important component of the aerospace remote sensing system, with its unique technical advantages, has broken through the application limitations of traditional remote sensing. It holds irreplaceable significance and profound implications at the levels of scientific research, industry application, and national strategy. The paper mainly explores the multi-scenario applications of unmanned aerial vehicle remote sensing technology in environmental protection. Firstly, it introduces the research background and significance, including the importance of environmental protection and the application prospects of UAV remote sensing technology in environmental protection.Then, for the three scenarios of atmospheric environment monitoring, water environment monitoring and soil environment monitoring, the overview, feature extraction and application of unmanned aerial vehicle remote sensing in each scenario were respectively discussed. Through the research in this paper, it can provide a theoretical basis and technical support for related research in the field of environmental protection, and also offer references and lessons for the application of unmanned aerial vehicle remote sensing technology in environmental protection.

Keywords: Unmanned Aerial Vehicle Remote Sensing Technology, Environmental Protection, Atmospheric Environmental Monitoring, Water Environment Monitoring, Soil Environment Monitoring

1. Introduction

Unmanned Aerial Vehicle (UAV) remote sensing technology, as a high-tech that has developed rapidly since the 21st century, has been widely applied in many fields due to its unique operational convenience and low cost. Especially in the field of environmental protection, UAV remote sensing technology, with its efficient and rapid data collection capabilities, has provided new solutions for environmental monitoring and assessment [1].

As the problem of environmental pollution becomes increasingly severe, traditional ground monitoring methods have been unable to meet the needs of large-scale and multi-dimensional environmental monitoring. The emergence of unmanned aerial vehicle remote sensing technology has broken this bottleneck. Unmanned aerial vehicles have the advantage of high flexibility and can operate in complex terrain conditions, significantly improving the efficiency and accuracy of environmental monitoring [2].

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The application of UAV remote sensing technology in environmental protection has attracted much attention in recent years. Currently, this technology has been successfully employed for monitoring the atmosphere, water bodies, and soil environments. For instance, Chen Bin and others, taking the grassland in Gansu Province as an example, constructed a joint monitoring scheme of "satellite remote sensing + unmanned aerial vehicle". They used orthophotography images and multispectral data to analyze vegetation coverage, desertification index, and biological disasters. The results showed that there were significant differences in vegetation coverage among different sample areas (for example, the Fan Du Kou Area of Min Le County reached 86.47%, while that in Taofeng Village, Suzhan County was only 24.35%). The contribution lies in achieving a quantitative assessment of grassland ecology, but the limitation is that the sample range is small, covering only 2466.67 hectares [3]. Zeng Yuan explored the application of UAV remote sensing in vegetation coverage, water environment, and biodiversity conservation. By analyzing the technical principles and advantages, it was pointed out that this technology can provide high-resolution data [4]. In particular, certain achievements have been made in areas such as air pollution monitoring, forest fire warning, and wetland ecological monitoring.

This article aims to discuss the multi-scenario applications of UAV remote sensing technology in environmental protection, with a focus on studying its applications and practical value in the atmospheric environment, water environment, and soil environment. It also aims to deepen the practical effectiveness of UAV remote sensing technology in environmental protection and promote its wide application and in-depth development in the field of environmental protection.

2. Application of unmanned aerial vehicle remote sensing in atmospheric environment monitoring

2.1. Overview of unmanned aerial vehicle atmospheric environment monitoring and feature extraction of remote sensing data

Atmospheric environmental monitoring is a core part of environmental protection. In recent years, with the advancement of technology and the increasing environmental protection requirements, it has developed rapidly, covering monitoring and analysis of air quality, distribution of pollution sources, and climate change etc. Insufficient monitoring accuracy can lead to data distortion. The problem exists in traditional monitoring instruments as well, and the root cause lies in their inability to achieve long-term and real-time monitoring, thus failing to ensure high data accuracy [5].

In the field of atmospheric environment monitoring, the working principle of UAV remote sensing technology consists of three core dimensions: Firstly, the UAV platform, which mostly adopts multi-rotor models such as quadcopters and hexacopters, utilizes hovering and low-speed flight characteristics to achieve targeted data collection in specific airspace; Secondly, the payload equipment, which can carry sensors for meteorology, gases, particulate matter, etc., to monitor relevant environmental indicators in real time and transmit data back; Thirdly, the data transmission system, which is the core key link in the technical implementation of the monitoring function [6].

After Chen Chen and others conducted remote sensing monitoring and analysis of atmospheric pollution sources, they needed to construct a diffusion model. Based on this model, they can analyze the causes of pollution sources and extract the characteristics of the pollution sources. Analyzing this model and extracting specific characteristics of the pollution sources can provide a basis for tracking and locating atmospheric pollution sources using UAV remote sensing monitoring. In the modeling of tracking and locating pollution sources, first, a diffusion model is constructed, and then the composition form of the pollution sources and their characteristics are analyzed through the model,

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which can lay the foundation for the tracking and location of pollution sources using UAV remote sensing monitoring [7].

2.2. Application of unmanned aerial vehicle remote sensing data in atmospheric environment monitoring

In the field of atmospheric environment monitoring, the application of UAV remote sensing technology is becoming increasingly widespread, mainly in areas such as air quality monitoring, pollutant dispersion simulation, and climate change research. By carrying high-resolution sensors and cameras, UAVs can obtain atmospheric data at the ground and low altitudes, providing a scientific basis for environmental protection [8].

The application of UAV remote sensing data in atmospheric environment monitoring includes: rapid identification of pollution sources. Tong Jingjun used low-altitude micro fixed-wing UAV remote sensing technology to collect and process aerial remote sensing data of the Xinfeng New Steel Factory in Fushun: Based on the longitude and latitude of the survey area and the factory planning map, the flight route and parameters were planned in the eMotion 2 software, and the unmanned aircraft was launched manually on site to collect images, and the data was recovered from the underside of the aircraft. Through aerial photography, 29 exhaust stacks were identified, while on-site investigation showed that the actual effective exhaust stacks were 38. Although there is an error, this method can still be used for the rapid identification of pollution sources [9]. Gas sensing monitoring: The unmanned aerial vehicle remote sensing technology can utilize high-precision gas sensors to monitor pollutants such as VOCs, SO2, NOx, and PM2.5 in the atmosphere. Different sensors have different detection sensitivities. For example, CO-B4 (0-1000 ppm), NO-B4 (0-20 ppm), and OX-B431 (0-20 ppm) have high sensitivity in detecting CO, NO, and O_3, respectively. Technicians like Zhang Jingjing can preset the flight path and time of the unmanned aerial vehicle, and within 30 minutes, the collected gas data can be converted into electrical signals [6]. Nowadays, the gas sensing modules are more lightweight and can monitor a wider range of gas types. When integrated with a PID monitoring device with ppb-level accuracy, their monitoring capabilities are further enhanced, providing precise data support for atmospheric environment governance.

3. Application of unmanned aerial vehicle remote sensing in water environment monitoring

3.1. Overview of unmanned aerial vehicle water environment monitoring and feature extraction of remote sensing data

Water environment monitoring, as an important part of environmental protection, covers various aspects such as physical, chemical, and biological indicators of water quality. With the rapid development of drone technology, its application in water environment monitoring has become increasingly widespread, becoming an efficient, rapid, and relatively economical monitoring method.

Traditional water environment monitoring relies on ground sampling and laboratory analysis, which has problems such as high cost, long cycle, and limited coverage. However, UAV remote sensing technology breaks through these limitations and can collect water body information on a large scale and at high frequency, significantly improving the monitoring efficiency and accuracy [10]. Wang Junling analyzed the application of drones in water environment management, constructed multiple remote sensing platforms to obtain comprehensive water environment

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information, and the conclusion showed that this technology can overcome the shortcomings of traditional monitoring and provide real-time data to support management decisions [11].

The data feature extraction of UAV remote sensing in the water environment mainly falls into three categories: spectral feature extraction, which identifies pollutant types and concentrations by analyzing the reflectance and absorption rates of water bodies, such as estimating the content of chlorophyll a based on specific band reflectance; morphological feature extraction, which analyzes the geometric features of water bodies to assist in identifying the distribution and change trends of water bodies; and dynamic feature extraction, which monitors water flow speed and direction, which is of great significance for studying pollution diffusion.

Fig. 1 illustrates the proportion of the importance of different characteristics in water environment monitoring.

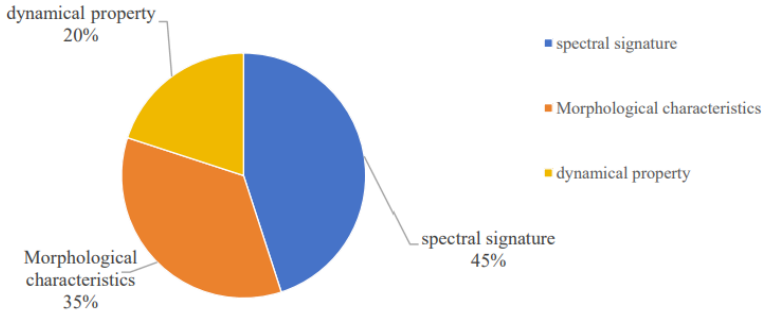

Figure 1. The significance of feature extraction in water environment monitoring (original)

As shown in Fig. 1, it can be seen that spectral characteristics play a significant role in water environment monitoring. This is because spectral characteristics can directly reflect the chemical composition and pollution status of the water body.

3.2. Application of unmanned aerial vehicle remote sensing data in water environment monitoring

In the field of water environment monitoring, the application of UAV remote sensing technology is becoming increasingly widespread, mainly in aspects such as water quality monitoring, identification of water pollution sources, and assessment of water ecological health. Through the high-resolution cameras and multispectral sensors carried by UAVs, detailed images and data of the water surface can be efficiently obtained, providing a scientific basis for environmental protection [12]. Liao Jianbo took the river environment as an example and proposed a UAV aerial photography plan to assist in supervision. Through practical examples, the feasibility and adaptability of this plan were verified. The main conclusion is that UAVs can achieve full river basin monitoring and frequent observations at specific points [13].

The application of UAV remote sensing technology in water environment monitoring mainly includes: Identifying pollution sources. Zhu Minglong et al. pointed out that in practice, technicians need to plan flight parameters to ensure the quality of data collection for UAV remote sensing monitoring. For example, in the monitoring of the water source transfer area of the South-to-North Water Diversion Project in a certain city, a UAV equipped with a CCD optical camera flew at a height of 500m at a speed of 110km/h, capturing 782 aerial images, covering an area of 27.53km², with a spatial resolution of 0.1m, capable of identifying tiny pollution sources; Hand-launched UAVs carrying thermal infrared cameras flew at a height of 400m at a speed of 75km/h, capturing

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thermal infrared video data, which can detect abnormal temperature areas and identify thermal pollution sources [14]. Multi-parameter water quality detection: For near-sea water quality monitoring, it is necessary to obtain over a dozen parameters such as water temperature, pH value, turbidity, and chlorophyll a concentration. The unmanned aerial vehicle is equipped with a multispectral water quality monitoring instrument and a thermal infrared sensor, which can achieve full-water-area coverage with a spatial resolution of 100 meters, capturing changes in water quality gradients in sensitive areas; through regular cruising for data collection, it can dynamically track eutrophication and predict water quality issues, providing scientific data support for the dynamic monitoring of near-sea water quality [15].

Fig. 2 shows the proportion of the application of unmanned aerial vehicle remote sensing technology in the water environment.

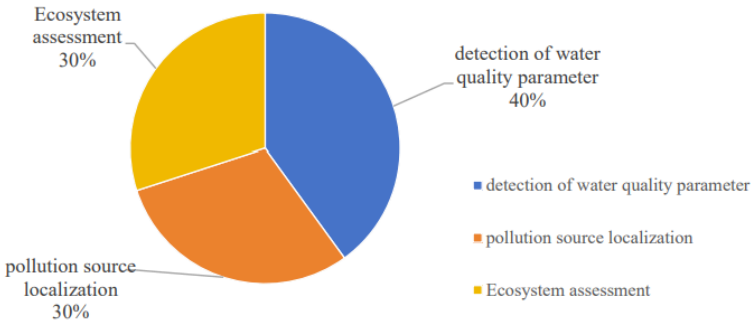

Figure 2. The proportion of unmanned aerial vehicles' application in water environment detection (original)

Fig. 2 shows the main application proportions of unmanned aerial vehicles in water environment monitoring. Among them, the monitoring of water quality parameters takes up a large proportion, indicating its significance in practical applications.

4. Application of unmanned aerial vehicle remote sensing in soil environmental monitoring

4.1. Overview of unmanned aerial vehicles in soil environment monitoring and feature extraction of remote sensing data

Soil environmental monitoring is an important means for assessing and maintaining the quality of land resources. It involves regular detection and analysis of soil composition, structure, and biochemical properties. With the development of technology, UAV remote sensing technology, due to its efficiency and flexibility, has been widely applied in soil environmental monitoring. It can provide large-scale and high-resolution soil information, which is of great significance for understanding soil conditions and their changing trends.

In soil environment monitoring, the application of UAV remote sensing technology mainly manifests as follows: UAVs are equipped with various sensors to collect core parameters, and are also equipped with multispectral and hyperspectral remote sensing equipment to conduct comprehensive detection and quantitative analysis of key influencing factors of soil erosion. The multi-dimensional data obtained by this technology provides important data support for assessing soil health status and identifying soil erosion areas. Secondly, UAV remote sensing technology can achieve rapid monitoring of soil coverage, vegetation index, etc., which is helpful for evaluating the degree of soil degradation and the effectiveness of ecological restoration. Moreover, in the

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monitoring of water and soil conservation in production and construction projects, UAVs mainly use visible light cameras, and can choose vertical or inclined photography methods according to different monitoring needs. Compared with visible light cameras, the application of laser radar is less common, but it has shown unique advantages in specific projects [16].

In soil environment monitoring, the application of UAV remote sensing technology relies on its efficient data collection capabilities and precise spatial positioning functions. By carrying multi-spectral or hyperspectral sensors, UAVs can obtain key parameters of the soil surface, such as soil moisture, vegetation coverage, and soil type, which are of great significance for assessing soil health and land management. Feature extraction is the core step in processing raw remote sensing data, and it requires filtering out effective monitoring information from a large amount of data. Common methods include principal component analysis (PCA), linear discriminant analysis (LDA), and convolutional neural networks (CNN).

4.2. Application of unmanned aerial vehicle remote sensing data in soil environmental monitoring

Application of Unmanned Aerial Vehicle Remote Sensing Data in Soil Environmental Monitoring: Identifying Soil Health. In the field of soil environmental monitoring, the application of UAV remote sensing technology is increasingly widespread, mainly in aspects such as soil erosion, soil moisture, and soil pollution. Through the high-resolution cameras and multispectral sensors carried by the UAV, detailed information on large areas of soil can be efficiently obtained, providing a scientific basis for soil health assessment and management. Taking the Mudanjiang area as an example, the technical characteristics analysis shows that it can provide precise data support for decision-making, indicating that UAV remote sensing effectively identifies areas of soil erosion and promotes the implementation of protection measures [17]. Soil organic pollutant detection: Feng Jian, based on the pre-processing results of soil spectral data, used the LAR algorithm to select and extract the characteristic variables. After a series of operations, the selection and extraction results of the characteristic variables of soil spectral data were obtained. Then, based on this, the spectral characteristic variables of soil organic pollutants were obtained from existing studies. By measuring the similarity between the two, it is possible to determine whether there is organic pollution in the monitoring area of the soil and to identify the types of organic pollutants, thereby achieving real-time monitoring of soil organic pollution [18].

5. Conclusion

This article systematically elaborates on the application of UAV remote sensing technology in multiple environmental protection scenarios, specifically covering three main aspects: atmospheric environmental monitoring, water environmental monitoring, and soil environmental monitoring. By analyzing the current research status, it clarifies the significant importance and development trend of UAV remote sensing technology in the field of environmental protection, laying a solid theoretical foundation for in-depth research.

In the application scenarios of environmental protection, this article describes the actual application status of UAV remote sensing in atmospheric environmental monitoring, water environmental monitoring, and soil environmental monitoring. Especially in the aspects of feature extraction of remote sensing data in different scenarios and data applications, combined with rich case analyses and practical explorations, it demonstrates how UAV remote sensing technology promotes environmental protection work towards a scientific and precise direction. It enriches the

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research content of UAV remote sensing technology and provides a valuable reference basis for researchers in the field of environmental protection.

In conclusion, UAV remote sensing has achieved remarkable results both in theory and practice, not only providing new ideas and methods for environmental protection applications, but also playing a positive role in promoting the development of green ecological environment construction work.

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