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Research on the Application of UAV Remote Sensing in Biodiversity Monitoring

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ABSTRACT

UAV remote sensing technology integrates unmanned aerial vehicles, communication, remote sensing, navigation (GPS) and Information Message Units(IMU) and other technologies, and has the ability to quickly obtain space information.In the context of accelerated global biodiversity loss, this technology provides a new means for biodiversity monitoring. The detection of biological diversity through remote sensing technology provides a new paradigm for species distribution modeling and ecosystem function research. With the decline of biological species around the world, the use of remote sensing technology provides key data support for the protection of endangered species. After the application of remote sensing technology to biodiversity detection, it helps to reduce technical costs, improve the quality of people's living environment, enrich people's spiritual values, etc., thereby producing positive social and economic impacts. This paper systematically sorts out the core principles and application status of UAV remote sensing technology, analyzes the adaptability of different sensors in animal and plant monitoring. That is the monitoring effect of different sensors under different lighting conditions, and discusses the path of constructing a collaborative monitoring method system for animals and plants, aiming to provide technical support for biodiversity conservation and ecological assessment.

KEYWORDS

UAV remote sensing; Biodiversity monitoring; Sensor adaptability; Light conditions; Collaborative monitoring

1 Introduction

The conservation and sustainable use of biodiversity is the core content of ecological civilization construction and a key indicator to measure sustainable development ability of the country. Traditional biodiversity monitoring methods have limitations such as high cost, poor timeliness, and limited coverage, making it difficult to meet the needs of dynamic monitoring. UAV remote sensing technology has gradually become an important means to make up for the gap in ground monitoring and satellite remote sensing scale by virtue of its strong flexibility, high timeliness and accurate resolution. With the reduction of technical costs and the improvement of the standardization system, UAV remote sensing is promoting the transformation of biodiversity conservation from "passive response" to "active prevention". It not only provides a new paradigm for species distribution modeling and ecosystem function research, but also provides key data for the protection of endangered species, which has important economic significance in reducing monitoring costs, improving the quality of the ecological environment, and enriching social spiritual values. Based on the current research status at home and abroad, this paper discusses the application path and innovation direction of UAV remote sensing in biodiversity monitoring. our country has accumulated more than 20 years of research experience in the field of UAV remote sensing, such as Flying Elephant system, Quick Eye system, and Huaying system have been put into practical applications. Compared with satellite remote sensing, low-altitude UAV perform prominently in grassland vegetation monitoring: although satellite remote sensing can quickly estimate regional vegetation coverage, the resolution is insufficient, making it difficult to characterize the characteristics of sparse grasslands. With its high resolution and flexible scheduling capabilities, UAV have become an effective supplement to ground surveying and satellite monitoring. In terms of technology application, Yang Hongyan etc. compared random forest algorithms (RF), such as OIF - RF, PCA - RF, and SBS - RF. Addition, she found that the SBS - RF algorithm had the highest accuracy in desert grassland vegetation classification, providing an optimized scheme for plant species identification. Guo Qinghua etc. pointed out that UAV remote sensing can make up for the scale gap between ground and space remote sensing, and extend the monitoring point results to the regional scale through accurate deduction methods, but the selection of sensors needs to be combined with research content and regional characteristics. Han Jie etc. focused on key technologies such as flight mission planning, remote sensing platform and remote control software integration, and proposed the application idea of combining UAV remote sensing with land and resource management.

Current research focuses on monitoring of a single species or a single time period, and the method system of collaborative monitoring of animals and plants and continuous monitoring of day and night is insufficient, and the balance between technology universality and pertinence has not been solved. UAV remote sensing systems are equipped with different types of sensors (Visible light sensor, Thermal infrared sensor, Multi-spectral sensor, laser radar) to obtain surface information: The visible light camera is suitable for monitoring vegetation coverage and plant morphology in a high-visibility environment during the day. Thermal infrared sensors can capture the temperature difference of objects, suitable for tracking animal activity trajectories at night. The multi-spectral camera can identify the spectral characteristics of plants and is used for species classification and growth status evaluation. Laser radar can reflect habitat topography and vegetation structure through 3D modeling. These sensors are combined with GPS and IMU to achieve precise positioning and rapid processing of spatial information. This paper integrates multi-source remote sensing data, designs a technical process suitable for simultaneous monitoring of animals and plants, and develops a monitoring scheme suitable for daytime (mainly visible light) and night (Thermal infrared sensor and laser radar) scenarios, so as to realize the continuous capture of dynamic changes in biodiversity and provide multi-dimensional data for biodiversity monitoring.

2 The concept of UAV remote sensing technology

UAV remote sensing technology is a comprehensive technology that combines UAV platform with remote sensing technology to obtain information on the earth's surface and target objects by carrying various sensors, and carries out data processing, analysis and application. It integrates aerial photography, remote sensing detection, automatic control, geographic information system (GIS) and other multidisciplinary technologies, and has become an important supplement and expansion of traditional satellite remote sensing and manned aerial remote sensing with its advantages of high flexibility, low cost, high resolution, and strong real-time. UAV remote sensing systems can be divided into hardware systems and software systems. The hardware system includes airborne system and ground monitoring system. The software system includes five parts: route design, flight control, remote monitoring, aerial camera inspection, and data that is processed in advance[1]. UAV remote sensing systems can also be divided into airborne remote sensing systems and control systems. Airborne remote sensing systems include airborne remote sensing equipment, stabilization platforms and mission equipment and the control system includes radio telemetry system and remote control system.

UAV remote sensing technology is divided into three complete systems: UAV platform, remote sensing sensor, data processing and analysis system, as shown in Figure 1. According to the model classification, UAV can be divided into multi-rotor UAV, fixed-wing UAV, and vertical take-off and landing fixed-wing UAV . The platform needs to have a stable flight control system, such as GPS/BDS positioning, automatic driving and obstacle avoidance functions),which ensure accurate flight according to the preset route and ensure the stability of data collection. Remote sensing sensors can be divided into the following four categories according to their working principles: optical sensors, thermal infrared sensors, microwave sensors, and laser radar. For data processing and analysis systems, the raw data (such as images and point clouds) obtained by UAV need to be preprocessed (such as splicing, correcting and denoising), interpreted (extracting feature features), and modeling (generating thematic maps and 3D models), and finally converted into usable information. Commonly used software tools include: Pix4D (image stitching and 3D modeling), ENVI (remote sensing image analysis), Arc GIS (geographic information integration), LiDAR360 (laser point cloud processing), etc.

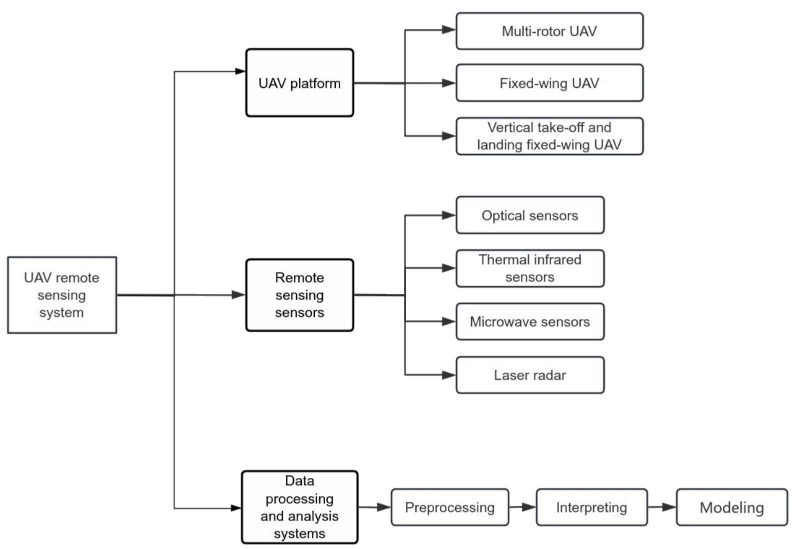

Figure 1 UAV remote sensing system

3 Selection of UAV remote sensing sensors under different lighting conditions

The working principles of different remote sensing sensors vary greatly, and their dependence and adaptability to lighting conditions are also very different. The sensor that passively relies on the external light source is the optical sensor. The sensor that passively relies on the thermal radiation of the ground object is the thermal infrared sensor. The sensor that emits signals autonomously is the microwave sensor, and the sensor that actively emits autonomously is Laser radar or called Li DAR.

The optical sensor directly depends on the lighting conditions by receiving the visible light reflected by the ground object in the mid-near infrared band, and the light intensity and angle will significantly affect the imaging effect. Under the condition of strong daylight, the solar radiation is sufficient, the reflection signal of the ground object is strong, and the sensor can capture rich spectral information and spatial details. The image has high brightness and strong contrast, and the details of surface organisms are clear, such as vegetation texture and water body boundaries. The differences between bands are significant, which is conducive to the classification of features. However, if the light is too strong, it is easy to cause over-saturation of highlights, resulting in loss of detail. Under cloudy and cloudy conditions, due to the weakening of the direct radiation of the sun due to the clouds, the reflection signal of ground objects is weakened, and no over-saturation that caused by direct light and less shadow. However, the overall brightness of the image is low and the contrast is poor; Atmospheric scattering is enhanced, and the image is easily grayed. Under dusk conditions, the light angle is low and the terrain shadow is long, which can enhance the three-dimensional sense of surface undulation, and the low-angle light reduces the reflection of the ground objects, but the overall brightness is low, and the shadow area is easy to be underexposed. Under night conditions, because the optical sensor relies on the reflected light from the sun, there is no external light source at night, and there is no reflected signal of the ground object, so it is almost impossible to image, and only in very special cases, such as the strong reflection of moonlight, can low-quality images be obtained. Among them, for band selection, researchers used fixed-wing UAV equipped with Micro MCA 12 Snap multi-spectral sensors to obtain high-resolution multi-spectral images (Zhao Qingzhan,1972; Liu Wei,1989; Yi Xiaojun, 1977). They set up study areas A and B and designed 8 groups (16 groups in total) respectively, and concluded that the bands 1, 6, 11, NDVI, NDWI, and the Mean parameter in the grayscale symbiosis matrix could be selected as the optimal band combination for their feature classification. Among them, the band characteristics of band 1 are differentiated from vegetation and soil rock surface. Band characteristics of band 6: the initial uphill position of the vegetation spectral response curve. Band characteristics of band 11: calculate the moisture sensitivity index of a specific crop.

The thermal infrared sensor receives the heat radiation emitted by the ground object itself and does not directly depend on the light, but the light will indirectly change the imaging effect by affecting the temperature of the ground object. Many researchers use thermal infrared sensors to conduct research on biological identification and detection, so thermal infrared sensors provide a large research path in the field of biological monitoring [8-10]. Under the condition of strong light during the day, due to the sun's heating of the surface, the temperature of the ground object increases, the thermal radiation intensity increases with the temperature, the image contrast is high, and the temperature difference of the ground object is significant. Under cloudy and cloudy conditions, due to the weakening of solar radiation by clouds, the heat absorption of ground objects is less, the contrast is reduced, and the temperature difference is reduced. Under dusk conditions, due to the weakening of solar radiation and the release of heat by features, the cooling rate of different heat capacities varies greatly, so the temperature of the ground objects is in a transitional state, and the temperature gradient is obvious. Under night conditions, because the sun cannot heat up, the ground organisms are in a natural heat dissipation state, which is suitable for monitoring a stable heat source.

Microwave sensors belong to active sensors, which autonomously emit microwave signals and receive reflected echoes for imaging, completely independent of external lighting. According to the different detection methods, microwave biosensors can be divided into direct and indirect types. Direct microwave biosensors achieve sensing response characterization for the detection of biological entities, while indirect microwave biosensors reflect biological information indicators indirectly by introducing the bio-material for detection or through the detection of the organic solution environment where the biological entity is located. Under bright daylight conditions, the imaging is stable and unaffected by strong light interference. Under overcast and cloudy conditions, unaffected by cloud cover and rain, the image quality is consistent with that of sunny days. Under twilight conditions, the effects of varying light intensity are stable. Under nighttime conditions, it can work normally without relying on any light source, making it suitable for nighttime monitoring.

Li DAR does not rely on external lighting conditions at all, but images may slightly differ under different lighting conditions. Under strong daylight conditions, data accuracy is high, with some minor interference from the strong light, but the impact is small. Under overcast, cloudy, and dusk conditions, the data quality is optimal, with no stray light interference. Under night conditions, it operates normally and is suitable for monitoring areas sensitive to nighttime.

In summary, different remote sensing sensors have significant differences in their dependence on and adaptability to illumination due to their different working principles. Optical sensors rely on external light sources, are greatly affected by lighting conditions, and are almost unable to capture images at night. Thermal infrared sensors rely on the thermal radiation of the objects themselves, with lighting affecting the temperature indirectly. Microwave sensors actively emit signals and do not depend on light at all. Li DAR actively emits laser beams and is basically unaffected by lighting conditions. Various types of sensors have different imaging characteristics under different lighting conditions.

4 Selection of remote sensing sensors for animal and plant drones

UAV remote sensing sensors are commonly used for the detection of plants and animals. Classified by sensor type, optical sensors include: visible light cameras, multi-spectral cameras, and hyper-spectral cameras, thermal infrared sensors , include infrared thermal imaging cameras, microwave sensors ,include multi-mode microwave sensors, synthetic aperture radar (SAR), and microwave radar modules, Li DAR (Light Detection and Ranging).

In UAV remote sensing sensors, those focused on detecting plant studies include: multi-spectral cameras and hyper-spectral cameras in optical sensors, synthetic aperture radar (SAR) in microwave sensors, multi-modal microwave sensors, and Li DAR. For example, researchers used multi-spectral imaging technology and hyper-spectral imaging systems to detect plant diseases and established a standard expert database of multi-spectral images(Nie Wenjin, 1990; Zhang Shiwan, 2005). Synthetic Aperture Radar (SAR) can be used for crop type identification, planting area measurement, yield prediction, crop growth monitoring, and soil moisture estimation. For example, utilizing multi-temporal and multi-polarization RADARSAT data and ENVISAT ASAR data can monitor rice growth, providing support for rice growth monitoring and yield forecasting. Multi-modal microwave sensors can monitor plant growth rate and health status by measuring the microwave reflection characteristics of plant leaves. They can also detect changes in moisture content on plant surfaces, helping to identify pest and disease issues early. Additionally, by monitoring the microwave reflection and transmission of plant leaves, the efficiency of photosynthesis in plants can be analyzed. Commonly used sensors for detecting animals include: thermal infrared sensors and microwave radar modules. The combined microwave radar module can accurately determine whether a pet is nearby, thereby automatically starting the feeding or watering program, and is applied in devices such as pet water dispensers and pet feeders. For example, the Feirui Intelligent low-power microwave radar module can be used in pet feeders, and the microwave radar sensing module can be used in smart pet water dispensers. Commonly used in the testing of plants and animals include: visible light cameras and visible light infrared thermal imaging. For example, thermal infrared technology can be used for the detection of livestock diseases as well as for research on plant salt tolerance [13,14]. Table 1 compares the technical characteristics and application scenarios of various sensor technologies.

Table 1 Comparison of technical characteristics and application scenarios

Sensor Type	Core advantages	Typical application scenarios
Multi-spectral Camera	Calculation of vegetation index and rapid large-scale monitoring	Agricultural yield estimation, forest resource survey
Hyper-spectral Camera	High spectral resolution, supports material composition analysis.	Identification and fine classification of plant diseases and pests
Li DAR	3D structure reconstruction, high-precision terrain surveying	Estimation of forest biomass, canopy analysis
Visible light camera	Low-cost, intuitive image acquisition	Plant phenotype observation, animal appearance recognition
Infrared thermal imaging camera	Nighttime / Concealed environment monitoring, temperature difference detection	Wildlife tracking, assessment of plant water stress
Visible light and infrared mixed sensor	Multimodal data fusion, balancing detail and penetration capability.	Comprehensive monitoring in complex environments (such as urban green spaces and protected areas)

5 Conclusion

This article systematically organizes the core system and current applications of drone remote sensing technology, analyzing the adaptability of sensors such as optical, thermal infrared, microwave, and Li DAR under different lighting conditions, and clarifying the application focus of various sensors in monitoring flora and fauna. Multi-spectral/high spectral cameras, synthetic aperture radar, etc. are suitable for plant monitoring, while thermal infrared sensors and microwave radar modules are suitable for animal monitoring. Visible light cameras and hybrid sensors can cater to both. Research indicates that current monitoring of single species or time periods has limitations. In the future, it is necessary to establish a multi-sensor fusion system for the collaborative monitoring of plants and animals, combined with optimization technologies for day and night scenarios, to provide more comprehensive technical support for biodiversity conservation and ecological assessment.

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