Review on unmanned aerial vehicle remote sensing and its application in coastal ecological environment monitoring

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Abstract: Unmanned aerial vehicles (UAV) and UAV-based remote sensors are becoming more technologically advanced and widely used in the ecological environment monitoring. The analyses of UAV remote sensing data can help to improve the input efficiency in ecological environment assessment, which can greatly improve the monitoring efficiency and reduce the impact on environmental pollution. This review introduces the common types of UAV, types of UAV-based remote sensors as well as UAV communication, and their practical application in different coastal ecological environment monitoring scenes: terrestrial pollution source, marine debris, algae disaster, which can provide fresh perspective and thought for producer and researcher to develop the UVA remote sensing application in this field.

1. Introduction

Unmanned Aerial Vehicles (UAV) is often called power driven, pilotless, air provides lift and reusable-aircraft [1]. Until the end of the 20th century, UAV was still mainly for military use, and is gradually expanding to civilian fields [2-3]. The development of UAV industry in China started late, it was not until the 21st century that China's UAV industry entered a stage of rapid development [4]. In recent years, as a new remote sensing platform, UAV is convenient to carry, flexible to take off and land, freedom from positioning and timing limitations, and able to cover large areas in short time periods, which greatly improved the efficiency of investigation. The spatial resolution of UAV image can reach centimeter level, which can also make up for the shortcomings of satellite remote sensing [6], and it is not being subjected to cloud obstruction that guarantee the data quality [7]. Because of the advantages of UAV platform, which make it widely used in forest resources investigation [8-9], atmospheric environment monitoring [10], ecological monitoring [11-12] and so on.
2. Development status of UAV Remote Sensing Technology

2.1. The development status of UAV platform
There are numerous of UAV airframes types, but the two most common are the fixed wing and rotary-wing. For each type has its own set of advantages and disadvantages: rotary-wing UAVs has the advantage in flight-stability, ease of operation, vertical take-off and hover capability, however, the coverage area and flight time are limited. Whereas, fixed-wing UAVs are capable of cover greater areas and longer flight times, but they couldn’t able to hover and need a larger takeoff and landing area than rotary-wing UAVs [13-14].

2.2. The development status of remote sensors
With the development of light and small UAV platforms, UAV-based remote sensors including accuracy, resolution, reliability, ease of use and affordability continue to occur. From the large types of imaging sensors, the most widely used in coastal ecological environment monitoring applications are: spectral, color and thermal cameras. Spectral cameras not only capture visible segments of electromagnetic spectrum, but also near infrared and shortwave infrared regions of the electromagnetic spectrum which are not visible to the naked eye. Multispectral cameras are capable of 3-10 bands from the electromagnetic spectrum [15]. Distinct from multispectral cameras, hyperspectral cameras can capture contiguous portions of the electromagnetic spectrum that consist of hundreds or thousands of narrow wave-length bands [16]. Color sensors can capture visible light and can collect many valuable data, which can be incorporated into deep learning workflows for automated object-based classification and discernment of imagery sets [17]. Thermal cameras capture the infrared regions of the electromagnetic spectrum [18]. Thermal imaging is the non-contact detection of infrared energy and convert it into electrical signals, which finally generate thermal images and temperature values.

2.3. The development status of UAV communication
The current UAV can be equipped with high-speed data link, which including 4G / 5G remote control and communication that can realize the real-time transmission of high-definition video data, hyperspectral, SAR and other large capacity data. The development of 5G networks will provide communication links with large bandwidth, high reliability and low delay for UAV applications, which promotes the development of UAV applications [19].

3. UAV remote sensing application in coastal environment monitoring
As the demand for the use of offshore waters is growing, which result in the contradiction of using the sea is becoming increasingly prominent. Relying on traditional and extensive manual means to monitor the large areas of offshore waters is no longer meet the practical needs. In recent years, with the development of UAV remote sensing technology, its application in coastal environment monitoring has been greatly booming [20].

3.1. Application of UAV Remote Sensing in terrestrial pollution source monitoring
Terrestrial sewage outlet into the sea has become one of the main sources of marine pollution and it is an important content of Marine environmental monitoring. However, the sewage outlets are usually large in quantity, widely distributed and concealed in most cases, conventional manual investigation work is huge and the cost is high, which are far from meet the actual needs of investigation work. Thus, research in this area monitor with remote sensing has been more and more applied. From existing studies, most studies applied remote sensing information to located the terrestrial pollution source by using spectral sensors and thermal sensors. UAV-based color and thermal remote sensors were applied to terrestrial pollution source monitoring have been studied by Zhang Y.M. [21], the terrestrial pollution sources could be directly recognized from the true color orthophoto image and the hidden terrestrial pollution sources could be detected by thermal infrared images according to the difference of thermal effect [22]. Li X.Y. et al. based on multispectral UVA survey technology investigated the outlets along
the Yellow Sea and the precision could reach 88.7% integrally, which provide strong technical support for the source-tracing and control of marine pollution [23]. Some studies have combined with multispectral and hyperspectral remote sensing data to extracted the water quality parameters and monitoring land-sourced sewage outfalls in Bohai Sea [24]. The rectification of terrestrial pollution brings new opportunities to the development of UAV remote sensing technology and the output analyses from UAV remote sensing data will provide a strong technical guarantee and support for the smooth development of Marine pollution control.

3.2. Application of UAV remote sensing in marine debris monitoring

With the development of coastal industry and the rise of coastal tourism, marine debris is an ubiquitous increasing threat to marine ecosystems which is of particular concern due to its durability, abundance and persistence in all the oceans of the world [25-26]. At present, marine debris monitoring mainly rely on situ monitoring, which require an enormous human effort, are time-demanding and remain insufficient at the global scale. UAV remote sensing have the potential to overtake these constraints that gradually applied in this field. From existing studies, most studies applied remote sensing information to address marine litter using multispectral and hyperspectral optical sensors. Both Toms et al. [27] and Aoyama, T. [28] all using hyperspectral remote sensing extracted of marine debris in the Sea. Some studies applied multispectral sensor in marine debris monitoring, Biermann et al. found plastic patches in coastal waters by using multispectral red-green-blue (RGB) in optical [29], Fall, L. et al. proposed an ad-hoc methodology for monitoring and automatically quantifying marine debris based on the combined use of a commercial UAV equipped with an RGB multispectral sensor and a deep-learning based software [30]. What’s more manned aircraft survey with visible and infrared cameras and LIDAR instrument was applied in marine debris survey in the Gulf of Alaska [31]. Some studies indicated that future goals in marine litter detection should be addressed with platforms including optical and SAR sensors [32].

3.3. Application of UVA remote sensing in algae disaster monitoring

Marine algae disasters such as green tide and red tide are increasingly affecting the offshore marine environment and the sustainable development of coastal economy in China [33]. Monitoring of algae disaster usually based on the study of spatial-temporal distribution characteristics of chlorophyll [34-35]. Chlorophyll has its specific absorption and reflecting spectrum, the information of chlorophyll concentration in seawaters could be retrieved with the help of multispectral and hyperspectral data based on their spectral characteristics. Significant studies have been carried out on spectral characteristics of seawaters in Chinese marginal seas, Li D.X. based on the high-precision multispectral data of UAV studied the relationship between NDVI and the distribution of green tide effectively extract the beach green tide in Yellow Sea [36]; Multispectral sensor was also used by Song D.B., using chlorophyll threshold segmentation method to extract the red tide information [33]. However, most of studies on algae disaster using remote sensing technical in China are mainly confined to observe the occurrence of algae disaster [37]. Thus, it is essential to further studies on the mechanism of algae disaster and dynamic process in relation to other marine environmental factors such as wind, Sea Surface Temperature (SST), Sea Surface Salinity (SSS) etc using satellite remote sensing data.

4. Discussion

Although the growing application of UAV remote sensing for research, the majority of the studies are mainly focused in the offshore region of the marine. These studies are characterized by having a greater flexibility to equipped with different sensors and other devices [38-39], as well as UAV flight height and spatial resolution factors that probably being one of the reasons why they have been primarily used to coastal environment monitoring. It is difficult in trade-offs between altitude and resolution in UAV-based data analysis and collection, thus the development of higher resolution sensors can solve these problems and allow users the ability to fly at higher altitudes and collect more usable remote sensing data per mission. Another limited factor is remoting sensing data reliability and accuracy, in order to solve this problem, investigation relates to the fusion of color, spectral and thermal data, which can
retain as much information as possible with the highest precision\cite{40}. As the improvement of autonomous flight force, flight radius and battery life of UAV, and the continuous development of UAV high-resolution earth observation payload and UAV measurement-control technology makes it possible for UAV play an important role in pelagic area supervision and more field\cite{41,42}.

5. Conclusions
This review introduces the common types of UAV, types of UAV-based remote sensors as well as UAV communication, and their practical application in different coastal ecological environment monitoring scenes: terrestrial pollution source, marine debris, algae disaster. Despite the growing application of UAV for research, the studies are mostly exclusively used for terrestrial research, the majority lack a comprehensive overview of its application in coastal ecological environment. This review provides researchers with fresh perspective and thought for the development and application of UAV remote sensing technology in different coastal ecological environment monitoring.

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