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Mangrove Interspecies Classification Based on UAV Hyperspectral Images

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Abstract: In recent years, the UAV light-weighted hyperspectral imaging system has become more available. It can provide high spatial and spectral resolution images for environment monitoring. Mangrove forest interspecies distribution map is important data source for the government to design the protection policy. A research on UAV hyperspectral remote sensing surveying of mangrove forest is implemented in Futian Nature Reserve area located In Shenzhen, China. The UAV-based hyperspectral images were collected and processed to get the geometrically corrected mosaicked reflectance data that was latter used to extract the mangrove interspecies map. Based on the hyperspectral data, the supervised pixel-based classification methods were implemented. Firstly, NDVI is used to distinguish mangrove forest from other ground object features based on the decision tree classification method with expert knowledge. Then MNF transformation is performed on the hyperspectral data to get the transformed feature that represents the most information of the hyperspectral bands. Next, the best exponential factor formula (OIF) method is used to analyze the first 10 band features chosen by the MNF transformation to get the optimal band combination for classification. Finally, the pixel-based maximum likelihood, minimum distance classification methods are used to classify the mangrove interspecies. The classification results show the distribution of mangrove areas. The pixel-based minimum distance method performs better and the overall classification accuracy can reach to 98.21%.

Keywords: Mangrove, Hyperspectral, Information Extraction, Futian Nature Reserve

1. Introduction

Mangrove forest is a woody plant community that grows in the intertidal zone of the tropical and subtropical coast and is periodically immersed in seawater. It is a complex ecosystem with both land and marine characteristics [1], an important ecological key area of the coast [2, 3]. The mangrove forest is also called as the "sea forest" and is the only aquatic forest ecosystem. It is a key carbon pool with unique ecological characteristics, and it has important research value for protecting the costal enviornment [4].

In China, there exist 37 species of mangroves located along the coastland of Guangxi, Guangdong, Hainan, Taiwan, Fujian and Zhejiang south areas. The mangrove forests can dissipate winds and waves to protect the mud coast, they can also purify seawater. However, with the development of national economy and coastal economic zone, the encroachment of man-made activities such as land reclamation, beach aquaculture, urbanization construction, mangrove resources have been deteriorating increasingly, such as area shrinkage, environmental deterioration and species structure simplitity [5-7]. Timely and accurate grasping the spatial pattern of mangrove communities can reveal the motivations, laws and mechanisms of mangrove wetland changes, provide valuable help and scientific basis for the protection and restoration of mangrove wetland ecosystems, and provide good data support for various forecasting studies such as value estimation and sustainable utilization plan formulation.

The traditional mangrove resources survey is based on the measured data, and has the disadvantages of high work cost, large influence by human factors, strong destructive damage to wetlands, and low survey accuracy [8]. Satellite remote sensing is the main way of mangrove resources survey at present, but there are also some problems [12, 13, 15]. For example, optical satellite remote sensing imaging is affected by the weather and it is difficult to obtain multiple effective images; and the distribution of mangroves in China is most in Zhejiang. It is distributed from Guangxi to Hainan in the south, and the coastline of the distribution area is about 9900 km. The scattered spatial distribution pattern of mangroves leads to the use of satellites, space shuttles and other remote sensing platforms to accurately survey large areas of mangrove resources. More remote sensing data is required, image collection is difficult and costly. In recent years, with the lighter weight and lower cost of imaging spectrometer, it is more convenient and faster to obtain hyperspectral images by using imaging spectrometer. With the development of aerial survey and remote sensing systems with strong maneuverability, low cost and high precision, integrating imaging spectrometers with drones to obtain hyperspectral data has become an emerging research field [9]. Compared with satellite remote sensing images and traditional aerial remote sensing images, low-altitude drones have flexible data acquisition methods, high image accuracy, clear images and rich ground features, which are more suitable for forestry research [10, 11, 15, 16]. Therefore, this paper takes Futian Mangrove Reserve in Shenzhen as the research area, uses the mosaic UAV hyperspectral remote sensing image to classify mangrove species, compares the accuracy of various classification methods, and proposes a classification process suitable for mangrove species classification.

2. Materials and Methods

2.1. Data Collection

The UAV-based hyperspectral images were collected and processed to get the geometrically corrected mosaicked reflectance data that was latter used to extract the mangrove interspecies map. The ZK-VNIR-FPG480 hyperspectral imaging system (ZKYD Data Technology Co., Ltd., Beijing, China) including an eight-rotor UAV platform (DJ 1 M600 Pro), an image stabilization platform, a hyperspectral imager, a high-speed data acquisition controller, and a position orient system (POS) was used to acquire the images. The hyperspectral imager and the Sky2 airborne GNSS receiver were pointed vertically downward on the drone DJI M600 Pro. The imager is at the center of rotation of the gimbal, which is used to keep the sensor horizontal when the UAV is moving. The sensor covers the spectral range of 400-1000 nm with a spectral resolution of 2.8 nm and a spatial resolution of 0.9 m at 1 km flying height. Figure 1 shows the hyperspectral images of two image strips covering the northwest section of Futian mangrove in Shenzhen City.

strip1 strip2

Figure 1. *True color images of two neighboring image strips (bands of 103, 63 and 27).*

2.2. Data Preprocessing

For the original hyperspectral data acquired by the UAV, a seamless mosaicking method is performed to get the seamless hyperspectral image of the study area [14], as shown in Figure 2. In this study area, there are six interspecies including unscented sea mulberry, sonneratia caseolaris, avicennia marina, kandelia candel, aegiceras corniculatum, bruguiera gymnorhiza.

Figure 2. *Ture color image of northwest side of Futian mangrove (combination of band 103, 63, 27).*

2.3. Mangrove Interspecies Information Extraction

2.3.1. Workflow of Mangrove Interspecies Classification

Mangroves need to be extracted before the mangrove interspecies are classified. A decision tree classification method is firstly used to separate mangroves and other ground objects using normalized difference vegetation index

(NDVI). If the NDVI of a pixel is greater than 0.4, then it was classified as mangroves.

In the hyperspectral image, there are 270 bands so the spectral reflectance of different types of mangrove species is quite useful for classification. However, there is a large correlation between some bands, and the noise is large. Therefore, it is necessary to separate the noise in the data. In the experiment, the minimum noise separation transform method was used to reduce the redundancy of the information with each other. First, the minimum noise separation transform (MNF) is performed on the image. The first 10 components contain most of the information of the original band, so they were chosen and then the optimal index factor formula (OIF) is used to analyze the multiple band combinations of the ten bands to obtain the best band combination.. Finally, the best band combination were used in the supervised classification methods to classify the mangrove forest interspecies. There are many methods for supervising classification, such as minimum distance method, maximum likelihood method, support vector machine method etc. By comparing various supervised classification methods, the classification method that is most suitable for classifying mangroves is used in application.

2.3.2. Tree Species Classification

The different classes of mangrove species were separated by the supervised classification. The different vegetation has different canopy characteristics on the original image. For example, the height of the sonneratia caseolaris is higher than that of other tree species, the brightness of the unscented sea mulberry is higher than the sonneratia caseolaris, The texture roughness of sonneratia caseolaris canopy is the largest in the image, followed by avicennia marina and aegiceras corniculatum, with aegiceras corniculatum scattered near the coast. The textures of bruguiera gymnorhiza and kandelia candel are relatively smooth, and they are distributed on the north and south sides of the avicennia marina and the sonneratia caseolaris. Six kinds of mangrove training samples were selected based on the pixels, and evenly distributed in the whole mangrove community.

The maximum likelihood method and the minimum distance method are used to classify the mangrove community. The maximum likelihood method is one of the most commonly used methods of supervised classification. It is based on the Bayesian criterion, assuming that each type of statistics per band is normal distribution, calculating the likelihood of each pixel with each training sample, and then classifying the pixels into the class with the greatest likelihood. The minimum distance method first calculates the mean vector and standard deviation vector of each type of training sample, obtains the center position of each class, and then calculates the distance of each pixel to the center of the class, and classifies the pixels into the class with the smallest distance.

3. Results

3.1. Data Dimension Reduction Results

The optimal exponential factor formula OIF is used to analyze various combinations of the first 10 components. The results of combining the two components with the largest OIF index of 2, 4, and 7 are shown in Figure 3.

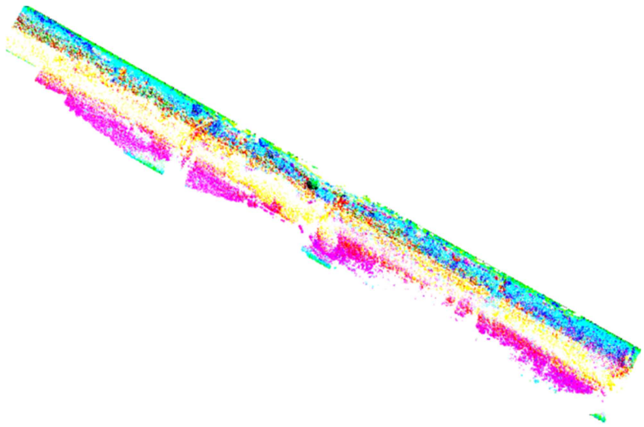
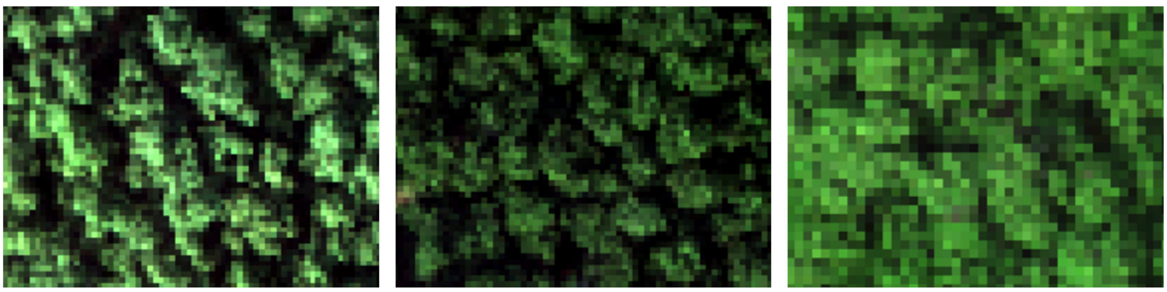


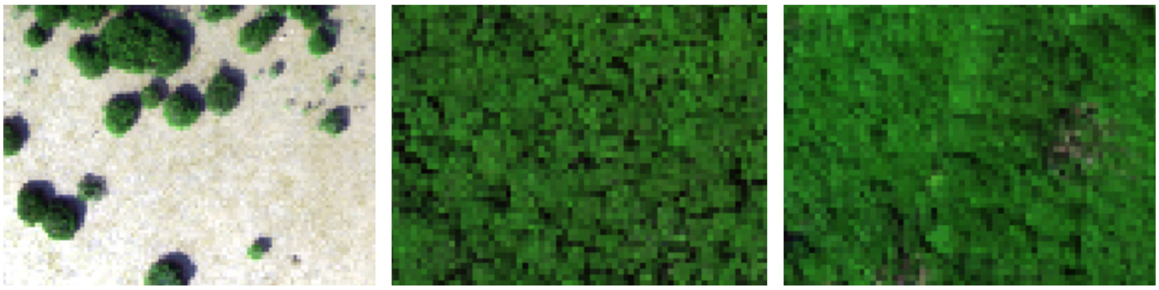
Figure 3. *The combination of the three component bands of 2, 4, and 7 after MNF transformation shows the result.*

3.2. Classification Result

An example of a sample vegetation canopy of each species is shown in Figure 4. The results of the maximum likelihood method and the minimum distance method are shown in Figure 5.

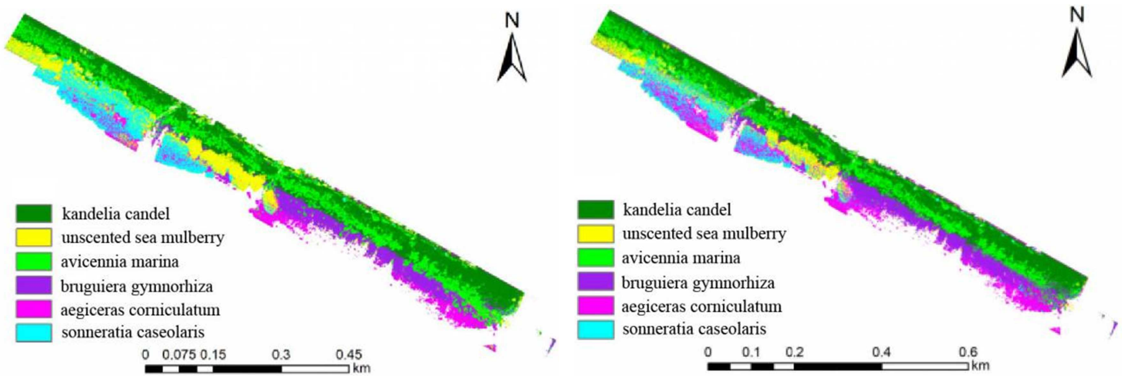


(a) unscented sea mulberry (b) sonneratia caseolaris (c) avicennia marina



(d) kandelia candel (e) aegiceras corniculatum (f) bruguiera gymnorhiza

Figure 4. *Sample vegetation canopy example.*



(a) maximum likelihood classification result (b) minimum distance classification result

Figure 5. *Comparison of classification results.*

The classification results are evaluated for accuracy and the confusion matrix is calculated. The maximum accuracy of the maximum likelihood method is only 81.71%, and the Kappa coefficient is 0.792. The minimum distance method has an overall accuracy of 98.2109% and a Kappa coefficient of 0.9240. According to the classification results map, the maximum likelihood method has a poor classification effect on unscented sea mulberry, kandelia candel and avicennia marina, and the mixed phenomenon is serious in each category; The minimum distance method has high precision, and the boundaries between the trees are obvious, and the classification is reasonable.

4. Conclusions

The results of the classification of mangrove species in Futian, Shenzhen show that the inter-species information extraction of mangroves based on hyperspectral imagery has advantages such as high resolution and obvious vegetation canopy interpretation. Based on the hyperspectral data of the mosaicked UAV, the proposed mangrove extraction and tree species classification model has good applicability to the subdivision of the mangrove interspecies community in Futian, Shenzhen. Using the decision tree classification method based on expert knowledge, using the normalized difference vegetation index NDVI to set the threshold, it is possible to effectively remove the vegetation pixels and extract the mangrove distribution area. The MNF transform is applied to the mangrove hyperspectral data, and the optimal band combination is selected in combination with the OIF index, which can effectively compress the data amount and remove the noise information. Based on the pixel minimum distance method, the classification effect of six mangrove species is better, and the boundary between various tree species can be clearly distinguished, and the overall classification accuracy can reach more than 90%. It can be seen that the inter-species classification of mangroves based on hyperspectral hyperspectral data has good development potential. The mangrove extraction and tree species classification model based on expert knowledge is suitable for inter-species classification and mapping of mangroves. This research provides effective technical support for further mangrove community structure study and its ecological protection policy establishment.

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Conflicts of Interest

The authors declare no conflicts of interest.

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