Exploring The Application of Remote Sensing Technology and Classification Methods in Urban Green Space Identification and Classification

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Abstract. Urban green space is a key component of urban ecosystems and plays an irreplaceable role in improving the ecological environment and enhancing the quality of human habitation. High-precision land use classification and urban green space identification are the basis for urban renewal and green infrastructure optimisation. Based on the relevant literature on urban green space and land use classification in recent years, this paper describes the main means and methods of urban green space identification and classification, and analyses and summarizes the characteristics of the methods and their applications. This paper concludes that supervised classification methods tend to have higher accuracy but higher cost, and unsupervised classification methods are prone to deviation in accuracy but lower cost. Finally, this paper analyses the shortcomings of remote sensing image technology and research methods in urban green space identification and classification, such as high accuracy and low error, and looks forward to future research on the spatial and temporal evolution of urban green space.

Keywords: Remote sensing; urban green space; land use classification; supervised classification; unsupervised classification.

1. Introduction

With the progress and development of urbanisation, modern cities have become highly developed human, economic and ecological systems organically composed of human settlements, in which the two most significant features of modern cities are high population concentration and high economic density. Urban green space is an important part of the urban ecosystem, which has the functions of improving urban climate, mitigating urban heat island effect, cleaning air and soil, maintaining biodiversity, etc., and providing ecological well-being that is beneficial to the survival of human beings. From a social perspective, urban green space parks have cultural and educational functions and health promotion functions [1,2]. Urban green space resources can determine the level of residents' welfare, i.e., the right of residents to access green resource services and the rights and interests brought by green space and play a key role in the protection and sustainable development of the urban environment. Therefore, it is important to ensure rational planning and scientific management of urban green space from both ecological and social perspectives.

High-precision identification of urban green space is the basis for urban renewal and green infrastructure optimisation. Remote sensing technology is used to obtain remote sensing images and streetscape images of the study area and then identify and study urban green spaces with high accuracy. Urban green space identification research mostly uses Landsat, IKONOS, TM, Quickbird, WorldView and Gaofen-2 (GF-2) and other series of satellite data [3] as the data source, and then uses supervised classification methods, unsupervised classification methods, or geographically weighted regression and other methods to identify and extract the green space in the study area, assess the accuracy and spatial analysis. Zhu Xiyue [4] used Landsat 8 OLI_TIRS remote sensing images of Qinhuangdao City in recent years and used both supervised and unsupervised classification methods to compare and analyse the distribution information of green space in Qinhuangdao City and put forward suggestions and measures conducive to the greening of urban areas. Wang Hongyan [5] selected Sentinel 2 high-resolution remote sensing images to assess the urban green space in the study area based on calculating the NDVI and FVC within the third ring of Beijing in the study area. Zhang Guozhen [6] and other scholars extracted the green space in Changsha urban area through high-definition remote sensing images and U-Net model, and the partition statistics showed that Yuelu District had the largest green space area and Furong District had the smallest, which was the same as the results of visual interpretation.

Based on the literature related to urban green space research and land use classification in recent years, this paper analyses and summarizes the supervised classification and unsupervised classification methods that are widely used in urban green space identification and classification and land use classification from the perspectives of data source acquisition, application of research methods, and the status quo and shortcomings, etc. Finally, it looks forward to the development and application of remote sensing imaging technology. Finally, the development and application of remote sensing image technology in the identification and classification of urban green space are prospected.

2. Data Source Access

2.1. Selection of Data Sources

When researching different types of land, different types of remote sensing image data should be selected according to the characteristics of the study area and classification targets. Different sizes of study areas require data of different precision resolutions, with medium- and low-resolution large-scale data generally selected for larger study areas and high-resolution remote sensing image data for smaller study areas. When classifying the research targets in the study area, different types of remote sensing image data are often selected by the size of the classification targets. Medium and low-resolution imagery is generally selected for larger classification targets, while high resolution imagery is required for smaller classification targets [7].

2.2. Characteristics of Different Data Sources

At present, in the classification extraction and monitoring of urban green space, Landsat TM/ETM+/OLI data, SPOT5 data (multispectral band spatial resolution of 10m), Quickbird data (spatial resolution of 0.61m) and other remote sensing images with different resolutions are more often used [8]. Landsat series of image data has a better time series, scholars are now more used in green space changes, and vegetation dynamic monitoring, can better study the dynamic development of the urban study area in the law [9,10]. Among them, Landsat 8 remote sensing image is beneficial to distinguish vegetation and non-vegetation on the image due to the narrowing of the wavelength range of the panchromatic image [11], and SPOT5 data are more often used in the classification and extraction of fine green space, and scholars, such as Chen Fanglin [12], use unsupervised classification methods to detect and track the changes of wetland within the study area by using the SPOT5 image data. Quickbird data also has advantages due to its high accuracy, but it is less applied in dynamic research and detection due to the difficulty and high cost of acquisition and the heavy workload of interpretation.

In summary, when selecting remote sensing image data, it should be combined with the conditions such as the current status of research and specific research objectives. Some commonly used data sources are shown in Table 1 [13].

Table 1. Selected Optical Remote Sensing Imagery Data Sources Commonly Used for Urban Green Space Classification

Name of the satellite	spatial resolution /m
Landsat-7	15. 30. 60
Landsat-8	15. 30. 100
SPOT-5	2.5. 5. 10
Quickbird	0.61. 2.44
Worldview-2	0.5. 1.85
Wordview-3/4	0.31. 1.24
GF-2	0.8. 3.2

3. Classification Methods and Current Status of Development Applications

When classifying different types of land, the more applied classification methods are supervised and unsupervised classification methods.

3.1. Methods of Supervised Classification

The main supervised classification methods are Maximum likelihood Classification, Minimum Distance Classification with Mahalanobis Distance.

3.1.1 Maximum likelihood Classification

Maximum likelihood Classification is a commonly used statistical analysis method for classifying remote sensing images based mainly on the Bayesian criterion. In remote sensing image classification, assuming that the spectral features of different feature types obey different normal distributions respectively, the feature class to which the image element most likely belongs can be determined by calculating the probability that the spectral features of the image element belong to the distribution of each feature type. Therefore, in the study of urban green space identification and classification, the identification and distribution of urban green space can be calculated and classified by this method.

The theoretical foundation of the Maximumlikelihood Classification method (Bayesian decision theory) is solid and the classification accuracy is high. When the training samples are selected reasonably and the data satisfy the assumption of normal distribution, high classification accuracy can be obtained to accurately distinguish different land use types and classify urban green spaces.

Zheng Yanlong [14] and other scholars used Landsat remote sensing images as a data source and maximum likelihood classification method to classify land use level 1 in Xian'an District, Xianning City, Hubei Province, and the results of the study showed that the overall accuracy of feature extraction in the region reached 93.7%. Guo Lina [15] and other scholars used the remote sensing image Landsat8 OLI as the information source to establish a hierarchical classification system for land use in the study area and selected the maximum likelihood classifier with the best classification effect and the highest classification accuracy for the initial classification of land classes through supervised classification experiments. The results show that the maximum likelihood classification reaches more than 94% in the classification accuracy of arable land, gardens, and artificial green space.

Sun Kun [16] et al. By comparing a variety of supervised classification methods, the results show that the accuracy of Maximumlikelihood Classification method is significantly higher than the accuracy of other classification methods, and comparing the detailed maps of the classified images, it is also better than the other classification methods, i.e., the Maximumlikelihood Classification method has a better classification effect in supervised classification.

The Maximumlikelihood Classification method has more stringent requirements on data distribution, which may lead to classification errors if the data distribution does not conform to normal distribution in practice. The calculation involves a large number of matrix operations and probability calculations, and for high-resolution, multi-band remote sensing image data, the amount of computation will increase dramatically, which is time-consuming and requires high hardware. In addition, due to the reliance on a large number of representative training samples, the selection of samples needs to cover the different features of each category, resulting in a high training cost for likelihood classification methods.

3.1.2 Minimum distance classification

Minimum Distance Classification method is based on the distance between samples in the feature space for classification. The core idea is to calculate the distance between the samples to be classified and the samples of known categories, and then classify the samples to be classified. Minimum Distance Classification method usually uses Euclidean distance to measure the distance between samples. Applying the minimum distance classification method can quickly get an approximate classification result, because its calculation is small and the accuracy requirements for the classification of different land types are not very demanding.

Dang Tao[17] and others used World View Ⅱ images of Zhongwei City for land cover classification research and compared the classification results with the traditional Minimum Distance Classification results based on image elements, and the results showed that the indexes of the object-based method were superior. Dong Qiliang [18] used the Xidongting District as the main study area, and used Landsat-TM and SPOT-5 medium and high-resolution remote sensing images as data sources, combined with the adaptive Minimum Distance Classification method to classify wetlands, and evaluated the classification effect. The results show that the overall accuracy of adaptive Minimum Distance Classification is higher than that of Minimum Distance Classification.

In terms of limitations, the Minimum Distance Classification assumes that the data of each category are normally distributed and have similar covariance structures. However, land use and urban green space data in real situations are often complex and irregular, resulting in poor classification results. In this regard, the results can be enhanced and improved by introducing more flexible models and dealing with non-linear problems.

3.1.3 Mahalanobis Distance

The Mahalanobis Distance considers the covariance structure of the data, which can eliminate the correlation between individual features and the influence of scale differences, and can more accurately reflect the real distance between data points. The Mahalanobis Distance method can effectively take into account the statistical characteristics of the spectral data of land use types, eliminate the mutual influence between bands and bands, and have a better effect on the classification of different land use types with more complex spectral characteristics.

Li Huayu [19] extended other methods using the Mahalanobis Distance to conduct classification experiments on wetland vegetation in the study area, and the experimental results showed that the overall classification accuracy of various types of vegetation reached 94.56%. Zhang Ming [20] and other scholars combined Landsat8 OLI remote sensing data to classify six major land cover types in Jiaozuo City using the Mahalanobis Distance method and obtained an overall classification accuracy of 81.22%, which is higher than the result of the minimum distance classification of 75.11%, and lower than the result of the maximum likelihood classification method of 87.15%.

Mahalanobis Distance has higher requirements for data distribution, which should obey the multivariate normal distribution. If the land use or urban green space data has a non-normal distribution such as skewed, multi-peaked, etc., it will make the result calculation inaccurate and lead to errors in classification. When utilizing the Mahalanobis Distance method, it can be combined with other distance measures such as Euclidean distance to combine the advantages in order to improve the classification performance.

3.2. Methods of Unsupervised Classification

Unsupervised classification, also known as cluster analysis, is performed by a computer that processes the data itself to make a classification but is unable to determine the attributes of the classification result [21]. The main unsupervised classification methods are K-Means Clustering Algorithm, and ISODATA Classification.

3.2.1 K-Means Clustering Algorithm

K-Means Clustering Algorithm is widely used in land classification and urban green space identification. K-Means Clustering Algorithm is often combined with remote sensing and GIS technology when analyzing remote sensing data images and combining them with Normalized Difference Vegetation Index (NDVI) to realize the classification and identification of urban green space. Data are acquired through remote sensing images, and data management and analysis are performed using GIS to improve the accuracy and efficiency of classification.

Mou Yan [22] and other scholars took Beijing as the study area and used K-Means Clustering Algorithm to study the distribution characteristics of land use, vegetation cover and the dynamic evolution trend of urban expansion in the study area from 2009-2017, and the results concluded that there are obvious loop differences in the changes of green land, cultivated land and building land in Beijing, but the overall urban green land maintains the growth trend.

Since the traditional K-Means unsupervised classification method is usually based on pixels for classification, it can only utilize a single spectral feature of the image, and the output results are more dependent on the input parameters, and the algorithm is inefficient, which often leads to a poor classification effect of the image. Yang Zenan [23] used a K-means unsupervised classification method based on Multi-scale Ratio cut (R-cut) segmentation to classify UAV images, and the results show that the combined classification method is more reliable and efficient compared to the traditional K-Means unsupervised classification method.

3.2.2 ISODATA Classification

Iterative Self-Organizing Data Analysis Techniques Algorithm (ISODATA), which is the Iterative Self-Organizing Data Analysis Techniques Algorithm. The ISODATA Classification method synthesizes the algorithm of K-Means Classification and the idea of hierarchical clustering algorithm and iteratively classifies the data through the automatic classification. It gradually optimizes the clustering results by continuously adjusting the clustering centers and members according to the pre-set parameters and similarity measures between data points and finally reaches a relatively stable clustering state that meets certain quality standards.

Liao Dong [24] and other scholars used 2018 Landsat-8 remote sensing images as a data source, and processed remote sensing images of Yongqiao District, Suzhou City, using maximum likelihood classification and ISODATA Classification in supervised classification and unsupervised classification, and the results yielded an overall classification accuracy of 38.35%, which is much lower than the result of 84.78% of the maximum likelihood classification of supervised classification methods. Xie Jintao [25] and other scholars used GF-2 remote sensing images as the data source and ISODATA Classification method to detect the ecological land in Qixingguan District, Bijie City. The results yielded an overall classification accuracy of 65.56%, which is lower than the 80.47% of the maximum likelihood method, and concluded that the unsupervised classification method is not suitable for high scoring images. Xing Wei [26] and other scholars used the TM remote sensing image of Landsat-5 as data and ISODATA Classification method to classify and extract the urban green space in the main urban area of Guangzhou City in 2009, and the results showed that the vegetation coverage in the study area was 35.88%, which was mainly concentrated in the urban center close to the Pearl River.

The unsupervised classification method is faster compared to the supervised classification method because it does not need a priori knowledge. However, in terms of the accuracy of classification results, the accuracy of unsupervised classification methods is often lower than that of supervised classification methods.

In addition, due to the lack of a priori knowledge utilization, ISODATA Classification methods may lead to some classification results that do not match the actual situation, such as misclassifying similar spectral but different land or green space types in the city. In addition, in terms of algorithm stability, if the setting and selection of parameters are not reasonable, it will lead to unstable clustering results and different classification results.

4. Recommendations and Outlook

Since urban green spaces are usually distributed in fragments and often have complicated boundaries, more attention should be paid to the classification accuracy in the improvement of the method to ensure the accuracy of the classification results. After obtaining remote sensing image data, remote sensing data with different accuracy should be reasonably utilized to minimize the error with the actual situation. The classification results obtained by supervised classification are more accurate, but it requires a large amount of a priori knowledge and training samples, and the general requirements for data are harsh, so the selection and use of samples should be optimized, and the use of Geographic Information System (GIS) and other technologies should be combined with the reality of topography, geomorphology, and the current state of land use and other information, so as to ensure that the samples are more comprehensive and the classification is more accurate. In terms of classification methods, although unsupervised classification is more efficient, it often lacks precision and requires certain manual operations. In the improvement of classification accuracy, existing classification methods such as K-Means can be combined with other mathematical methods, which can not only improve the stability and accuracy of clustering but also reduce the cost of manual operation to a certain extent.

As far as the current research results on geographic planning are concerned, the land use classification method has been developed comprehensively and maturely with the help and support of remote sensing image data; whereas the more detailed identification and classification of urban green space relies on high-precision data and further manual classification. In addition, there is a large amount of literature on landscape pattern change and ecological environmental effects at home and abroad, but there is still a limited amount of literature on urban green space, urban green space planning and spatial and temporal changes. Urban green space resources can determine the level of residents' welfare, i.e., the right of residents to access green resource services, enjoy the rights and interests brought by green space, and play a key role in the protection and sustainable development of urban environment. Therefore, in the future, academics can strengthen the research on the relationship between the spatial and temporal evolution of urban green space and the ecological and environmental effects, which can provide a more comprehensive understanding and deepen the knowledge of urban environmental problems and the improvement of human habitat quality.

5. Conclusion

This paper explores the application of remote sensing image data and classification methods in urban green space identification and classification and makes a summary. At present, there are abundant remote sensing data sources that can be used for land use classification, such as urban green space identification and classification, among which, Landsat TM/ETM+/OLI, SPOT5 and other series of data are more frequently used. In terms of classification methods, supervised classification methods require a lot of training of the classification model before classification, so the time required is often long and costly. The excessive number of training times in training may lead to wrong classification results and degradation of classification accuracy. In addition, classification methods such as the Marginal Distance are more demanding on the data, and if the difference with the real situation is large, the classification accuracy will be affected. Unsupervised classification does not require pre-training and can handle a large amount of data. However, its classification results often have a large gap with the actual categories and require further manual operations for matching.

As far as the results of the current research and statistics are concerned, the classification accuracy of supervised classification methods is generally better than that of unsupervised classification methods in urban green space identification and classification. If the pursuit of high-precision and low-error classification results, supervised classification is a better choice; if the approximate classification results are needed, such as when the study area is large, the unsupervised classification method is more efficient in terms of its advantages.

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