ISSN: 2664-9640

Research on Light Pollution Issues based on Airborne Radar Point Cloud Data

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Abstract

It is of extensive significance to evaluate the risk degree of light pollution and prevent the harm of light pollution. In this paper, 149 airborne radar point cloud data were processed by Southlidar software, and the point cloud data were processed by progressive morphological filtering function, and seven geographic information indexes were formed, including green coverage, ground area percentage, construction area percentage, water body area percentage, and road area percentage, and the relationship between them and the risk factors affecting light pollution was found. Then, according to the seven indicators, the classification basis of light pollution risk level based on entropy weight-fuzzy comprehensive evaluation model was established, and the light pollution risk level was divided into I. to IV levels according to the evaluation results. Secondly, the linear discriminant analysis model is used to establish the canonical discriminant function to judge the risk degree of the sample data of City, Suburban, Countryside and protected areas.

Keywords

Color Rendering Index; Discriminant Analysis; Entropy Weight Method; Progressive Morphological Filtering.

1. Fuzzy Evaluation Determines the Light Pollution Level Model

1.1. Data Selection and Collection

1.1.1. Selection of Data

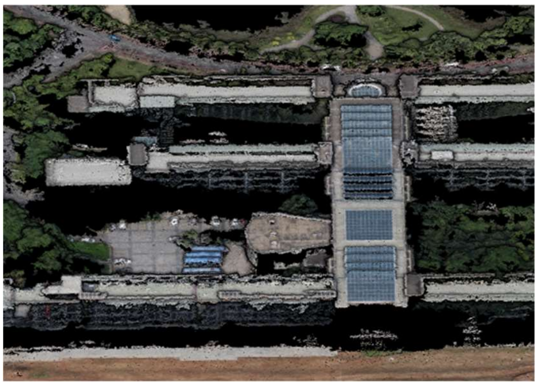
To be able to calculate the relevant index values, this paper needs to obtain relevant data such as ground area, construction area, green vegetation area, road area, etc. Traditional remote sensing image data is two-dimensional data, which is supported by auxiliary information, but it is difficult to reflect the complete information of the city fully and concretely. UAV airborne radar point cloud data can reflect the situation in each part of the city in detail and concretely. Therefore, this paper selects UAV airborne radar point cloud data as the data basis for the calculation of relevant indicators.

1.1.2. Acquisition of Data

In this paper, 149-point cloud data covering the city, suburbs, rural areas and protected areas of Guangzhou were collected based on large-scale point cloud data collection based on UAV aerial survey.

The same city sampling, from the most developed areas of the city gradually sampled outward, selected from the most serious developed areas of light pollution, radiated outward to the nature Protected area with light pollution, the sample points include almost all the light pollution, through the review of relevant research reports that the distribution of light pollution in most parts of the world is in line with the trend of light pollution gradually weakening from the city center to the natural area, so the sample city is selected from Guangzhou and the surrounding areas.

Due to the limited scanning measurement range, for large-size objects or large-scale scenes, a complete measurement cannot be carried out at one time, and multiple scanning measurements must be carried out, resulting in the data cannot meet the requirements of model realism and local real-time research, so it is necessary to preprocess the point cloud data in the 3D size such as denoising, simplification, registration and hole filling.



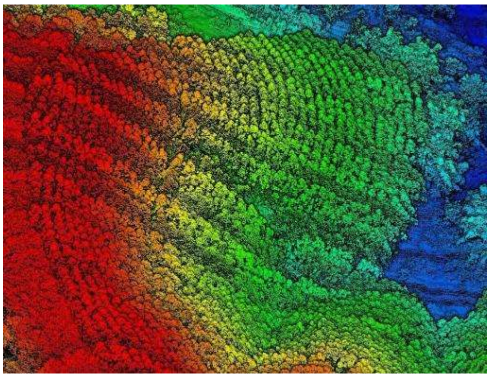


Fig 1 Point cloud data images of cities, suburbs, rural areas, and protected areas

1.1.3. Deep Mining based on Progressive Morphological Data

With Southlidar software, basic processing and precise measurements can be performed on point cloud data. The software has the function of progressive morphological filtering and the measurement of point clouds, which can divide the point clouds into different layers according to types, including ground, high vegetation, low vegetation, water bodies, railroad tracks, power lines, and road surfaces. The measurement function of the point cloud can accurately measure the various spatial information of these layers. Using this information, various data indicators can be obtained to evaluate the factors of light pollution.

In this paper, the data is first subjected to progressive morphological filtering, and the point clouds that need to be analyzed are imported into the software, and the several types of point clouds are classified in a refined manner by using progressive static chemical filtering. Each 3D coordinate point in the figure is assigned a datum layer, and the most important thing in the progressive morphological filtering is to distinguish the ground surface and others, and the elevation difference threshold can be determined according to the topographic slope of the study area.

In urban areas, the main non-surface data includes cars, greenery, and buildings. The size of individual cars and trees is much smaller than the size of a building, and most of the non-surface data can be removed after the first few iterations of the elevation difference, but the building will be removed last. The maximum height difference threshold can be set to the height of a building, such as the minimum building height, to ensure that the building complex is identified. The best results are usually achieved by repeatedly comparing filtered and unfiltered data. On the other hand, for forest area reserves, it is not necessary to set a fixed maximum height difference threshold to remove trees, which is usually set to the maximum height difference within the study area.

The scattered noisy point cloud data can be filtered by progressive morphological filtering analysis, and the elevation distribution can be generated by the manual surface DM model, which can clearly classify the surface point cloud and non-surface point cloud data and visualize the entire process.

The point cloud data of the above four types of areas are classified, and the data of buildings, green plants, water bodies, roads and streetlights in each region are calculated according to the type of point cloud data.

After calculating the percentage data of the ground, green plants, buildings, water bodies and pavements of the point clouds in the above regions, the global nighttime light vector data United States of the National Oceanic and Atmospheric Administration were compared with the global nighttime light vector data of the National Oceanic and Atmospheric Administration, and the nighttime light density and total nighttime intensity of the cities summarized in the point clouds were analyzed in ArcGIS. The result is data such as: Table 1Shown:

Table 1. Data table of light pollution-related indicators (only some data are displayed)

Category	Ground area (%)	Green coverage (%)	Building area (%)	Building height(m)	Water body area (%)	Number of water bodies	Road area (%)
Suburban	1.25	74.30	4.50	2.00	0.00	0.00	24.70
Countryside	8.00	13.00	50.51	5.00	15.00	1.00	25.00
Protected area	1.00	55.00	1.50	3.00	24.00	3.00	0.00
City	11.00	7.00	76.00	40.00	0.00	0.00	7.00

2. Model Establishment and Result Analysis

2.1. The Topsis Entropy Weight Method is Used to Figure Out the Factor Weight

The Topsis entropy weight method is a commonly used comprehensive evaluation method, which can make full use of the information of the original data to objectively assign weights, and the results can objectively reflect the gap between the evaluation schemes, so the entropy weight method is selected to determine the weights.

In this paper, eight second-level importance evaluation indexes are used to score the influencing factors of light pollution in MATLAB, according to the Tops is entropy weight method. The weights of the eight evaluation indicators are 0.8109, 0.9394, 0.8583, 0.8533, 0.6356, 0.6841, 0.86688 and 0.8109, respectively, and the weights of the first-level indicators are 0.5 and 0.5 for ecological indicators and economic indicators.

2.2. The Fuzzy Logic Membership Function Is Used for Comprehensive Evaluation

Since the impact index of light pollution is determined by many factors, including both ecological factors and economic factors, the use of fuzzy comprehensive evaluation model can avoid the subjectivity of analytic hierarchy process and make the evaluation criteria of light pollution more scientific and reasonable.

(1) Calculation of comprehensive evaluation matrix

The membership function was used to process each index to obtain a comprehensive evaluation matrix. There is an obvious positive correlation between ground, building area, building height, road area percentage, and light pollution risk level, so the large membership function is used to deal with these indicators. There is an obvious negative correlation between green plants, percentage of water area, and number of water bodies and light pollution intensity, and should be treated by small membership functions. Finally, a comprehensive evaluation matrix is obtained.

(2) Calculate the comprehensive score of fuzzy comprehensive evaluation

ISSN: 2664-9640

The higher the score, the greater the risk of light pollution in the city, and the lower the score, the smaller the risk of light pollution in the city.

Table 2. Fuzzy Comprehensive Judgment Comprehensive Score (Partial)

Rank	1	2	3	4	5	6	7	8	9	10
Score	3.811	3.506	3.127	3.110	3.106	3.104	3.084	3.084	3.060	2.973

In this paper, the upper quartile, median, and lower quartiles are used to divide the pollution risk index into four levels. The classification results are as follows:

Table 3. Grade distribution of light pollution risk indicators

Level	Class I	Class II	Class III	Class IV
Indicator range	<1.32	[1.32,1.7]	[1.7,2.0478]	>2.0478

2.3. The Discriminant Analysis Model Was Used to Formulate Light Pollution Measurement Standards

Under the premise of fuzzy comprehensive evaluation, the discriminant analysis was used to develop a measurement standard for the degree of light pollution in the area except the sampling point.

(1) Data labeling

In order to facilitate the discriminant analysis, the label range of the total evaluation score is divided according to the index range of light pollution risk level, and it is stipulated that the label of grade I is 1, that of grade II is 2, that of grade III is 3, and that of grade IV is 4.

(2) Determine the discriminant function of non-standardized canonicals

Discriminant analysis is used in MATLAB to derive established discriminant function coefficients, such as Table 4 show.

Table 4. Unstandardized authorized discriminant function coefficients

Index	Function One	Function Two	Function Three
Ground (x1)	-0.020	0.015	-0.018
Greenery (x2)	0.067	0.036	0.026
Building Area (x3)	-0.020	0.054	0.017
Building Height (x4)	-0.007	0.022	0.025
Water body area (x5)	0.071	0.067	-0.044
Number of Water Bodies (x6)	1.001	0.284	-0.428
Road Area Percentage (x7)	-0.039	0.040	0.008
(constant) b	-2.360	-3.922	-1.295

Table 5. eigenvalue

Function	Eigenvalue	Variance percentage	Cumulative percentage
1	11.048 amps	95.2	95.2
2	0.420 amps	3.6	98.9
3	0.132 amps	1.1	100.0

The sum of the eigenvalues of the first and second discriminant functions is 11.468, and the percentage of variance is 98.9, indicating that functions 1 and 2 can explain 98.9% of the variance, but function 3 can only explain 1.1% of the variance, and the information that can be explained is very little and not representative, so functions 1 and 2 are selected as the measure of light pollution risk level. The non-standardized established discriminant function is:

$$Y_1 = -0.02x_1 + 0.067x_2 - 0.02x_3 - 0.007x_4 + 0.071x_5 + 1.001x_6 - 0.039x_7 - 2.360 \tag{1}$$

$$Y_2 = 0.015x_1 + 0.036x_2 + 0.054x_3 + 0.022x_4 + 0.067x_5 + 0.284x_6 + 0.04x_7 - 3.922 \tag{2}$$

(Y1, Y2) obtained by the above function is the light pollution risk assessment value of the sample.

The average values of each group of indicators were substituted into the above discriminant functions, and the central coordinates of each cluster were (4.647, 0.517), (1.542, -0.557), (-2.152, -0.700) and (-3.849, 0.749), respectively. The Euclidean distance can be used to find the distance between the light pollution risk assessment value of each sample and each cluster center, and the closest cluster center of each sample belongs to the cluster.

3. Verification of Model Accuracy

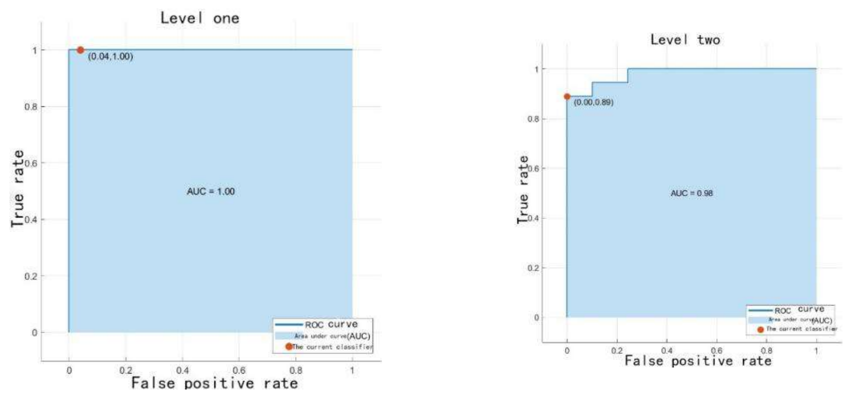


Fig 2. ROC curve results (in the form of 1, level 2 as an example)

ROC curves are empirically fitted using observational data and do not require any distribution assumptions about the test results.

The area under the ROC curve is 1, p=0.04 at the first level and 0.04 at the second level89, p=0.00; The lower area of the ROC curve at the level 3 level was 0.94, P=0.06, and the lower area of the ROC curve at the level 4 was 0.82, P=0.02. The larger the area under the curve, the better the effect, indicating that the prediction of light pollution risk level established in this paper is meaningful.

4. Advantages and Disadvantages of the Model

4.1. Advantages of the Model

(1) The progressive morphological filtering has a clear subdivision standard for processing point clouds, and compared with the current widely used remote sensing data, the surface and non-surface data of a sampling area can be accurate to the centimeter level when the accuracy is not fine enough, which is conducive to the accuracy and precision of the data collection in this paper, and the morphology has a certain effect on the processing, denoising and enhancement of the image and has been well verified.

(2) The entropy weight method is used to confirm the evaluation index of light pollution sample data, and the Topsis model is used to calculate the weights, and compared with the analytic

hierarchy process, the entropy weights can more objectively analyze the weight relationship of each index data category, and the influence can be well reflected in the model description of the index data.

(3) The linear discriminant analysis is used to explain and classify the gradingFor the weighted average evaluation value calculated in the fuzzy evaluation, in the discriminant analysis, it is different from the analytic hierarchy process, because the data statistics in this paper are large, the analytic hierarchy process will have an impact on the sameness of the hierarchy ranking, so the consistency analysis will not pass, the discriminant analysis can be very good, and the sample data can be projected to the correlation after the classification of the trained data, that is, the linear correlation.

(4) The linear discriminant analysis is used to explain and classify the gradingFor the weighted average evaluation value calculated in the fuzzy evaluation, in the discriminant analysis, it is different from the analytic hierarchy process, because the data statistics in this paper are large, the analytic hierarchy process will have an impact on the sameness of the hierarchy ranking, so the consistency analysis will not pass, the discriminant analysis can be very good, and the sample data can be implicated to the correlation after the classification of the trained data, that is, the linear correlation.

4.2. Disadvantages of the Model

In progressive morphological filtering, there will be a certain deviation in the processing of point cloud data, and some 3D data points will be interpolated and supplemented when the values are missing, so part of the authenticity is lost. The entropy weight method ignores the importance of the index in the process of calculating the weight, which leads to a difference from the original index.

5. Conclusion and Prospects

Based on the research on light pollution evaluation and classification of point cloud data, the following conclusions can be obtained:

(1) Compared with traditional remote sensing data, point cloud data has the characteristics of high precision, easy identification and easy classification in the evaluation of light pollution. Spatial information can be processed more accurately using software related to point cloud processing. Using accurate spatial information, detailed indicators can be obtained to evaluate the degree of light pollution. Therefore, the use of point cloud data as the basis for the evaluation index of light pollution can make the evaluation of light pollution more accurate and effective.

(2) Through the evaluation results, it can be found that the higher the degree of urbanization, the more serious the degree of light pollution, and the lower the degree of light pollution in places with abundant green plants, indicating that green plants have an obvious negative correlation with light pollution, and the degree of light pollution can be reduced by planting green plants appropriately in the bustling metropolis. Nature reserves and rural areas are not highly urbanized, so the degree of light pollution is not high, and nature reserves can be considered to be basically free of light pollution.

(3) Discriminant analysis can be used to predict the degree of light pollution in other regions on the basis of this data, and the prediction results have positive significance for the early warning and prevention of light pollution in cities. At the same time, the discriminant analysis model is simple and easy to use, which can not only process the indicators extracted from point cloud data, but also the data of other remote sensing information. Based on this model, a risk discrimination model for different remote sensing data can be established.

ISSN: 2664-9640

(4) Because it is difficult to obtain the point cloud data of airborne radar at present, it is difficult to evaluate the light pollution by using the data, and because the point cloud data is relatively small, the model that should be trained by the data has certain defects, but with the continuous popularization of point cloud data, the training database can be continuously improved, and the generalization ability and accuracy of the trained risk assessment model will be improved.

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