Journal of Artificial Intelligence Practice (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jaip.2024.070201
ISSN 2371-8412 Vol. 7 Num. 2

Integration of GIS and Artificial Intelligence Algorithms in Rural Landscape Protection and Planning

Wei Songjiayi

School of Rural Revitalization, Jiangsu Open University, Nanjing, 210036, China
815853410@qq.com

Keywords: GIS Technology; CNN Algorithm; Rural Landscape Protection and Planning; Dynamic Monitoring

Abstract: This article explored the application of the integration technology of GIS and artificial intelligence (AI) algorithms in rural landscape protection and planning. By analyzing the problems existing in traditional methods, the article elaborated on the necessity and feasibility of combining GIS (Geographic Information System) and CNN (Convolutional Neural Network) algorithms to improve data processing capabilities and strengthen comprehensive analysis capabilities. Through case studies and empirical analysis, the article demonstrated the practical application effect and potential of this fusion technology, providing a new perspective and method for the scientific planning and effective protection of rural landscapes. In the experimental stage, four experiments were designed to evaluate the performance of GIS and CNN fusion. In the first landscape basic feature extraction experiment, the CNN algorithm achieved an accuracy of 95% in extracting features from rural landscape images; the Multi-layer Perceptron algorithm achieved 85%; the RF (Random Forest) achieved an accuracy of 80%; the Support Vector Machine (SVM) achieved 82%. Although the CNN algorithm achieved a processing time of 2 seconds, it had a high accuracy advantage. In the second landscape diversity assessment experiment, the method of integrating GIS and CNN improved species richness by 15%, landscape heterogeneity by 20%, and landscape connectivity by 25%. In landscape change detection experiments, the fusion technology of GIS and CNN has significant advantages in capturing subtle landscape changes. In the experimental data conclusion, the fusion technology of GIS and CNN had a high performance advantage in improving rural planning and management processes.

1. Introduction

Rural landscape planning has new solutions, such as the combination of GIS and convolutional neural networks. In the current society, people are paying increasing attention to the protection and planning of rural landscapes, which makes the research of algorithm integration particularly important. Traditional planning methods have faced many challenges, such as insufficient data processing capabilities and difficulty in dynamic monitoring. The combination of GIS and CNN can effectively process and analyze large-scale and complex geospatial data, which helps to improve the accuracy and efficiency of planning. Therefore, the integration of research algorithms is expected to better protect rural landscapes and meet the needs and expectations of the public.

This study provides a new solution for rural landscape planning, which is the fusion algorithm studied in this paper. The experimental results from the experimental stage show that compared with traditional methods, this fusion technology has shown significant advantages in landscape feature extraction, change detection, and predicting public satisfaction. This study not only demonstrates the potential of GIS and CNN integration technology in rural landscape planning, but also provides new technological paths and ideas for future rural landscape protection, planning, and public participation. Therefore, this study has important theoretical significance and practical application value.

This article first introduces the background and significance of the research. Subsequently, the research methods and experimental designs for the integration of GIS and CNN technologies are described in detail, including data collection and preprocessing, and landscape feature analysis. On this basis, the article analyzes the experimental results, highlighting the application advantages of GIS and CNN fusion technology in rural landscape planning, and explores its impact on predicting public satisfaction. Finally, the article points out the limitations of the research and proposes directions for future research.

2. Related Works

In recent years, numerous researchers have explored the application of GIS in spatial data processing and analysis, as well as the potential of artificial intelligence in data mining and pattern recognition. For example, in the context of rapid development in various industries in the current society, rural revitalization has become one of the focuses of people's attention. To achieve the development of safe rural areas, a series of security issues need to be addressed. Xu Xue believed that starting with a video surveillance system operation and maintenance management platform can to some extent solve these problems [1]. Ha Yuhui conducted an analysis on the application of land development and consolidation based on GIS geographic information technology. GIS geographic information technology, as an important technology, can provide certain convenience for land development and consolidation [2]. Peng Jinchen and others explored the relationship between landscape pattern evolution and human interference, providing a theoretical basis for regional landscape pattern optimization and ecological sustainable development [3]. Yan Qinghua and others analyzed the advantages and disadvantages of Anle Village through field investigations and interviews with relevant personnel, using image data and GIS software technology, as well as made relevant plans for the layout of village industries, in order to consolidate and expand the achievements of poverty alleviation and effectively connect with rural revitalization [4]. These studies indicate that technological advancements provide new tools and methods for rural landscape planning, but also reveal the limitations of a single technology in dealing with more complex and multidimensional problems.

Although GIS and artificial intelligence have made progress in rural landscape research, their potential for integrated applications has not been fully explored. Some preliminary studies attempt to combine the two. On the basis of analyzing the characteristics of soil and water conservation work data, Shi Wei elaborated on the key technologies and functional modules for establishing a regional soil and water conservation visualization system, including model and GIS integration, as well as multi-source data fusion [5]. Wang Honglei and others designed an integrated regulatory process to address the difficulties and actual situation of the special work on rectifying the illegal occupation of farmland and building houses in rural areas of Guizhou Province, including automatic detection of suspected illegal behavior, on-site verification, and tracking of rectification. By studying technologies such as satellite remote sensing, artificial intelligence, and GIS, a dynamic supervision system for the construction of houses on illegally occupied farmland in rural areas has been implemented based on a new regulatory process [6]. However, these attempts often have shortcomings in terms of integration methods and practical application scenarios, and have not fully utilized the complementary advantages of the two.

3. Methods

3.1 Data Collection and Preprocessing

In this study, data collection is divided into two main stages, with the aim of collecting comprehensive information to support the needs of rural landscape planning and public satisfaction prediction. The first step is to collect spatial data from publicly available online databases using Geographic Information Systems (GIS). These data include but are not limited to land use types, transportation network layout, infrastructure distribution, and the situation of natural resources. These data are sourced from the archives of the National Geospatial Information Agency, local governments, and reports from historical projects, ensuring that the data collected in this study is both extensive and diverse [7-8].

Secondly, during the research phase, non spatial data including demographic characteristics, economic development indicators, environmental quality reports, and historical public satisfaction survey results are collected through socio-economic surveys and open data platforms. These data provide a necessary foundation for understanding the socio-economic background of rural areas. For missing socio-economic data, the mean filling method can be used, which replaces the missing value with the average value of the corresponding indicator. If S_{ij} represents the j-th standard value of the i-th sample, and if S_{ij} is missing, Formula (1) can be used to represent:

$$S_{ij} = \frac{1}{N}\sum_{k=1}^{N} S_{kj} \tag{1}$$

In Formula (1), N represents the number of samples without missing the indicator. For normalization, in this study, geospatial data and socio-economic data are normalized. The normalization of geospatial data can be achieved using Formula (2):

$$G' = \frac{G - \mu_G}{\sigma_G} \tag{2}$$

In Formula (2), the mean and standard deviation of all pixel values in the dataset are μ_G and σ_G, respectively. The normalization formula for socio-economic data can also be represented by Formula (3):

$$S' = \frac{S - \min(S)}{\max(S) - \min(S)} \tag{3}$$

In Formula (3), $\min(S)$ and $\max(S)$ are the minimum and maximum values of all elements in vector S. For feature extraction, in this study, convolutional neural networks are used to extract advanced features from geospatial data. It is assumed that the output of the convolutional layer is as shown in Formula (4):

$$F = f_{CNN}(G') \tag{4}$$

In Formula (4), f_{CNN} represents the mapping function of the CNN model; the extracted feature matrix is F; G' is geospatial data. Through the above preprocessing steps, high-quality and standardized data can be obtained, laying a solid foundation for subsequent GIS and CNN fusion analysis [9].

3.2 Landscape Features

"Landscape features" refer to specific combinations of several elements in a certain area, as well as their repeated distribution patterns in that area. This is significantly different from "landscape regionalism" and "landscape uniqueness". "Landscape regionalism" and "landscape uniqueness" mainly emphasize that patterns in specific regions are unique. "Landscape features" are a common landscape attribute that describes the similar evolution process of the same type of landscape features in spatial distribution in different regions. In other words, "landscape features" focus more on commonality rather than individuality [10-11].

Before conducting landscape feature analysis, it is necessary to preprocess the spatial data and satellite images in GIS. This includes cropping, scaling, and normalizing the image to meet the input requirements of the CNN model. Next, the trained CNN model is used to extract features from the preprocessed image data. This process involves the collaborative work of convolutional layers, pooling layers, and fully connected layers, which can automatically recognize and learn key features in the image, thereby providing support for subsequent landscape evaluation and planning decisions.

The above operations can extract a series of important features from rural landscape images, including the distribution of land cover types and the spatial distribution of key natural resources. These features are extracted through the fusion analysis of GIS and CNN, and are further used to evaluate the ecological value of landscapes, monitor environmental changes, and predict future trends in landscape changes [12].

3.3 Planning Scheme Generation

At the level of ecological framework, the main goal of rural landscape planning is to form an ecological landscape pattern, and protect the natural environment of the countryside and the historical and cultural heritage of the site. At the same time, it also faces the problem and challenge of balancing the improvement of the quality of life of rural residents, natural protection, cultural and historical inheritance, and new industrial construction in the context of large-scale development [13-14].

Horizontally, the ecological framework mainly includes four aspects: protection of ecologically sensitive areas, construction of landscape structures, design of elastic ecological landscape environments, and integration between artificial nature and natural environment. These four major contents are also distributed at different scales in the vertical three-level planning.

After in-depth analysis of landscape features, the next step is to use these analysis results to develop specific rural landscape planning plans. This study adopts a novel strategy that combines the spatial analysis capabilities of geographic information systems with the image processing and pattern recognition capabilities of convolutional neural networks, ensuring that the planning scheme fully considers the multidimensional features and complexity of rural landscapes.

4. Results and Discussion

4.1 Evaluation of Basic Feature Extraction Capability

In the basic feature extraction capability evaluation experiment, the performance of CNN algorithm and MLP, RF, SVM algorithms in rural landscape image feature extraction tasks was evaluated and compared. The experiment focused on analyzing the performance of each algorithm in two key indicators: accuracy and processing time. The accuracy and processing time of each algorithm were recorded and plotted in charts to visually demonstrate the performance of each algorithm.

The CNN algorithm had the highest accuracy in extracting features from rural landscape images, reaching 95%. The accuracy of MLP algorithm was 85%; the accuracy of the RF algorithm was 80%; the accuracy of SVM algorithm was 82%. In terms of processing efficiency indicators, CNN required 2 seconds, while the RF algorithm only required 1 second. From the above data results, it can be seen that although CNN is not the best in terms of time efficiency, its accuracy in feature extraction is significantly better than other comparative algorithms, as shown in Figure 1:

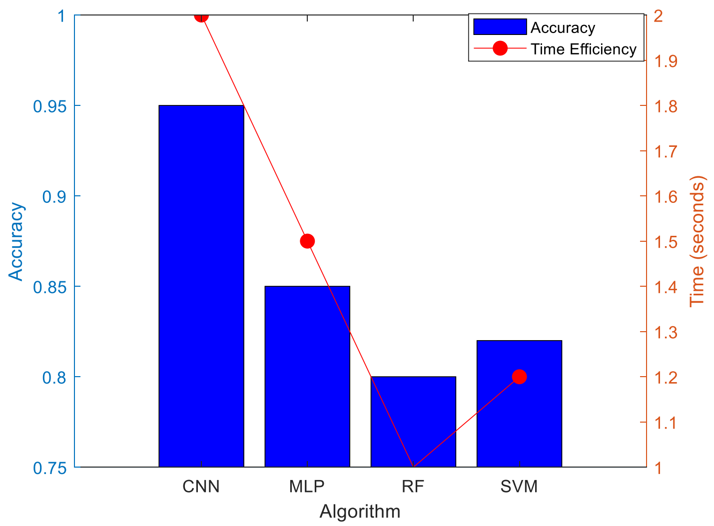

Figure 1: Evaluation of basic feature extraction capability

4.2 Landscape Diversity Assessment

In landscape diversity experiments, the differences in the impact of traditional remote sensing image interpretation techniques and modern technologies that integrate Geographic Information Systems (GIS) and Convolutional Neural Networks (CNN) on landscape diversity in rural landscape planning were compared. The experiment focused on three key indicators: species richness, landscape heterogeneity, and landscape connectivity. The data from these three indicators can evaluate the potential of GIS and CNN fusion technology in improving the quality and diversity of rural landscape planning.

In Figure 2, the research algorithm GIS and CNN fusion technology in this article improved species richness by 15%, landscape heterogeneity by 20%, and landscape connectivity by 25%, all of which were better than traditional methods. From the above data conclusion, it can be seen that the fusion technology of GIS and CNN has significantly optimized the accuracy and efficiency of rural landscape planning, and has shown strong advantages in maintaining and enhancing landscape diversity, as shown in Figure 2:

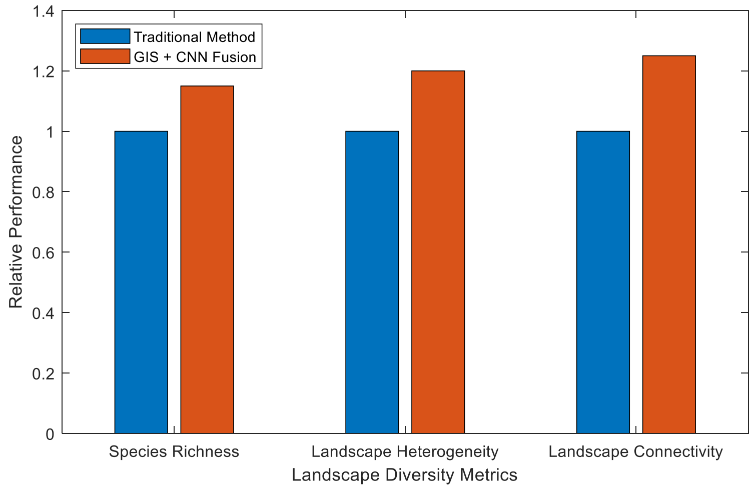

Figure 2: Landscape diversity assessment

4.3 Landscape Change Detection Experiment

In the landscape change detection experiment, the fusion technology of GIS and CNN and traditional remote sensing image interpretation technology were evaluated for their ability to detect rural landscape changes during the experiment, and the differences in landscape change detection accuracy between these two technologies were evaluated. The specific data changes are shown in Figure 3:

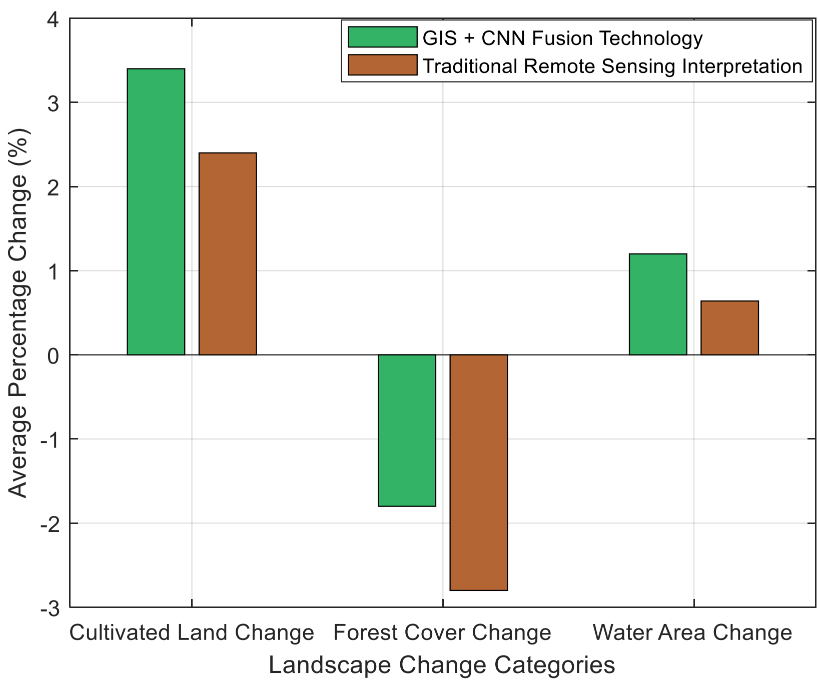

Figure 3: Landscape change detection and evaluation

From Figure 3, it can be seen that the average increase rate of cultivated land area change using GIS and CNN fusion technology was 3.4%, compared to 2.4% using traditional methods. This means that the technology that combines GIS and CNN can more effectively detect small changes. Whether it is the reduction of forests or the increase of water bodies, the research algorithm in this article can be more sensitive to it. It's because it can see very subtle differences, even if the changes are not significant, it can still grasp them.

4.4 Public Satisfaction Assessment

In the last experiment of this article, the impact of different rural planning schemes on public satisfaction was evaluated. Key socio-economic indicators such as population density, economic growth rate, infrastructure level, and environmental quality were recorded in the experiment. The specific data details are shown in Table 1:

Table 1: Public satisfaction assessment

Planning_ Scheme	Population_ Density	Economic_Growth_ Rate	Infrastructure_ Level	Environment_ Quality	Predicted_Public_ Satisfaction
A	50	4	3	4	3.8
B	100	2.5	4	3	3.1
C	150	1	2	2	2.2

In Table 1, it means that Plan A had a high satisfaction score of 3.8, as there were fewer people and a better environment. A good living environment is crucial for satisfying everyone in rural planning. However, Plan C only scored 2.2 points because the environment is average with a large number of people, resulting in low satisfaction. Therefore, when planning rural areas, it is important to balance development and environmental protection, which can not only sustain development but also satisfy residents.

5. Conclusions

This article evaluated the performance of combining GIS and CNN technologies in rural landscape planning and predicting public satisfaction. The results of the experimental stage indicated that the combination of research techniques in this article was superior to traditional methods in extracting landscape features, evaluating landscape diversity, and detecting changes. This discovery provides new ideas and technical support for rural landscape protection and planning, which can help develop more scientific and reasonable planning schemes, increase public participation, and improve satisfaction. Although some achievements have been made in this study, there are also some limitations, such as the universality of the model and its adaptability in complex environments, which still need further verification. Future research can attempt to introduce more types of data and more advanced algorithmic models into the combined framework of GIS and CNN, in order to improve the model's generalization ability and accuracy.

References

[1] Xu Xue. Research on a GIS based digital video monitoring and operation management platform [J]. Architectural Development, 2021, 5 (4): 27-28.

[2] Yuhui Ha, Zhiwei Wen. Land development and consolidation application based on GIS geographic information technology [J]. Geological and Mineral Surveying (2630-4732), 2020, 003 (001): P.110-111.

[3] Peng Jinchen, Ye Changsheng, Gan Feng. A study on the relationship between landscape pattern changes and human interference in the urban agglomeration around Poyang Lake [J]. Journal of Environmental Engineering Technology, 2024, 14 (2): 1-11.

[4] Yan Qinghua, Liu Ping, Wen Shijun, et al. Research on Village level Industrial Layout and Planning under the Background of Rural Revitalization - Taking Anle Village in Daguan County as an Example [J]. Green Technology, 2023, 25 (5): 201-206.

[5] Shi Wei, Wu Zhitao. Design and application of a GIS based visualization system for regional soil and water

conservation achievements [J]. Experimental Technology and Management, 2022, 39 (4): 7-9.
[6] Wang Honglei, Xie Yijuan, Liu Shiqi, et al. Research and Implementation of Dynamic Monitoring and Supervision Technology Platform for Building Houses on Randomly Occupied Farmland in Guizhou [J]. Geographic Information World, 2022, 29 (6): 16-20.
[7] Xie H, Zhu Z, He Y, et al. Integrated framework of rural landscape research: Based on the global perspective[J]. Landscape Ecology, 2022, 37(4): 1161-1184.
[8] Gabriele M, Brumana R, Previtali M, et al. A combined GIS and remote sensing approach for monitoring climate change-related land degradation to support landscape preservation and planning tools: The Basilicata case study[J]. Applied Geomatics, 2023, 15(3): 497-532.
[9] Renjing Z, Jiarui L I U, Xiong L I. Domestic and Foreign Research Hotspots on Rural Landscape (2000—2020)[J]. Landscape Architecture, 2022, 29(3): 12-18.
[10] Kaim D, Ziółkowska E, Grădinaru S R, et al. Assessing the suitability of urban-oriented land cover products for mapping rural settlements[J]. International Journal of Geographical Information Science, 2022, 36(12): 2412-2426.
[11] Otero Peña D, Perrotti D, Mohareb E. Advancing urban metabolism studies through GIS data: Resource flows, open space networks, and vulnerable communities in Mexico City[J]. Journal of Industrial Ecology, 2022, 26(4): 1333-1349.
[12] Zhuang Q D, Hussein M K, Ariffin N F M, et al. Landscape character: a knowledge mapping analysis using CiteSpace[J]. International Journal of Environmental Science and Technology, 2022, 19(10): 10477-10492.
[13] Mira I G, Sarabia-Bautista J. Multiscaled archaeological survey in eastern Iberia: ancient settlement dynamics, agrarian practices, and rural landscapes [J]. Journal of Field Archaeology, 2022, 47(7): 471-485.
[14] Omarzadeh D, Pourmoradian S, Feizizadeh B, et al. A GIS-based multiple ecotourism sustainability assessment of West Azerbaijan province, Iran [J]. Journal of Environmental Planning and Management, 2022, 65(3): 490-513.