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Research Article

Optimization of Urban Landscape Planning and Layout under Multicriteria Constraints

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The layout and planning of urban landscape has a strong correlation with urban land utilization rate and ecological environment index. Urban landscape architects have a hard time dealing with these interrelated factors. This study uses a multicriteria constraint algorithm to optimize the relevant factors in urban landscape layout and planning. The convolutional long short-term memory (ConvLSTM) method was used to extract temporal features for urban landscape layout and planning tasks. Compared with the multicriteria algorithm without constraints, the multicriteria algorithm with constraints can better optimize the layout and planning tasks of urban landscape, and the maximum error of this method is only 1.96%. At the same time, the distribution of errors is more uniform under the multicriteria constraints, and it is all within 2%. The fusion of the multicriteria constraint algorithm and the ConvLSTM algorithm can better predict the relevant factors of the urban landscape layout, and the linear correlation coefficients of the three relevant factors have reached a high standard.

1. Introduction

Landscape layout is an important task in the process of urbanization, which is conducive to improving people's living standards and ecological environment [1]. Urban landscape layout and planning is not a single task, and it has an important relationship with urban land utilization, ecological environment index, and people's living layout [2, 3]. A better urban landscape layout and planning is conducive to the comprehensive development of the city. The urbanization process has achieved relatively great success, in which the urban landscape layout is also a more important task [4, 5]. Urban landscape can improve the image and ecological environment [6]. Although urban landscape is not the main engineering task of a city, it also affects the overall process of urban development. A city needs a good balance between the layout of the urban landscape and the relationship between the land utilization and the urban ecological environment [7, 8]. An urban landscape layout and planning project will enhance the competitiveness of the city, and it will attract more human resources. From a further perspective, it also boosts the urban economy [9]. The use of scientific and technological means to realize urban landscape layout can not only improve the rationality of landscape layout, but also improve the timeliness and efficiency of urban landscape layout, which can save financial expenses for the government.

From an intuitive point of view, the layout and planning of the urban landscape will affect the overall layout of the city. Generally speaking, a city will arrange the industrial area, commercial area, and residential area in an orderly manner. Most urban landscapes will be arranged in industrial and residential areas [10, 11]. Therefore, the layout and planning of the urban landscape will affect the overall layout of the city [12]. From this factor, the research on the layout and planning of the urban landscape is also more important for government managers than traditional design methods. In industrial areas, designers usually arrange many large vegetation as the main landscape [13]. The purpose of such a landscape is mainly two-fold, it can absorb more air impurities, and then it can purify the air. It can also be used as a kind of urban landscape to improve people life mood. In residential areas or commercial areas, designers often arrange more urban cultural landscapes [14, 15]. It also allows people to appreciate the way the cultural atmosphere of the city passes through the urban landscape. The layout and planning of urban landscape should not only consider the urban land utilization rate and the urban ecological environment, but also need to consider the type of urban landscape [16]. Moreover, the layout and planning of the urban landscape requires a series of changes over time. For urban landscape designers and managers, this is a complex job. The multicriteria constraint algorithm will take constraints of urban landscape design into account, and it can provide some reference opinions on the layout and laws of urban landscape under the constraints. For the temporal characteristics of urban landscape, the neural network method can extract the temporal characteristics of urban landscape [17, 18]. The effective combination of these two methods can solve the layout and planning tasks of urban landscape.

The multicriteria constraint optimization algorithm can make a series of classification of the research objects according to the research objectives. The constraints of urban landscape are mainly the utilization rate of urban land and the requirements of urban ecological environment [19, 20]. The multi-accuracy constraint algorithm can use these two conditions as constraints. The advantage of the multicriteria constraint algorithm is that it can consider the constraints of the research object compared to other types of multicriteria algorithms. This is an algorithm with more engineering significance. For the temporal characteristics of urban landscapes, the recurrent neural network method can fully extract the temporal characteristics of urban landscapes [21]. For most multicriteria constraint algorithms, it is difficult to consider the time characteristics of constraints. If the multicriteria constraint algorithm and the neural network method are effectively integrated, the ConvLSTM model can make the multicriteria constraint algorithm fully consider the time characteristics of the constraints. It can lead to inaccurate decisions about the layout and planning of the urban landscape. The integration of multicriteria constrained algorithm and neural network technology is a reasonable study for the layout and planning tasks of urban landscape.

This study mainly studies the feasibility and accuracy of multicriteria constrained algorithms and neural network techniques in urban landscape layout and planning tasks. Similarly, this study also uses the ConvLSTM algorithm to study the spatial and temporal characteristics of urban landscape layout. It will predict the relevant features of the urban landscape layout. It mainly consists of five sections. The first section mainly introduces the importance of urban landscape layout and planning and the necessity of multicriteria constrained algorithms. The current state of urban landscape layout is illustrated in Section 2. The application of multicriteria constrained algorithms and neural network techniques in urban landscape layout and rule tasks is studied in Section 3. Section 4 mainly introduces the feasibility and accuracy of multicriteria constraint algorithms and neural network methods in urban landscape layout and rule application. This study introduces the accuracy and feasibility of the ConvLSTM algorithm in predicting the characteristics of urban landscape layout by using the average error distribution, linear correlation coefficient, and error hotspot distribution map. The summary of the article is in Section 5.

2. Related Work

Reasonable urban landscape layout and planning has become a research hotspot in today's society. Many researchers have studied the relevant factors in urban landscape layout and planning. Chen et al. [22] believed that the process of urbanization has affected the planning and layout of the urban landscape, which is also a way of life that people pursue. Urban architecture and urban landscape design are complex tasks. The landscape layout of the waterfront has been studied by using related factors such as spatial scale, time scale, and plant arrangement. This research method has a certain role and reference value for the long-term development of the landscape layout of coastal cities. Zhou et al. [23] have found that the urban landscape layout planning will improve the urban ecological environment and people's living environment. This study uses the composite ecological theory to conduct a comprehensive evaluation of the urban landscape layout, which includes environmental factors, social factors, and economic factors. The analytic hierarchy process and the weighted function method are also used to study the diversified space construction scheme in the layout of the urban landscape and the sustainable development strategy of the urban landscape. The results show that this method can be used to evaluate the factors related to urban landscape layout. In order to improve the three-dimensional greening landscape scheme in the urban landscape layout, Mei [24] used the extended analysis method to study the vertical greening scheme of the urban landscape and the layout scheme of the corridor. He also comprehensively considered the needs of urban residents and the development status of the city, and it conducted related research on the layout of urban landscape. The results of the study show that this method can improve the satisfaction of urban landscape design, and the satisfaction degree of this method can reach more than 90 points. This has been improved by more than 15 points over the traditional urban landscape design scheme. Meng et al. [25] believed that grass landscape can improve the diversity of urban landscape layout, which is also a necessary item in urban landscape layout. It used the theory of modern financing model to study the influence of grassland landscape on the ecological environment and development resources of urban landscape. This method also provides a new idea for the layout planning of urban landscape. Peng [26] has already considered that digital technology will bring new development strategies to the development of urban landscape layout. He has studied the determinants of urban landscape layout planning and the influence of spatial systems using neural network methods and wireless sensor network technology. Digital methods can be very helpful in the layout and planning of urban landscapes, which also make full use of urban land. This method can relieve the pressure of urban land use by urban landscape layout. Liu [27] has already considered that the traditional landscape layout planning method can no longer meet the design requirements of multiple schemes and large scenes. Virtual reality (VR) technology and 3D visualization technology have been used by him to study the layout and planning strategies of urban landscapes. He created 3D virtual scenes of urban landscapes by using the spatial roaming sorting method. The simulation and experimental results illustrate that VR technology can improve the efficiency of urban landscape layout and planning, which is also a more intuitive method. Lu et al. [28] established a set of evaluation indicators for the correlation between urban landscape design and ecological environment management. At the same time, it used the two-dimensional numerical calculation method and the uncertainty error evaluation (UEE) method to establish the research idea of horseshoe-shaped landscape design. The error evaluation (EF) can be as a standard indicator for measurement, and this method can effectively resolve the contradiction between urban landscape layout and ecological environment. This scheme can be used as a reference for landscape design and ecological environment managers. Through the above research, it can be found that the urban landscape layout and laws have important impact on the ecology and the living environment. This study uses a multicriteria constraint approach to investigate the impact of related factors in urban landscape layout and planning tasks. This study uses the multicriteria constraint method to achieve effective classification of urban landscape data, and it also uses the ConvLSTM method to achieve the prediction of urban landscape-related features.

3. The Application of Multicriteria Constraint Algorithm and Neural Network

3.1. The Introduction to Time Characteristics of Urban Landscape Planning. The layout and planning tasks of urban landscape need to consider urban land utilization and urban ecological environment factors, which need to be comprehensively considered according to the needs of residents and the type of urban landscape [29, 30]. From these influencing factors, it can be seen that the layout and planning of urban landscape also needs to consider the time factor. The urban land utilization rate will change greatly with the changes of urban policy and economy [31, 32]. This shows that the layout and planning of the urban landscape is a temporal task. A single multicriteria constrained algorithm cannot extract the temporal characteristics in urban landscape layout and planning tasks, which may cause inaccuracy of the algorithm. The ConvLSTM algorithm can memorize historical state information well, and it can extract temporal characteristics in urban landscape layout and planning. This study fully combines the advantages of the multicriteria constraint and the ConvLSTM algorithms, which can well complete the relevant characteristics of urban landscape layout and planning tasks.

3.2. The System Design of Multicriteria Constraint Algorithm. The main goal of this research is to realize the prediction of the layout and planning of the urban landscape through the multicriteria constraint algorithm and the ConvLSTM algorithm. The multicriteria constraint algorithm is constrained by factors such as urban land utilization and ecological environment. The ConvLSTM algorithm mainly realizes the extraction of temporal features of urban landscape-related factors. In this study, the multicriteria constraint algorithm and the ConvLSTM algorithm are effectively integrated. Figure 1 shows the systematic design scheme of multicriteria constrained algorithm and neural network approach in urban landscape layout and planning. The data related to urban landscape features are first classified and processed by using a multicriteria constraint algorithm, and these processed data will be input into the ConvLSTM neural network. First, the constraints of this study are the utilization rate of urban land and the level of ecological environment. It requires three factors of the type of urban landscape layout, residents' satisfaction, and government economic level as the time features to be extracted. The iterative process of multicriteria constrained algorithms and neural network methods is a continuous process. This method can achieve optimal prediction of urban landscape layout when the model is trained.

The multicriteria constraint algorithm is a link that adds constraints on the basis of the multicriteria algorithm. The multicriteria constraint algorithm can realize the optimization of the target under certain constraints. Figure 2 shows the basic workflow of the multicriteria constraint algorithm. In Figure 2, factors 1–3 refer to urban land type, economic level, and residents' needs, respectively. These three characteristics are closely related to the design of urban landscape. It is mainly composed of target layer, criterion layer, object layer, constraints, and so on. The target layer is the optimization goal it wants to achieve. The criterion layer is an optimization criterion specified by the designer, which can determine the direction of optimization. The layout and planning of the urban landscape will be optimized within these two constraints. In the actual urban landscape layout engineering task, it can add different constraints for optimization.

For the multicriteria constraint algorithm, there are many matrix solving operations, which need to verify the consistency of the weights. Equations (1) and (2) show the calculation process of the consistency check. Equation (3) shows an indicator of the agreement ratio. CR is the coefficient for the consistency test. In practical engineering, the value of CR needs to satisfy $CR < 1$. Generally speaking, the value of CR is less than 1 to meet the requirement of multicriteria constraints. However, if the CR value is less than 0.5, it means that the actual design requirements in the project have been met. If the value $CR > 1$, the judgment matrix was required to modify. Otherwise, it is difficult to get the desired optimization objective. CI is the consistent value. $\lambda_{\max}$ is the eigenvalue of the matrix. n is the number of parameters.

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \tag{1}$$

$$\lambda_{\max} > n, \tag{2}$$

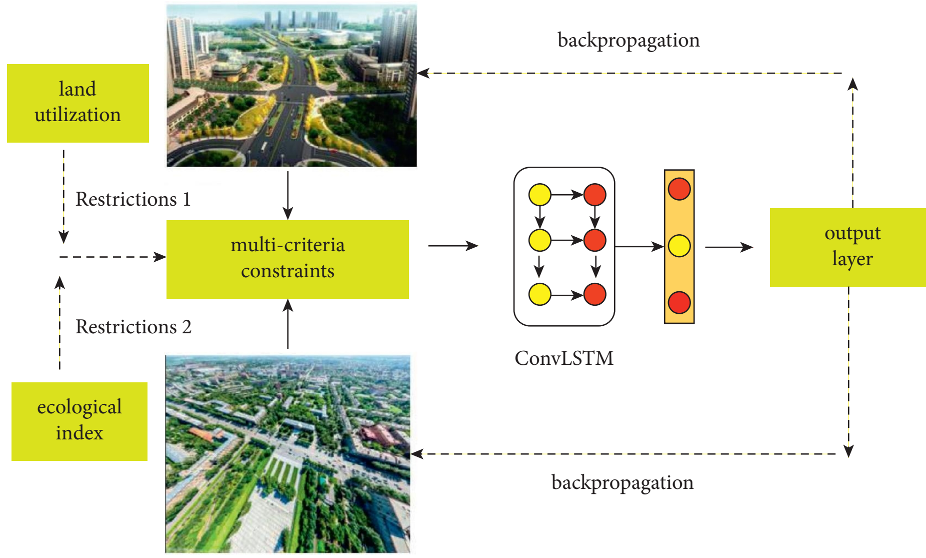

FIGURE 1: The systematic design of urban landscape layout and planning.

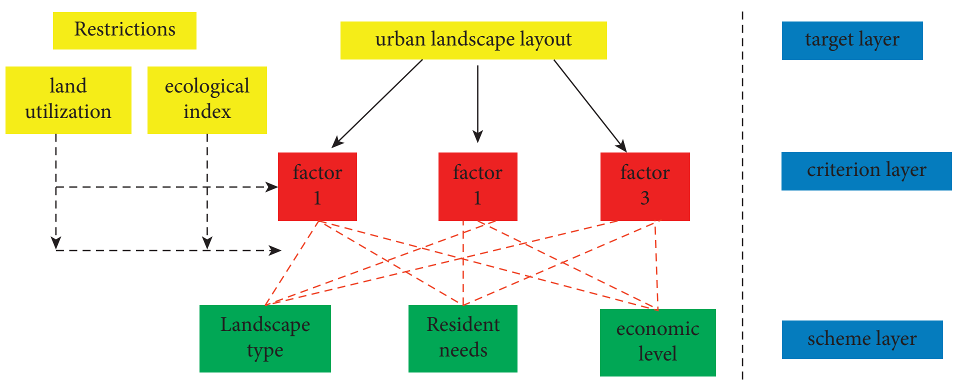

FIGURE 2: The workflow of multicriteria constrained algorithm.

$$CR = \frac{CI}{RI}. \quad (3)$$

When CR > 1, it needs to adjust the weight of each row or column of the matrix. There are several ways to adjust matrix weights. Equation (4) shows the adjustment method of the average method matrix weights. Equation (5) shows how the geometric mean method adjusts the matrix weights. Both methods make matrix weight adjustments based on average values. Finally, it needs to adjust the value of CR to CR < 1, where ω is the weight. a_{ij} represents the different data of the matrix.

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, \quad (4)$$

$$\omega_i = \frac{\left(\prod_{i=1}^{n} a_{ij}\right)^{1/n}}{\sum_{k=1}^{n}\left(\prod_{i=1}^{n} a_{kj}\right)^{1/n}}. \quad (5)$$

3.3. Introduction of ConvLSTM Algorithm. The related features of the urban landscape layout have obvious spatio-temporal features, and the ConvLSTM neural network can process both the spatial and temporal features of the data features. From the above description, it can be found that temporal features are involved in the layout and planning tasks of urban landscapes. This study adopts the ConvLSTM neural network method to study the temporal characteristics in urban landscape layout and planning. This algorithm will be combined with the multicriteria constraint algorithm. Figure 3 shows the workflow of the ConvLSTM algorithm. The LSTM neural network method mainly includes four gate structures: input gate, forget gate, refresh gate, and output gate. The main advantage of this algorithm is that it can memorize historical state information very well. The main reason why it is able to accomplish this task is that the structure of ConvLSTM contains many gate structures. The forget gate can selectively filter the historical information, and it assigns weights to the value of the historical information. Only the data contained in larger weights can be fed into the next process. If it is used in the optimization task of

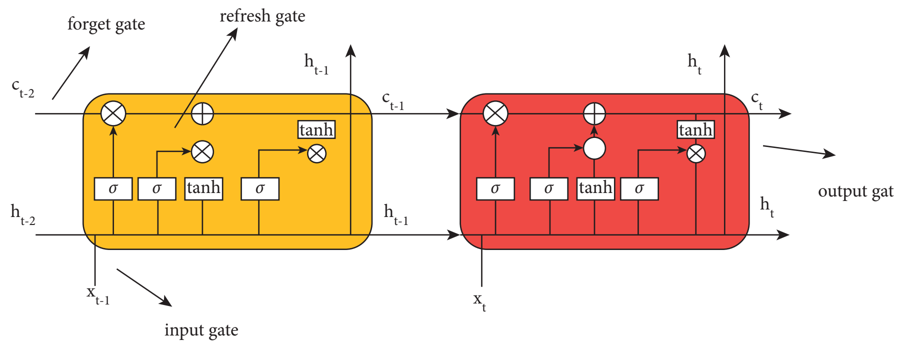

Figure 3: The workflow of ConvLSTM algorithm.

urban landscape layout and planning, it cannot memorize historical time information. It could reduce the accuracy of the algorithm. In this study, the ConvLSTM algorithm will be arranged in the end of the multicriteria constraint algorithm, which is also a continuous iterative process. The output data of the multicriteria constraint algorithm are the input data of the ConvLSTM algorithm. In this study, the tanh activation function was adopted as a function of nonlinear processing of the data.

Only larger weights will enter the input gate through the forget gate. Other historical state information will be forgotten. Equation (6) shows how the forget gate is calculated. The input gate will input historical state information and current state information at the same time. The input gate also assigns different weights according to the distribution of values. Equation (7) shows how the input gate is calculated, where the h_{t-1} is historical state data. x_t is the current state data. And the σ and tanh represent the activation function. The W and b are the weight matrix and the bias parameter, respectively.

$$i_t = \sigma\left(W_{xi}{}^{*}x_t + W_{hi}{}^{*}h_{t-1} + W_{ci}\circ C_{t-1} + b_i\right), \tag{6}$$

$$f_t = \sigma\left(W_{xf}{}^{*}x_t + W_{hf}{}^{*}h_{t-1} + W_{cf}\circ C_{t-1} + b_f\right). \tag{7}$$

Refreshing the gate will update the weights. The input data contain historical information and information about the current state. The refresh gate will repeatedly assign weights to these data for subsequent calculations. Equation (8) shows how the refresh gate is calculated. X_t represents the input of the LSTM layers at the time t. h_t is the corresponding output of the X_t. c_t is the state unit of the LSTM at time t.

$$C_t = f_t\circ C_{t-1} + i_t\circ \tanh\left(W_{xc}{}^{*}x_t + W_{hc}{}^{*}h_{t-1} + b_c\right). \tag{8}$$

The final gate structure of the ConvLSTM algorithm is the output gate. The output gate will be entered information according to the distribution of weights, which will contain data of historical state information and current state information. Equation (9) shows the calculation criteria for the output gate. The activation function is a necessary structure for every deep learning method, which can nonlinearly process and map the data. Equation (10) shows the calculation rule for the activation function. c_t is the state unit of the LSTM at time t. The tanh is the activation function.

$$o_t = \sigma\left(W_{xo} * x_t + W_{ho} * h_{t-1} + W_{co}\circ C_t + b_o\right), \tag{9}$$

$$h_t = o_t\circ \tanh\left(C_t\right). \tag{10}$$

Equation (11) shows the calculation criteria for the mean square error (MSE) loss function, which will calculate the error between the predicted value and the real value. q^{real} is the real value, and q^{pre} is the optimized value.

$$L = MSE\left(q^{real}, q^{pre}\right) = \frac{1}{nm}\sum_{k=1}^{N}\sum_{j=1}^{M}\left(q_{kj}^{real} - q_{kj}^{pre}\right)^2. \tag{11}$$

The data related to urban landscape layout and planning need to go through the workflow of data cleaning and data preprocessing, whether it is a multicriteria constraint algorithm or a ConvLSTM algorithm. For the multicriteria constrained algorithm, it needs to collect urban land utilization and ecological environment index data. These two kinds of data may be missing to some extent, which requires data cleaning function. For the ConvLSTM algorithm, it needs to collect data such as urban landscape types and resident needs, which are quite different. This requires data preprocessing, which will normalize the data. Data cleaning needs to fill in the missing values, and the filled values are 0 or 1. Data preprocessing is to map the data values, and the data are processed into values of the same distribution and the same interval.

4. Result Analysis and Discussion

In this study, the multicriteria constraint algorithm is used to optimize the urban landscape layout and planning. The constraints are urban land utilization and ecological environment index. Then, use the ConvLSTM algorithm to predict the related factors of the urban landscape. These data come from the data of a landscape planning in Shanghai. This study analyzes the prediction accuracy for both constrained and unconstrained work environments. Figure 4 shows the prediction errors for the two cases. It can be seen from Figure 4 that the multicriteria algorithm with constraints and the ConvLSTM algorithm can more accurately predict the layout and planning tasks of urban landscapes. The prediction errors of the three factors of the urban landscape layout are relatively low under the constraints. This shows that the urban land utilization rate and the

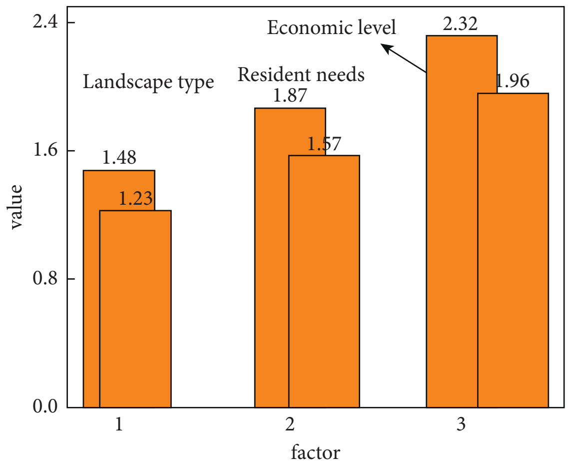

Figure 4: The prediction errors for the two conditions.

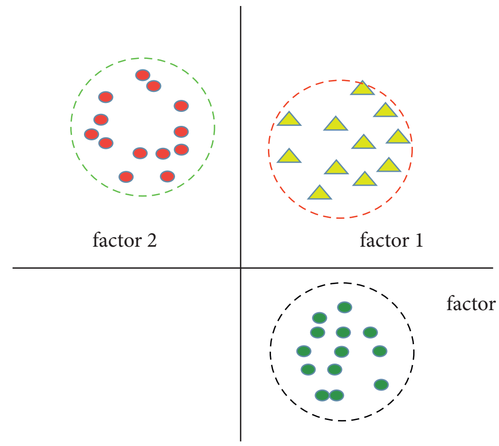

Figure 5: The distribution of the objective optimization by algorithm with constraints.

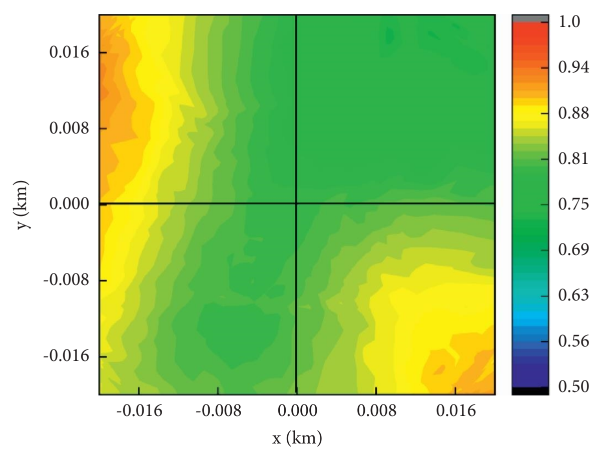

Figure 6: The hot spot distribution map of urban landscape layout.

ecological environment index have an important influence on the layout and planning of the urban landscape. This also shows that the multicriteria algorithm with constraints can more accurately optimize the urban landscape layout. In general, both the multicriteria algorithm and the ConvLSTM algorithm can predict the relevant factors of the urban landscape layout well whether it contains conditional constraints or it does not. For the working conditions with conditional constraints, the maximum prediction error is only 1.96%, and this part of the error has a great relationship with the economic situation of the city. The smallest prediction error is only 1.23%, which is a relatively satisfactory error. From the perspective of the lower error range, the largest reduction is 0.3%, and this part of the error comes from the characteristics of residents' needs.

Through the above description, we have found that the multicriteria algorithm with constraints and the ConvLSTM algorithm can more accurately predict the relevant factors of urban landscape layout. In order to more intuitively show the accuracy of the multicriteria constraint algorithm in the objective optimization, Figure 5 shows the distribution of the three influencing factors of the urban landscape layout. Factor 1 refers to land type and factor 2 to economic level. Factor 3 refers to resident demand. The three factors of urban landscape layout have been well optimized and classified. These three factors can be well divided according to the optimization criterion, and they can be well distributed in different quadrants. If the data can be well separated, and the distance between different types of data is relatively large, this shows the superiority of the algorithm. The multicriteria constraint algorithm has separated the three factors of urban landscape layout well, and there is no intersection between the data of these three factors. This shows that the multicriteria constraint algorithm can better optimize the goal of urban landscape layout. Also, the spacing between data for the same factor is relatively small.

The hot spot distribution map of urban landscape layout and planning can reflect the distribution of urban landscape more intuitively. As shown in Figure 6, the hot spot distribution map of the urban landscape was illustrated. It can be clearly seen that there is a strong distribution of hot spots in the edge area of the landscape area, while there is a lower distribution of hot spots in the center of the landscape area. This situation is quite consistent with the actual urban layout of Shanghai. The heat distribution map can well reflect the distribution of the landscape and the general shape of the landscape. The yellow area represents the layout of the urban landscape, and the green area represents the layout of the river landscape. This method can also make a good prediction of the flow direction of the river landscape. This can reflect that this method can provide designers with a good reference for urban landscape layout, whether it is the multicriteria constraint method or the ConvLSTM algorithm. The urban landscape thermal distribution map provides a good reference for landscape designers intuitively.

This study compares the differences between multicriteria algorithms with and without constraints. Constraints can guide the optimization direction of urban landscape layout and planning within a certain range, which can make the related factors of urban landscape layout more accurate. Figure 7 shows the hot spot distribution of urban landscape layout errors under unconstrained conditions. In

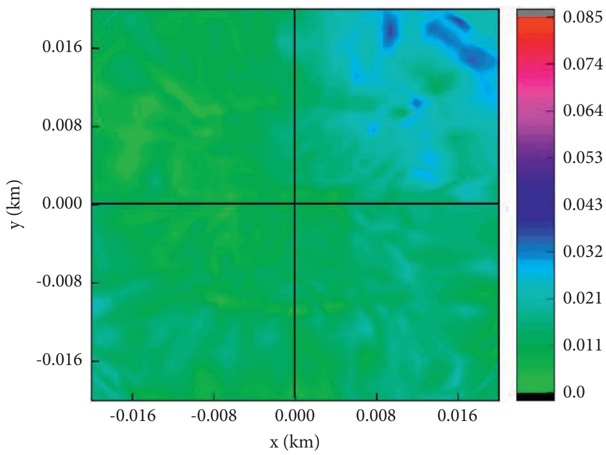

FIGURE 7: The hot spot distribution of urban landscape layout errors under unconstrained conditions.

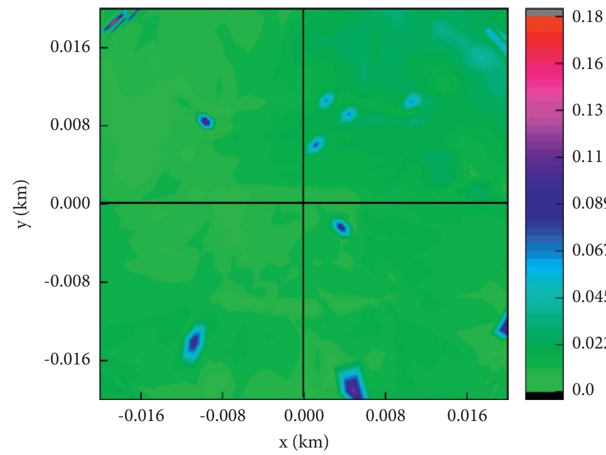

FIGURE 8: The distribution of urban landscape layout errors at constrained conditions.

general, the multicriteria algorithm can complete the optimization task of urban landscape layout without constraints, and most of the errors are basically within 2%. However, there is a certain difference in the error distribution of the urban landscape layout optimized by this method, which the error distribution is not uniform. Larger errors are mainly distributed in the edge area of the urban landscape, which is the landscape distribution of rivers. It has a smaller error for locations where the thermal distribution is strong. This shows the multicriteria algorithm without contain constraints, and it also can better complete the optimization task of urban landscape layout. Figure 8 shows the distribution of urban landscape layout errors under constrained conditions. For the multicriteria algorithm with constraints, it can better optimize the layout and planning tasks of the urban landscape. It can be seen from Figure 8 that the thermal distribution optimized by this method has smaller error, and the error distribution is relatively uniform. It does not have a large error gradient. This shows that the integration of multicriteria algorithm, constraints, and ConvLSTM algorithm can well complete the optimization task of urban landscape layout and planning. Most of the errors are within 2%, and it does not have a large error distribution.

The linear correlation coefficient can reflect the correlation between the optimal value of the urban landscape layout and the actual value. The closer the data point is to $y = x$, the higher the reliability of the optimal value. Figure 9 shows the optimal linear correlation coefficient of urban landscape layout. Generally speaking, when the linear correlation coefficient exceeds 0.95, it achieves a good prediction effect. The predicted linear correlation coefficients of the neural network methods used in this study all exceeded 0.975. The red part represents the optimal value distribution of the multicriteria algorithm with constraints, and the blue part represents the optimal value distribution of the multicriteria algorithm without constraints. This optimized value is well distributed on both sides of $y = x$, which shows that there is a good correlation in both cases. But optimized values with constraints have better correlation. This shows that the urban land utilization rate and the ecological

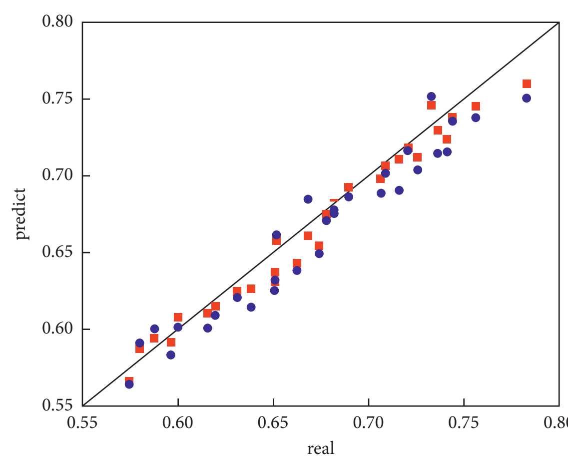

FIGURE 9: The optimal linear correlation coefficient of urban landscape layout.

environment index have a specific and important relationship with the layout of the urban landscape.

5. Conclusions

The layout and optimization of urban landscapes is a complex task for landscape architects. There is an important relationship with urban land utilization and ecological environment index. The layout of the urban landscape will respond to the long-term development of the city. In the early stage of urban landscape layout, it needs to comprehensively consider all factors, which will improve the comprehensive layout of the city. However, the layout and planning of the urban landscape is a task with many complex factors. If it only relies on the urban landscape designer to consider these factors, which will reduce the efficiency of urban landscape layout.

This study uses the multicriteria constraint algorithm to optimize the related factors of urban landscape layout and planning. It also uses the ConvLSTM algorithm to predict the related factors of urban landscape layout. At the same time, this study compares the difference between the multicriteria algorithm with constraints and the multicriteria algorithm without constraints. In general, the multicriteria algorithm with constraints has higher accuracy for the optimization of urban landscape layout and planning than without constraints. The maximum error of the multicriteria algorithm without constraints is 2.32%, while the maximum error of the working conditions with constraints is only 1.96%. The multicriteria algorithm with constraints can improve the optimization accuracy. From the hot spot distribution map, the distribution with constraints is relatively uniform, and it has a small error gradient. The case without constraints has a large error at the edge of the urban landscape, and its distribution is not uniform.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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