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Computer-Aided Design AND APPLICATIONS

Building Layout Optimization Modeling Based on CAD and Deep Learning

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Abstract. The demand for urban construction land is increasing with the growth of urban economy, and there are more and more contradictions between urban development and urban buildings. Designers aim to create a method or product that solves people's living problems and is more in line with the harmonious coexistence between human beings and nature by studying the relationship between human beings and the environment and between human beings and nature. In this article, urban architectural space layout with performance constraints, and an optimization method of urban architectural space layout based on CAD and improved Convolutional Neural Network (CNN) is proposed. The mathematical model of urban architectural space layout CAD modeling is established to realize the parametric description of urban architectural space. The results show that this algorithm is more accurate for urban building layout optimization, which is 26.78% higher than the traditional layout optimization algorithm, and can accurately locate the edge contour of the optimized space. The whole layout optimization solution process is smooth and rapid, and it can quickly approach the optimal solution. This shows that the application of PSO algorithm can better solve the problem of urban building layout optimization.

Keywords: CAD; Deep Learning; Architectural Layout; Particle Swarm Optimization
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1 INTRODUCTION

The building is one of the main elements of the city and the supporting skeleton of the smart city. The 3D fine model of the building becomes the spatial carrier of all kinds of information in the city, which affects the efficiency of the government in managing the city and plays a vital role in serving the citizens' daily life. The goal of 3D reconstruction is to obtain the 3D data of this information carrier, which can help people get the 3D geometric information, spatial information and even color information of the target object through one or more images. The growth of surveying and mapping technology provides more and more ways to obtain surveying and mapping geographic information. Therefore, the number of data sources for building 3D modeling is increasing, providing researchers with more choices. Only by integrating relevant information such as geometry, semantics, topology and attributes can the building model realize intelligent services such as virtual roaming, comprehensive query and intelligent analysis in a real sense, and provide scientific analysis and reasonable suggestions for modern urban development planning, social security maintenance, traffic safety guarantee and urban disease treatment. From traditional measurement data to image data, and now to point cloud data, modeling methods are booming. In the process of building smart cities, how to choose is a new problem. Building layout optimization is a complex problem, which needs to comprehensively consider the needs and limitations of architects, structural engineers, mechanical engineers, electrical engineers and other aspects. Building layout optimization modeling based on CAD and deep learning can help us better solve this problem. First of all, we need to use CAD model the architectural layout. CAD software can help us quickly create and edit building models, including walls, doors and windows, roofs, etc. At the same time, we can also use CAD software for structural analysis and mechanical calculation. Deep learning technology can help us extract useful features from a large number of data, and use these features for prediction and decision-making. In terms of building layout optimization, we can use deep learning technology to optimize the building layout, so as to improve the use efficiency and comfort of the building. Specifically, we can use the deep learning technology to classify and identify the architectural layout to determine which layout schemes are feasible and which are not. We can also use deep learning technology to evaluate and predict the building layout to determine which layout scheme is the best. Finally, we need to combine CAD and deep learning technology to realize the optimal modeling of building layout. Specifically, we can use CAD to design and model the building layout, and use deep learning technology to optimize the building layout. We can also use CAD software for structural analysis and mechanical calculation, and input these data into the deep learning model to improve the accuracy and reliability of the model.

Designers aim to create a method or product that solves people's living problems and is more in line with the harmonious coexistence between human beings and nature by studying the relationship between human beings and the environment and between human beings and nature. The representations of 3D data are mainly divided into three types: point cloud, voxel and grid. Because the representations of 3D data are not unique, and each representation has its own advantages and disadvantages, different algorithms and methods need to be designed for different 3D data to obtain a good 3D model. Its final output forms are also diverse and divergent, which can be a specific product, a service or an abstract idea, and the resulting final scheme will also present diversity due to the different ideas of designers. The new technology represented by deep learning (DL) is gradually changing the growth of various fields. Data-driven deep modeling learning technology, with enough data sets, uses the designed network model for training, which makes the task of 3D reconstruction simple and vivid from the original complexity and becomes a new research direction at present. The purpose of this article is to study the methods of building 3D modeling based on CAD and DL technology, and compare and analyze the modeling efficiency, automation, model fidelity and other aspects of the modeling methods, and give reasonable suggestions for large-scale building 3D modeling in the growth of smart cities. With the increasing complexity of indoor space structure, the requirements of indoor space for internal structure space layout are getting higher and higher. Therefore, researchers in this field have studied the indoor space layout of buildings and achieved certain results. Wang et al. evaluated the 3D space status of urban buildings in the city according to the obtained remote sensing image data, and optimized the layout of urban buildings in three aspects: visual effect, thermal environment and architectural landscape according to the above evaluation results.

On the basis of urban construction planning, this article combines the connotation and concept of conductive thinking to design the technical methods, content, and compilation ideas of urban architectural layout. A feature extraction method for indoor spatial layout of buildings has been proposed. By using the method of reconstructing three-dimensional visual feature information, a visual inspection model for indoor spatial layout of buildings was established. A visual feature extraction system for indoor layout of buildings has been constructed, improving the spatial feature extraction ability. The innovative contributions based on the scale decomposition results of visual images of indoor spatial layout of buildings are as follows: In this article, a building layout optimization modeling method based on CAD and DL is proposed, and the traditional CNN is improved by PSO algorithm. The modeling effect of the improved CNN is verified by simulation experiments. The results show that PSO-CNN can obtain more reasonable, feasible and scientific spatial optimization results than standard traditional CNN, and its operation efficiency is obviously improved, which can provide scientific basis for architectural spatial planning.

(1) According to the structural characteristics of architectural space, an optimization method of urban architectural space layout is proposed, and the mathematical model of urban architectural space layout CAD modeling is established to realize the parametric description of urban architectural space.

(2) In this article, PSO is applied to solve the spatial layout optimization problem of urban buildings with performance constraints, and good results are obtained.

The first section describes the background of using CAD software to design and model building layout. Section 2 analyzes the particle swarm optimization test of different scholars' research results. In Section 3, the 3D building automatic modeling and DL model are constructed. Using image data to complete the three-dimensional modeling of the building, and extract the three-dimensional modeling object from the image. Section 4 building layout optimization modeling based on improved CNN model based on particle swarm optimization algorithm. Section 5 analyzes the research results. In building scene CAD modeling, the feature recognition task is represented as a search problem. Using the space search ability of particle swarm optimization algorithm, the optimal solution rule satisfying the fitness value is obtained. In Section 6, the features of multi view images are extracted by transfer learning, and the features are fused by collecting the dimensions of views.

2 RELATED WORK

Asadi and KARAMI [1] carried out the architectural analysis of the competitive algorithm of the objective function. Through the environmental analysis and test of particle swarm optimization algorithm, it considers the evaluation results of the minimum test of refuge with path risk. The repeatability test of the algorithm shows that the best environment test algorithm has the best goal optimization. Cao et al. [2] analyzed the scenario simulation framework model of urban spatial ecological development. Through the analysis of environmental automation parameter planning by adjusting the regional weight factors, the simulation idea of land spatial planning is carried out. The environmental element configuration mode developed by the company has been effectively designed and planned. Croce et al. [3] built a Building information modeling for point cloud machine learning. By measuring the digital features of architectural heritage, it carries out semantic expression and analysis of architectural 3D, and uses Building information modeling to construct descriptor features for the management semantics of geometric information. D'acci [4] analyzed the diversity of network recognition for the morphological characteristics of topological and geometric structures. It analyzes the potential parameterization of the distance of the network space state by calculating the spatial cognition of the standard of urban road space geometry. Elbes et al. [5] analyzed the building construction and interactive network of intelligent city. It makes a scientific analysis of man and nature on the mobile planning and layout of urban buildings. Through the intelligent building constraints of the positioning algorithm, the urban building layout is optimized. The system also provides a reference for energy management and use of intelligent buildings. Hamedianfar et al. [6] conducted ultra-high resolution pixel analysis on the geographical image of urban building layout. By analyzing the pixel characteristics of spectrum and geometric texture, the proposed image classification data are compared. It has made a certain contribution to the intelligent method of land subtropical high. Ji et al. [7] carried out an analysis of building frames with convolution network changes. Through the analysis of ultra-high resolution building pixels, it constructs a widely used building network spatial layout attempt. The semantic segmentation is used to analyze the robustness of parallax training. Experiments show that it has certain advantages in the object analysis and evaluation of pixels. Kuras et al. [8] carried out the machine learning algorithm of sensor hyperspectral and analyzed the urban structure and material properties. Through the machine learning algorithm of radar sensor coverage, the urban surface transfer analysis is completed. The analysis introduces the building planning system of the city category. Law et al. [9] conducted research and Analysis on the evaluation of urbanization by street neural network. Through the quality evaluation of the street frontage as the data quality analysis of the scale research, its analysis constructs the great potential of the deep learning method in the design of urban information. Le et al. [10] conducted intelligent planning analysis of building energy efficiency. Based on artificial intelligence neural network, the energy efficiency heat load estimation of building intelligent city planning is compared. Through building energy efficiency analysis load of intelligent variance estimation, the potential of performance model is determined. One of the important links of urbanization development is the construction of complex transportation system. In order to make the operation of urban public transport lines more reasonable, Lin et al. [11] built a multi-objective public transport scheduling optimization model. Better adaptive particle swarm optimization is achieved by scheduling and optimizing the bus routes of urban passengers. Newton et al. [12] carried out an in-depth study of the architectural design of the anti-Sexual network. By conducting 2D and 3D analysis on specific architectural styles, training data management was carried out to control the construction of the generated architectural visual model. The research results confirm the diversity of using datasets for control. PłOszaj et al. [13] provided guidelines for energy layout in early architectural design. The layout of the program of functional Carbon footprint building design is analyzed by calculating the machine learning model of hybrid training. The results of multiple criteria analysis indicate that building parameters need to incorporate possible relationships of building optimization during the accident design stage. Wu et al. [14] conducted an analysis of the construction engineering dataset for CAD drawings. By using semantic rich similarity layout to calculate complexity, a high-quality building optimization algorithm was constructed for intelligent building sensor 3D feature capture. For non-formal optimization algorithms, they detect the inherent symmetry of building reflections. Yi et al. [15] carried out ultra-high resolution urban building depth learning neural network pixel segmentation. By analyzing the depth residuals of the sampling network in the architectural feature map, the aviation image analysis of city segmentation semantics is constructed. In terms of holistic expression, it has made a significant improvement in visual shape architecture.

3 3D BUILDING AUTOMATIC MODELING AND DL MODEL

Whether using image data or using point clouds to build 3D building modeling, it needs the support of many theoretical knowledge. Using image data to complete 3D modeling of buildings, what needs to be done is to extract 3D modeling objects from images. The main content of extracting modeling objects is the outline of buildings. How to extract the outline of buildings more efficiently and accurately will have an important impact on subsequent modeling. Under the theme of sustainable development, it is not only an important topic in the field of land use, but also an urgent task to rationally use limited building space and promote the sustainable use of land resources to realize the optimal layout of building space and promote the transformation of building space distribution from scattered to reasonable gathering. In the process of feature extraction of building indoor space layout, the determined feature parameters are interfered by many factors, which leads to poor convergence of feature extraction. Evolutionary DL is an artificial intelligence algorithm, which is widely used in many fields. It is an intelligent algorithm that combines natural algorithm and evolutionary mechanism, and has the ability of fast optimization, and the obtained optimal solution can solve the problems encountered in the research process. Therefore, this article uses the evolutionary DL algorithm to extract the layout features of building interior space.

In automatic 3D modeling, features are extracted by programmed methods and contours are digitized manually. Large-scale lidar data sets must be classified by multi-step procedures. Automatic classification programs usually include classifying ground points, classifying points on the ground into several categories, and grouping and classifying buildings according to their plane characteristics and other attributes. Due to the in-depth study of big data and computer hardware, DL came into being. DL is a new multi-layer neural network algorithm. It can imitate the human brain, get the key information efficiently and accurately in the face of a large number of perceptual data, and alleviate the local minima of traditional training algorithms. Figure 1 shows the running mode of CNN in this article.

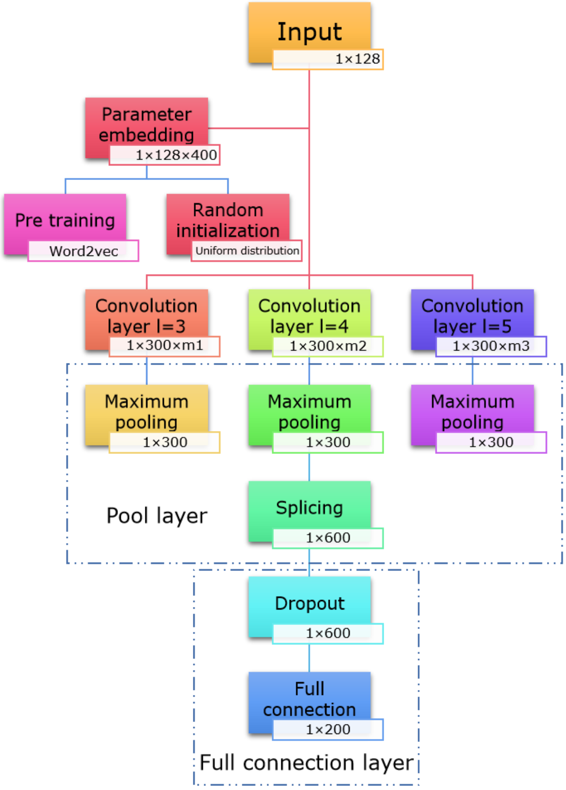

Figure 1: CNN operation mode in this article.

The whole life cycle of a building is a conceptual description of the process of building changes over time, from the decision-making of a building project to the demolition of the building. The divided network structure formed by connecting and combining multiple neuron unit structures is the traditional ANN. Traditional ANN establishes the function connection mapping relationship between output and input by matrix multiplication, and each independent parameter in the parameter matrix represents the correlation information between an output value and an input value.

The problem of building space layout needs to consider not only the change of fitness value of objective function, but also the choice of building space aggregation direction. If only the optimization strategy of standard PSO algorithm is used, the spatial layout of buildings may move closer or gather in one direction. Is defined as:

$$s(i,j)=(X*W)(i,j)+b=\sum_{k=1}^{n_{in}}(X_k*W_k)(i,j)+b \tag{1}$$

The general process can be simply summarized as follows: firstly, the training samples are labeled, and then a learning model is obtained by training the existing training samples. Finally, all the inputs are mapped into fixed types of output results by using this model, and the purpose of classification is achieved after judging the results. When the sample size B of small batch data changes, the learning rate ε must be changed accordingly, generally through the average of parameters, namely

$$\theta^{(t+1)}=\theta^{(t)}+\varepsilon(\frac{1}{B}\sum_{t'=Bt+1}^{B(t+1)}\frac{\partial \log p(V^{(t')}\mid\theta)}{\partial\theta}) \tag{2}$$

Different from the traditional shallow learning structure, DL model is a multi-layer sensor with multiple hidden layers. Learn more advanced data layers from low to high. The DL form combines the more abstract high-level features with the low-level features to study the attribute categories or features of data, so as to discover their distribution features.

4 OPTIMIZATION MODELING OF BUILDING LAYOUT BASED ON IMPROVED CNN MODEL BASED ON PSO

The most important thing in DL is to learn some nonlinear function mapping through the network, and the way to realize this nonlinear operation is to realize it through the activation function in the network. To act as an activation function in a neural network, it needs to meet the following properties: nonlinearity, differentiability and monotonicity. Deep neural network is a supervised learning model. Because it has changed the way of full connection of neural network in the past, it directly adopts the way of partial connection in neurons, thus reducing the number of parameters learned in the network, reducing the complexity of the training process and improving the efficiency. The process of building image recognition based on PSO neural network is shown in Figure 2.

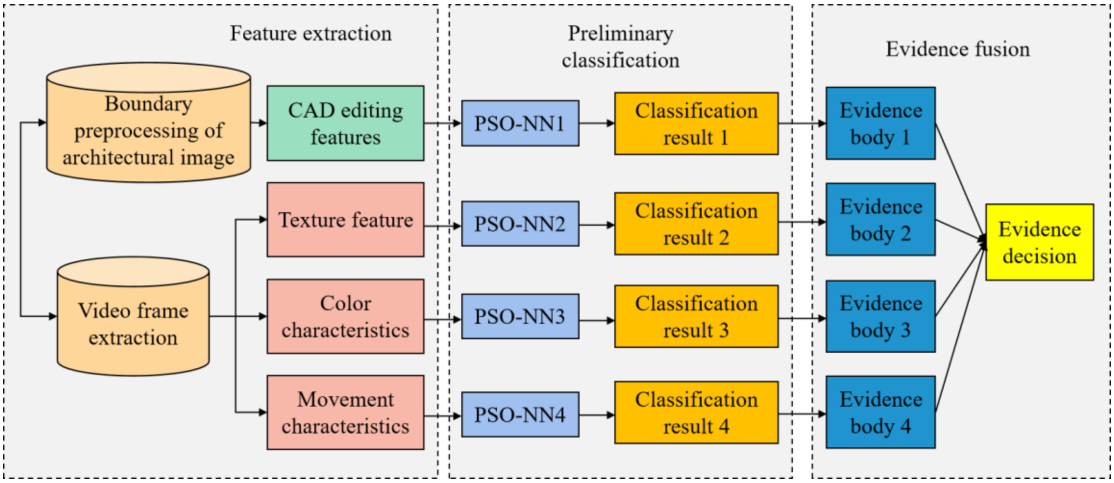

Figure 2: Building image recognition process.

Particle swarm search process is shown in Figure 2. On the basis of PSO, this algorithm adds some operators of genetic algorithm, which can give a hybrid probability to the particles in the particle swarm. This hybrid probability is determined by the user and has nothing to do with the fitness value of the particles. In each iteration, each particle is hybridized according to the hybridization probability to generate the same number of offspring particles. If the fitness value is higher than that of the parent particles, it will be replaced, otherwise, it will not be replaced. The position of the child particle can be obtained by arithmetic weighting of the position of the parent particle:

$$x_1^{'} = px_1 + (1-p)x_2 \tag{3}$$

$$x_2^{'} = (1-p)x_1 + px_2 \tag{4}$$

Among them, x_1, x_2 is two D-dimensional parent particles; $x_1^{'}, x_2^{'}$ is the D-dimensional child particle generated by cross; p is a D-dimensional random vector that obeys a uniform distribution, and each component in p is in $[0,1]$.

In the process of using deep neural network to extract image features, there are several ways to improve the training effect: (1) ReLU deactivation function is used instead of sigmoid activation function. (2) Use the Dropout layer reasonably to prevent over-fitting. (3) When Sigmoid activation function is used, Hessian-Free optimization method is used. In order to solve the problem of over-fitting, you can generally increase the amount of data.

The characteristic of CNN is that the high-level information is more and more abstract. Simple feature fusion operation only combines features. Although it can enrich feature information, it is also easy to introduce unimportant information, resulting in redundancy of feature information, which will have a bad influence on the final feature extraction effect. In order to further optimize the convolution layer output characteristics of the self-encoder, it is necessary to use the attention mechanism. The update formula of link weight W_{ij} is:

$$W_{ij}^{(t+1)} = kW_{ij}^{(t)} + \varepsilon \frac{\partial L}{\partial W_{ij}^{(t)}} \tag{5}$$

$$O_P = F_n(\cdots(F_2(F_1(XW_1)W_2)\cdots)W_n \tag{6}$$

$$E_P = \frac{1}{2}\sum_j (Y_{Pj} - O_P)^2 \tag{7}$$

The purpose of this article is to study the methods of building 3D modeling based on CAD and DL technology, and compare and analyze the modeling efficiency, automation, model fidelity and other aspects of the modeling methods, and give reasonable suggestions for large-scale building 3D modeling in the growth of smart cities. The texture data of buildings can be obtained in two ways, one is to simulate the texture, and the other is to collect the texture on the spot. The simulation method can quickly complete the texture mapping process, but there will be some differences with the real texture of the building; The texture collected in the field can achieve good results by texture mapping after processing, but it takes a long time to process texture data and texture mapping. See Figure 3 for the feature extraction process of building scene.

The traditional communication management mode based on CAD drawings has improved the communication mode in a certain sense, and the owner's wishes can be better expressed by using CAD drawings as the medium. However, from the owner to the designer, there will inevitably be misunderstanding of information when drawing drawings, and the design of CAD drawings cannot fully express the owner's wishes. The traditional manual modeling is effective but inefficient. The emerging method based on oblique images and laser point clouds can quickly build a large urban model automatically or semi-automatically, but it lacks indoor information and is expensive. In view of this situation, it is undoubtedly a very good solution to automatically or semi-automatically identify building components and complete the building 3D model construction from CAD drawings. In order to improve the accuracy of 3D model generation, this article designs a strategy based on multi-network collaborative learning and two-stage training to train the multi-view 3D model generation network.

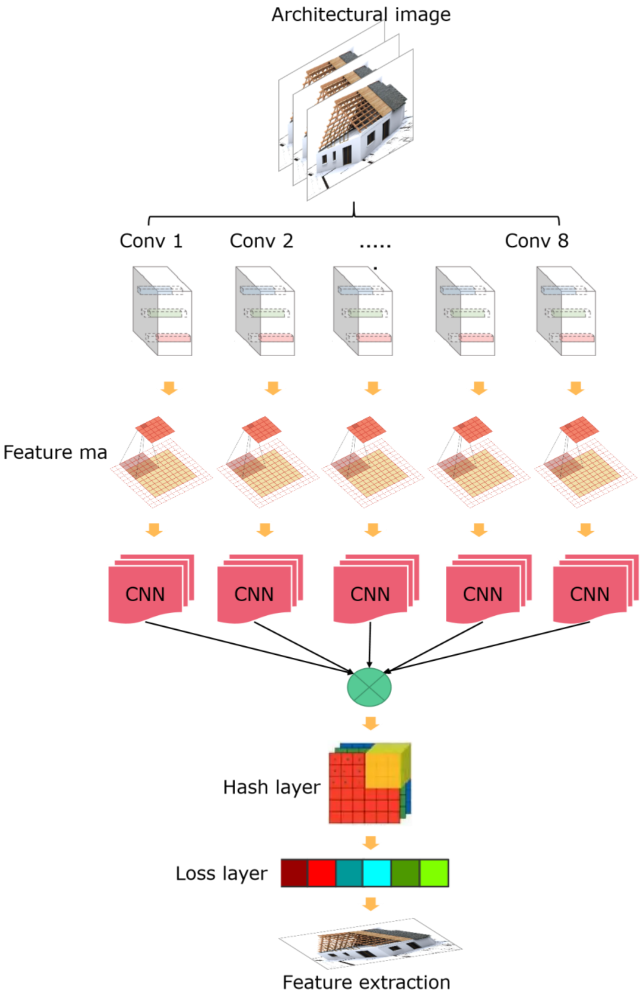

Figure 3: Feature extraction process of building scene.

During the training, the self-encoder network is used as the auxiliary network of the network that directly uses the multi-view image features to generate the 3D model, and the parameters of the two network modules are trained separately until the model converges.

Assuming that the architectural scene is W, the boundary is WSB and all polygon obstacle areas in the area are Q_i, then:

$$W = \{WSB, Q_1, Q_2, \cdots, Q_m\} \tag{8}$$

Where m is the number of polygon obstacle areas.

Singular value decomposition (SVD) is an algorithm that can be applied to any matrix decomposition.

$$y = Wx \tag{9}$$

Its computational complexity is u, v. If W is subjected to singular value decomposition, and W is approximately replaced by the first t important eigenvalues after decomposition, the decomposition formula is:

$$W = U\sum V^T \approx U\sum_t V^T \tag{10}$$

5 RESULT ANALYSIS AND DISCUSSION

In view of the needs of smart cities and building management at this stage, it is very important to construct 3D models from 2D CAD graphics simply and efficiently, and it has high economic value. The network puts forward the features of each view image through transfer learning, and uses a view dimension pooling operation to fuse the features of multiple view images. The fused features will be input to the decoder network as the aggregated information representing the target object to recover the 3D model information. According to the building space information model, the smallest unit of space is mainly the composition relationship between space and building components, but for the building space information model, besides the composition relationship between these components and space, there are often topological relationships such as spatial connectivity, spatial adjacency and spatial inclusion.

In building scene CAD modeling, the task of feature recognition is expressed as a search problem, and the optimal solution rules satisfying the fitness value are obtained by using the spatial search ability of PSO. Many problems in feature recognition, such as knowledge acquisition of classification, clustering and prediction, can be expressed or transformed into optimization problems, and then can be solved by PSO. As shown in Figure 4, the running time comparison results of this algorithm and the traditional CNN model are given.

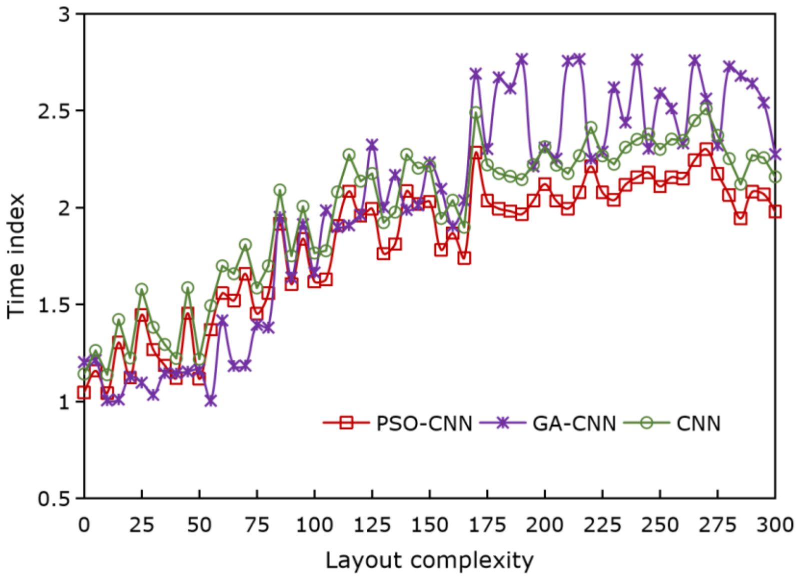

Figure 4: Calculation time comparison of the algorithm.

It can be seen that although the algorithm in this article did not show obvious advantages in the initial stage, when the complexity of spatial optimization is increasing, the algorithm in this article shows high running efficiency. A large number of neurons collectively learn the patterns in the data to be analyzed through training, and form a nonlinear function to describe complex nonlinear systems, which is suitable for mining classification knowledge from nonlinear spatial systems with complex environmental information, fuzzy background knowledge and unclear reasoning rules. It has an important and far-reaching influence on computer science, artificial intelligence and information technology, and can be used for classification, clustering and feature mining in CAD modeling of architectural scenes.

Eight body position strings are randomly generated to form an initial population. By calculating the fitness value of each individual (the reciprocal of the sum of squares of residuals), three individuals with larger fitness value are selected to participate in cross calculation, and one of the three new individuals is randomly selected for mutation operation, and three individuals with larger fitness value are still retained to participate in the next round of calculation. The parameters of the prediction model obtained by genetic calculation of X coordinate and Y coordinate data are shown in Table 1.

Model	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Residual*
X	115.611	5.694	0.752	11.562	6.689	2.407	/	/	3433.41
Y	34.522	4.681	0.965	3.211	10.154	3.212	3.052	9.795	13481.07

Table 1: Parameter estimation of building space barycenter coordinate prediction model.

A lot of calculation work needs the support of computer system. Various spatial dynamic feature recognition algorithms have their own complexity, and the increase of data volume aggravates the increase of calculation amount when the model is running, and a lot of calculation work obviously cannot be separated from the support of computer system.

Although DL model usually needs careful hyperparameter adjustment, it can achieve high performance in a relatively small range of hyperparameter adjustment. Once the training is completed and the weights of the graph neural network and regression model are fully learned, the rest of the test samples that the DL model has not encountered before are tested by regression. The trained DL model can accurately predict the initial evaluation score. Compare the recall and accuracy of the algorithm for spatial pattern optimization, as shown in Figure 5 and Figure 6.

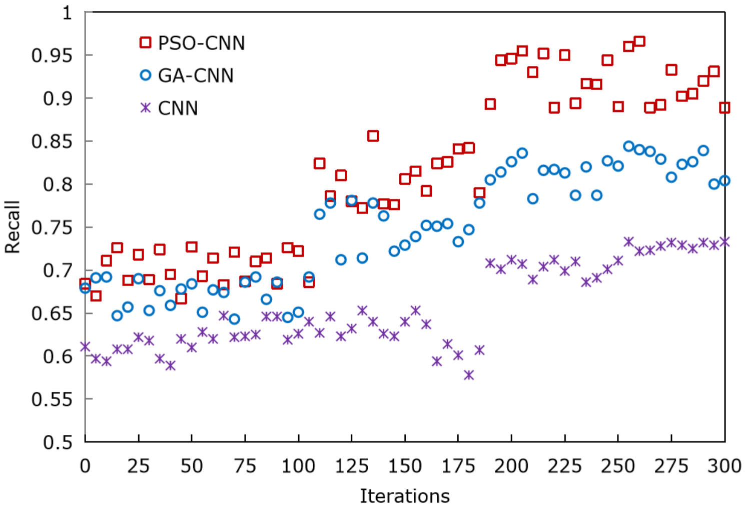

Figure 5: Comparison of recall of spatial pattern optimization.

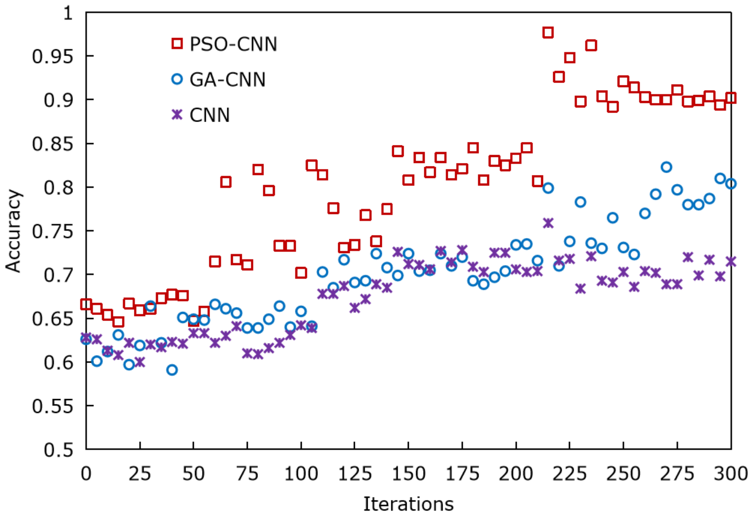

Figure 6: Comparison of spatial pattern optimization accuracy.

The evolutionary DL algorithm is used to control the convergence of feature parameters and complete the extraction of architectural space layout features. From the test results, it can be seen that the accuracy of this algorithm for urban building layout optimization is higher, which is 26.78% higher than that of the traditional layout optimization algorithm, and it can accurately locate the edge contour of the optimized space. Figure 7 shows the variation curve of the optimal solution of particle swarm optimization.

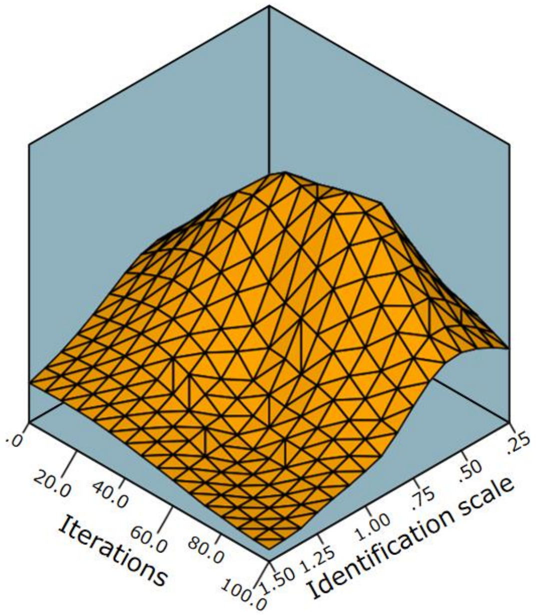

Figure 7: Variation curve of optimal solution of particle swarm optimization.

It can be seen from Figure 7 that the whole layout optimization solution process is smooth and rapid, and it can quickly approach the optimal solution. This shows that the application of PSO algorithm can better solve the problem of urban building layout optimization. The results show that PSO-NN can obtain more reasonable, feasible and scientific spatial optimization results than standard traditional CNN, and its operation efficiency is obviously improved, which can provide scientific basis for architectural spatial planning. The proposed method effectively improves the ecological floor area ratio, and the layout design results can meet different functional requirements, and the layout results are more reasonable, which lays a foundation for the growth of urban buildings.

6 CONCLUSION

With the increasing complexity of indoor space structure, the requirements of indoor space for internal structure space layout are getting higher and higher. The representations of 3D data are mainly divided into three types: point cloud, voxel and grid. Because the representations of 3D data are not unique, and each representation has its own advantages and disadvantages, different algorithms and methods need to be designed for different 3D data to obtain a good 3D model. In order to improve the quality of architectural space layout, this article proposes an evolutionary DL-based feature extraction method for architectural space layout, and determines its edge sequence according to the extracted indoor space layout parameters. The evolutionary DL algorithm is used to control the convergence of feature parameters and complete the extraction of architectural space layout features. The results show that PSO-NN can obtain more reasonable, feasible and scientific spatial optimization results than standard traditional CNN, and its operation efficiency is obviously improved, which can provide scientific basis for architectural spatial planning. The CAD 3D model generation network extracts the features of multi-view images by transfer learning, and fuses the features by pooling the dimensions of the views. The overall structure and training method of the network are helpful for the network to converge faster and improve the accuracy. How to integrate the above models and optimize their performance to improve their working efficiency will be the focus of future research work.

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