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Computer-Aided Design AND APPLICATIONS

Design of Outdoor Space Based on Human-machine Interaction and Deep Learning

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Abstract. In essence, human-machine interaction (HMI) is the expansion of human wisdom and skills. It uses computers to simulate human senses such as vision, hearing and touch, and realizes efficient natural HMI between visitors and exhibits through 3D HMI technology. As the media of information integration, outdoor interactive space has achieved better display effect through cutting-edge interactive technology in its design process. Aiming at the complex outdoor scene, this article proposes a computer-aided design (CAD) method of outdoor space based on HMI and deep learning (DL). The laser point cloud mapped into a two-dimensional horizontal grid is divided into vertical units and horizontal units by using an adaptive variable threshold clustering algorithm, and the suspended environment characteristics in a 3D scene are effectively expressed. The results and data analysis prove the effectiveness and practicability of the outdoor space CAD method in this article.

Keywords: Human-Machine Interaction; Computer Aided Design; Outdoor Space; 3D Modeling
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1 INTRODUCTION

Due to the growth of control theory and HMI, the application environment of intelligent unmanned system has been extended to outdoor unstructured scenes, so the ground autonomous system with high throughput and adaptability to autonomous environment has become the research focus in this field. Deep learning-based color feature based indoor human following for mobile robots is a common human-machine interaction technology that can accurately understand and follow human behavior through machine learning algorithms. First, it is necessary to collect the image data in the indoor environment, which can be collected by cameras or other sensors. For the collected image data, preprocessing is required, including image preview, color space conversion, and normalization of image size. Use deep learning algorithms to extract features from preprocessed

image data, extracting feature information related to human behavior, such as the contour, posture, and motion trajectory of the human body. Based on the results of feature extraction, object detection algorithms can be used for human detection and recognition, including YOLO, Faster R-CNN, etc. Algabri and Choi [1] combine robot motion control commands with real-time image data to achieve real-time tracking of human behavior. It should be noted that in practical applications, other factors need to be considered, such as the mechanical performance of robots, sensor accuracy, environmental changes, etc., which need to be adjusted and optimized according to specific application scenarios. At the same time, deep learning algorithms also require appropriate parameter adjustments and model optimization to improve the accuracy and robustness of the algorithm. Interactive space is a kind of exhibition space with a sense of future science and technology, its composition depends on machines and 3D virtual information technology, and the industrial design of interactive machines involved also has certain industrial science and technology aesthetics. By using the design of interactive space, the actual function of machines and the industrial science and technology aesthetics of machines are presented and expressed at the same time. Space planning tool is a common indoor 3D space generation design tool that can be used to determine the layout and spatial allocation of buildings. It is usually designed using a visual interface based on the designer's experience and prior knowledge. Space planning tools can quickly generate preliminary design solutions, but further optimization and adjustments may be required to meet performance requirements. Topology optimization tool is an advanced indoor 3D space generation design tool that can be used to determine the optimal layout and connection of buildings to improve their performance and efficiency. It usually uses mathematical optimization algorithms that can automatically generate design solutions, but requires setting appropriate optimization goals and constraints. Topology optimization tools can generate high-quality design solutions, but may require longer computation time and more computing resources. Barbieri and Muzzupappa [2] determined the best layout and connection mode of the building to meet its Functional requirement. It usually uses methods such as simulation and experimentation to evaluate and compare different design schemes to determine the best design scheme. Performance driven design methods can generate high-performance design solutions, but they require a longer design and evaluation time, as well as the use of professional simulation and experimental tools. When the human brain processes the visual information, human beings will make a quick response and judgment to the environment. Therefore, it is an inevitable development trend for intelligent systems to endow machines with human visual functions, and this trend has a decisive impact on the growth of HMI. Computer vision focuses on the methods of acquiring, processing, analyzing and understanding digital images, and thinking about how to extract high-dimensional data and abstract digital or symbolic information from the real world. In the exploration of various new spaces, interactive space design has become a striking aspect of contemporary design. The roles of users and designers are vague, and they jointly create and determine the generation of space environment, which makes the concept of space design change and show various cultural meanings. For beginners in computational design, providing design references and guidance is very important. For example, some architectural design cases and tutorials can be provided to help them understand the principles and techniques of architectural design. In addition, some online architectural design tools and resources can be provided, such as an online architectural drawing library, design specifications, and tutorials, to help beginners better design. Beginners in computational design can obtain more help and support by providing interactive learning and communication platforms. Chen et al. [3] introduced virtual reality and augmented reality technology to construct a computational design novice for in-depth exploration of architectural design. Use virtual reality technology to create realistic architectural design scenes and models, allowing beginners to design and experience in a virtual environment. In addition, augmented reality technology can be used to combine architectural design elements with actual scenes to help beginners better understand and apply architectural design knowledge. Through these methods and measures, computational design novices can better grasp the basic knowledge and skills of architectural design, stimulate

their creativity and imagination, and thus create more excellent and practical architectural design works.

On the basis of CAD aided Interaction design of interior space, graphic transformation design is needed, including 2D graphic transformation and 3D graphic transformation. Graphic transformation design should consider user needs and practical application scenarios in order to achieve efficient and accurate design. On the basis of graphic transformation design, surface modeling and Solid modeling design are required to achieve more sophisticated and complex design. Surface modeling and Solid modeling design should consider the needs of different application scenarios in order to achieve more accurate and reliable design. After determining the Interaction design and graphic transformation design, it is necessary to consider the design of input devices, including mouse, keyboard, touch screen, etc. The design of input devices should consider the user's usage habits and needs in order to achieve efficient and accurate input. Erdolu [4] conducts testing and evaluation after completing Interaction design, graphic transformation design and input device design to verify the feasibility and effect of the design. Testing and evaluation should include user testing, functional testing, performance testing, etc. to identify and address potential issues and risks. Urban management and urban planning need accurate urban spatial structure information, and it is a universal demand for urban management, urban planning and intelligent transportation system to create and update accurate urban models and urban spatial model databases at this stage of urban development. In today's digital age, thousands of information data are generated all the time, among which images are an important way for human beings to perceive information, and the image content is often intuitive and rich. The main purpose of computer vision research is to make computers have the ability to perceive and understand the contents of images like human beings, so it has become an indispensable direction of HMI research. With the increasing demand for 3D spatial information, 3D models should not only have high geometric accuracy and visual realism, but also provide richer scene knowledge and semantic information. Because the outdoor environment is unstructured, random and complex, the effective modeling of the 3D environment by the ground autonomous system is the basis for its autonomous navigation and environmental exploration. Because different kinds of segmentation algorithms have the best applicability, different point cloud segmentation methods can be used according to different scene combinations to overcome the shortcomings of each segmentation method, so as to achieve the best segmentation effect. Semantic 3D model can ensure users' full cognition of the scene, enhance the user experience, and support object tracking and retrieval, thus deepening the usability of location services.

Biomimetic architecture is a branch of architecture that focuses on the functional organization and image composition of certain organisms in the biological world. Its purpose is to optimize the design and function of buildings by applying the natural laws and principles of the biological world. Among them, the application of bio inspired adaptive envelope is an important biomimetic technology that can make buildings more adaptable to the environment and improve their performance. Bioinspired adaptive envelope refers to an adaptive feature on the surface of an organism that enables it to better adapt to changes in the external environment and maintain its stability and functionality. In biomimetic architecture, this technology can be applied to the exterior walls, roofs, doors and windows of buildings to enhance their adaptability, functionality, and aesthetics. Hafizi and Karimnezhad's [5] use of sustainable materials refers to the use of environmentally friendly, renewable, or recyclable materials for building construction. This approach can reduce environmental damage and resource waste, while improving the quality and sustainability of buildings. In short, bio inspired adaptive envelope based biomimetic architecture can help us better understand and apply the laws and principles of nature, while also improving the performance, comfort, and sustainability of buildings. The growth of new calculation theory, structural form, building materials and new industrial technology has a far-reaching impact on modern architecture, and one of the most remarkable features is the extensive application of spatial structure. Outdoor space carrying complex information includes not only the communication between people in different spaces and at different times, but also the communication between people and things, people and the environment. Scientific and systematic processing of these

complex and diverse outdoor space information can not only ensure the smoothness of information dissemination, but also avoid bringing property and even life damage to people and cities in some special scenes. Using CAD model, designers can easily analyze and adjust spatial objects, thus achieving the purpose of interactive design. The research on contemporary interactive space design from the perspective of philosophical irrationality deepens the space cognition, enriches the design connotation and expands a new perspective for space design creation. This article presents an outdoor space CAD method based on HMI and DL:

(1) In this article, the typical scenes in outdoor 3D environment are identified by using the Convolutional Neural Network (CNN) model, and the vertical units are sampled in a highly discrete way, thus the corresponding topological structure is constructed.

(2) Aiming at the complex outdoor scene, a CAD 3D modeling method based on topological elevation model is proposed, and the laser point cloud mapped to the 2D horizontal grid is divided into vertical units and horizontal units by using the adaptive variable threshold clustering algorithm, so as to realize the effective expression of the suspended environment characteristics in the 3D scene.

This article first introduces the development requirements of outdoor display design of outdoor space, then puts forward an improved method of computer-aided 3D modeling of outdoor space combined with DL model, and finally verifies the effectiveness of this method in outdoor space design.

2 RELATED WORKS

Digital manufacturing refers to the use of digital 3D printing, CNC machining and other technologies to convert digital models or drawings into actual objects. Through digital manufacturing technology, high detail models and parts can be produced, enabling rapid prototyping and production. CNC machining is a manufacturing technology based on digital models, which uses computer-controlled machine tools for cutting processing. CNC machining can process materials such as metals and plastics, achieving high-precision manufacturing. By combining CAD software and digital manufacturing technology, Jose et al. [6] quickly produced high-detail models and parts. Digital manufacturing technology can achieve rapid prototype manufacturing, and samples can be produced in a short period of time for testing and evaluation. Digital manufacturing technology can reduce manufacturing costs and save costs when producing multiple samples or a small amount of production. Digital manufacturing technology can select different types of materials for processing and can be selected according to design requirements. In a word, the combination of Computer-aided design and digital manufacturing technology can help designers and engineers to quickly produce high detail models and parts, and improve design quality and production efficiency. In architectural applications, biomimetic folding mechanisms are a new type of mechanism design that can achieve flexible, efficient, and foldable applications of building structures. Krner et al. [7] conducted a three-dimensional modeling of a biomimetic folding mechanism, establishing the overall structure of the mechanism and detailed models of each component. Through structural modeling, comprehensive analysis and optimization of the overall and detailed structure of the mechanism can be achieved. The movement simulation of the mechanism is carried out by using Computer-aided design software to simulate the movement state and performance of the mechanism under different conditions. Through motion simulation, we can analyze the motion law, force condition, motion track, etc. of the mechanism, and then optimize the design of the mechanism to improve the stability and reliability of the mechanism. In the process of mechanism design and manufacturing, it is necessary to select appropriate parameters, such as size parameters, material parameters, etc., to ensure the optimal performance of the mechanism. These sensors can include temperature sensors, humidity sensors, light sensors, motion sensors, etc., used to collect environmental data and user behavior information. These data can be transmitted through network connections to the responsive architecture of an intelligent environment for analysis and processing. The responsive architecture

of an intelligent environment refers to its ability to dynamically adjust its functionality and performance based on the environment and user needs. Through intelligent analysis, intelligent environments can better understand users' needs and preferences, and provide more intelligent and personalized services. In summary, an intelligent environment is an interactive and collective platform. Lee et al. [8] implement key behaviors through sensor responsive architecture, monitor and respond to changes in the environment and user needs, and provide more intelligent and personalized services. Having both responsive architecture and collective platform characteristics, it can achieve information sharing and collaborative work. Lin [9] uses a universal algorithm framework to help architects model topology algorithms by inputting geometric intentions. It first defines a data structure to store the geometric intent and topology information of the input. Use two-dimensional array, Adjacency list, Adjacency matrix and other data structures to represent graphs or networks. Design an algorithm flow to process topology information based on the input geometric intent. According to the designed algorithm flow, implement specific algorithm logic. For example, you can use C++, Python and other programming languages to implement algorithms such as Depth-first search or Breadth-first search. Finally, the processed topology Information visualization can be output visually for users to better understand and analyze. You can use some visualization tools, such as Graphviz, Matplotlib, etc., to visualize and output graphics or networks. This algorithm framework can help architects model topology algorithms by inputting geometric intentions. By defining data structures, designing algorithm processes, implementing algorithms, testing and debugging, and visualizing output, a universal topology algorithm model can be constructed, suitable for different geometric intentions and application scenarios.

CAD based topology optimization system is a computer-aided design tool for optimizing geometric shape and structure. The system uses a topology optimization algorithm based on a variational model, which finds the optimal structure by minimizing the deformation energy of the structure under a certain load. This algorithm considers factors such as the geometric shape of the structure, material distribution, and boundary conditions to determine the optimal structural design. By incorporating the dynamic response of the structure into the optimization process, more accurate and reliable structural design can be achieved. Liu and To [10] analyzed that the system has a visual user interface that allows users to easily create, modify, and evaluate designs. The visualization interface can display information such as the geometric shape, material distribution, constraint conditions, and optimization results of the structure, to help users better understand the optimization process and results. Different optimization algorithms, constraints, and optimization objectives can be selected based on specific application requirements to achieve the best structural design. CAD based topology optimization system is a powerful Computer-aided design tool, which can help engineers and designers better understand and optimize geometric shapes and structures. By considering factors such as dynamic feature shapes and modeling historical evolution, more accurate and reliable structural design can be achieved. Auto CAD can be combined with virtual reality technology to provide students and teachers with an interactive and immersive learning experience. By creating virtual models and scenes, students can conduct simulation operations on computers and gain a deeper understanding of building design and construction processes. Auto CAD can be integrated with data analysis and visualization tools to help teachers and students better understand and analyze data in building design and construction processes. For example, Auto CAD can be used to collect size and performance data of buildings and import them into data analysis software for further analysis and visualization display. Ma et al. [11] using Auto CAD to design a network architecture teaching system can help teachers and students better understand and master the process of architectural design and construction, improve teaching effectiveness and learning efficiency. At the same time, this system can also provide students with a wider range of practical opportunities, helping them better adapt to the needs of practical work scenarios. In interior design, the combination of Computer-aided design (CAD) and augmented reality (AR) technology can provide many advantages, one of which is volume video. Volume videos can add dynamic elements to interior design, providing a richer and more intuitive experience. In the design of the director's room at the Trinity College Museum, O'dwyer et al. [12] used volume videos to provide users with a more intuitive understanding of the

design's appearance and spatial experience. By adding volume videos to CAD models, users can browse and adjust design plans in real-time during the design process, better understanding the details and characteristics of the design plan. By using volume videos, users can more clearly perceive the scale and proportion of space. By combining volume video with AR technology, users can browse design solutions in real space, thereby better understanding the effectiveness of design solutions in actual environments. Volume videos can provide users with dynamic elements, such as rotating 3D models, dynamic textures, and colors. These dynamic elements can make the design scheme more vivid and attractive, while also helping users better understand and remember the details of the design scheme. By combining CAD and AR technology, designers can better achieve design goals while improving design efficiency and quality.

Additive Construction is an advanced construction method that allows for the production of building structures by printing materials layer by layer. CAD/CAM (Computer-aided design and Computer-aided manufacturing) system is a very important tool in building additive manufacturing, which can be used to design and manufacture complex building structures. In CAD/CAM systems, topology optimization is a very important technique that can be used to determine the optimal layout and connection method of building structures, in order to improve the strength, stiffness, and stability of the structure. Topology optimization is usually achieved using mathematical optimization algorithms, among which the robust and efficient topology optimization algorithm based on function representation is a very useful algorithm. A robust and efficient topology optimization algorithm based on functional representation can represent a building structure as a mathematical function, and use optimization algorithms to find the optimal function value to determine the optimal layout and connection method of the building structure. Popov et al. [13] optimize the layout and connection of building structures to improve their strength, stiffness, and stability. By optimizing the design parameters of building structures, the weight of the structure is minimized, thereby reducing manufacturing and transportation costs. By optimizing the design parameters of building structures, the energy efficiency and environmental friendliness of buildings can be improved. The principle of embedded steady-state is an important concept in architectural design, which emphasizes the coordination and adaptability between the building and its environment. How to adapt to excessive solar radiation is an important consideration in the design of architectural forms and skins. Firstly, it is necessary to understand the environmental and climatic conditions of the building location, especially the situation of solar radiation. Historical meteorological data, solar trajectory data, and local sunlight can be collected to better understand the problems faced by buildings. Showkatbakhsh et al. [14] analyzed the adaptability and response measures of buildings to solar radiation based on their functions and needs. Define design goals based on the analysis results of the environment and requirements. These goals should be flexible for adjustment and optimization in the subsequent design process. Explore different design options based on design goals. When implementing the design, attention should be paid to the selection of materials, the quality of construction, and the setting of monitoring systems. After implementation, it is necessary to regularly monitor the performance of the building in order to adjust and optimize the design. Tai and Sung [15] used computer-aided methods to digitally archive the perception and experience of architectural space. By collecting relevant data on architectural space, including information on space size, shape, layout, materials, colors, and other aspects. The laser scanner, 3D camera, Total station and other equipment can be used for data acquisition, and the collected data can be processed and integrated to obtain a digital model of the building space. In addition to collecting spatial data, it is also necessary to collect human perception data in the building space. Analyze and process the collected spatial and perceptual data, and convert them into digital archives. You can use Computer-aided design software (such as AutoCAD, SketchUp, etc.) to build and edit spatial models, store and archive models. The archived digital models can be visually displayed, and Computer-aided design software can be used to render and present the models, so as to achieve a more realistic and vivid display of architectural space.

Hybrid Evolutionary algorithm is a hybrid algorithm based on Evolutionary algorithm and other optimization algorithms. It combines the advantages of different algorithms to form a more

efficient and powerful optimization method. In the field of conceptual architectural design, hybrid Evolutionary algorithm can be used to solve complex design problems, such as architectural design, structural design, etc. Firstly, it is necessary to determine design variables, namely design parameters that can be optimized and adjusted, such as the shape, size, materials, etc. of the building. Wang et al. [16] define one or more objective functions based on design requirements and objectives to evaluate the quality of the design. The objective function can be an indicator of aesthetics, functionality, sustainability, and other aspects. The intelligent generation method of building structures based on topology optimization and deep learning is an intelligent building structure design method that combines topology optimization and deep learning technology. Wang et al. [17] used deep learning neural network technology to intelligently generate and optimize building structures. By training neural networks, the characteristics and laws of building structures can be learned, and more innovative and practical building structures can be generated based on these characteristics and laws. The Surrogate model is a mathematical model used to approximate physical experiments, which can be applied to topology optimization and performance improvement of building structures. By building a Surrogate model, virtual experiments can be carried out on computers to optimize the design of building structures and reduce the cost and risk of physical experiments. In topology optimization based architectural design and development, detail control strategy is a very important part. Yan et al. [18] used parametric design methods to define and control variables and parameters during the design process. By adjusting and optimizing parameters, topology optimization and performance improvement in architectural design can be achieved. A lightweight mobile outdoor augmented reality method that uses deep learning and knowledge modeling for scene perception to improve the learning experience. This method uses sensors and cameras to collect data on the outdoor environment, including geographic location, temperature, humidity, light, images, and sound. Zhao et al. [19] preprocessed the collected data, including denoising, correction, and standardization. Use deep learning models to classify and recognize preprocessed data to determine the current scene. You can use models such as Convolutional neural network (CNN) or Recurrent neural network (RNN) for scene perception. Based on the current scenario, select the corresponding knowledge models from the knowledge base, including geographic models, biological models, historical models, etc. You can use technologies such as Knowledge graph or rule engine to model knowledge. Combining knowledge models with the actual environment, augmented reality technology is used to overlay virtual elements into the actual environment, providing a more diverse and interactive learning experience. It can be implemented using augmented reality frameworks such as ARCore or ARKit. Receive user input and feedback through technologies such as touch screen or voice recognition to adjust the presentation and effectiveness of augmented reality content. Based on user interaction and feedback, update the knowledge model and environmental data to continuously improve scene perception and enhance the effectiveness of reality presentation. The advantages of this method are lightweight, scalable, and highly interactive, which can improve the experience and effectiveness of outdoor learning through deep learning and knowledge modeling.

In this article, an outdoor space CAD method is proposed based on the design concept of HMI and DL intelligent model. This method combines CNN model to identify typical scenes in outdoor 3D environment, and adopts adaptive variable threshold clustering algorithm to realize effective expression of suspended environment characteristics in 3D scene.

3 OUTDOOR DISPLAY DESIGN OF OUTDOOR SPACE

In the modern society where information is expanding day by day and technology is highly developed, people need more ways to get effective information and more communication and exchanges. As a unique space for cultural exchange, with the rapid growth of the times and the constant changes of people's needs, the exhibition space is no longer limited to the simple functional satisfaction of displaying items, and the modern exhibition hall has become the main place for public information sources and cultural exchanges. Exhibition space is a medium to transmit effective information in modern society, which can integrate information and spread it

fully and effectively between people and between people and society. The optimization of information in urban outdoor space not only needs multidisciplinary and interdisciplinary research and cooperation, but also needs to stand on the basis of people-oriented, have a deep understanding of the different needs of different people and scenes in public environment, and show them through environmental design, product design, interactive design and other means.

The outdoor display design of outdoor spaces is an important field of design, which can create attractive display spaces through reasonable planning and design to display products, promote brands, or hold events. The following is the process of outdoor display design:

Clear design objectives: Firstly, it is necessary to clarify the design objectives, including the display content, display purpose, display time and location, etc.

Select a display venue: Based on the design objectives, choose a suitable display venue. The venue should consider factors such as pedestrian flow, safety, display effectiveness, and operability.

Determine display architecture: Design the display architecture, including display layout, booth design, and display placement.

Consider visual elements: Use visual elements to attract the audience's attention, including displayed colors, fonts, graphics, and lighting.

Choose appropriate materials: Choose appropriate materials to build the display space, including brackets, fabrics, lighting fixtures, etc.

Consider interactivity: In order to attract more viewers, some interactive elements can be designed, such as touch screens, demonstration platforms, interactive games, etc.

Safety considerations: During the design process, safety issues need to be considered, such as the fixation of exhibits, the stability of booths, and the safety of visitors.

Installation and testing: After completing the design, installation and testing are required. During the installation process, it is necessary to consider the safety of personnel and the protection of exhibits.

Monitoring and maintenance: During the display process, it is necessary to monitor the condition of the exhibits and the reactions of the audience, and make timely adjustments and maintenance.

It should be noted that outdoor display design needs to consider multiple factors, including natural environment, social culture, economic factors, etc. At the same time, innovation and practicality need to be emphasized in the design process to meet the needs and expected effects of the audience.

The interactive design in modern exhibition space design revolves around the exhibition theme, and uses various scientific and technological media technologies to carry out two-way situation design. The audience can not only receive more colorful knowledge theories in the participation experience, but also be inspired by the subconscious mind in the interactive environment. Intelligence is also an important design of HMI. Intelligent design mainly makes people feel that they are in an optimal state under any circumstances. Intelligent interactive design will improve people's living standards and change their living environment. In essence, HMI is the expansion of human wisdom and skills. It uses computers to simulate and realize human senses such as vision, hearing and touch, and realizes efficient natural HMI between visitors and exhibits through 3D HMI technology. The hierarchical matching strategy oriented to topological structure and elevation map unit is adopted to realize accurate matching between different scenes and build a topological elevation map with global consistency. Using the identified environmental characteristics and elevation map to generate dual environmental constraints, autonomous path planning adapted to outdoor terrain can be realized.

4 3D MODELING OF OUTDOOR SPACE CAD

4.1 Outdoor Space Image Segmentation and Feature Extraction

Image-based 3D scene modeling technology has the advantages of low data acquisition cost and high efficiency of automated model, which greatly reduces the cost of modeling, makes it possible to model a large-scale, high-precision and automated city, and further promotes the wide application of urban 3D models in smart cities, smart transportation and other fields. However, where the environmental characteristics are not obvious, the lack of matching characteristics will make the empty 3D solution unreliable and lead to the failure of model generation; Where the image is occluded, there is no matching point, which will lead to model loopholes, distortion and so on. Problems such as distortion, large amount of model data, and difficulty in model simplification make it relatively difficult to carry out subsequent applications of 3D models based on image generation. Image 3D scene modeling has good effect in outdoor or shooting scenes with good viewing angle, but it is difficult to effectively restore the scene structure in indoor environment.

In essence, CNN belongs to a multi-layer perceptron. It has the advantages of unique local connection mode and shared weights, which not only greatly reduces the model parameters to make the network more convenient to optimize, but also effectively prevents the network data from being over-fitted. The CNN image processing mode is shown in Figure 1.

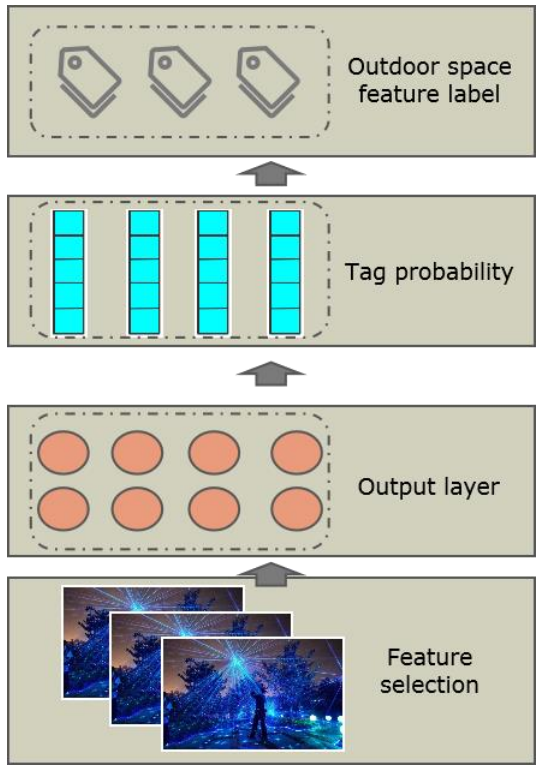

Figure 1: CNN model.

Assuming that the input and output functions of outdoor space image feature information are expressed as R and R' respectively, the bilateral filtering discrete form expression of outdoor space image feature information is as follows:

$$R'=[k,\ j]=\sum_{m=-p}^{p}\sum_{n=-p}^{p}B[m,n,k,\ j]R[k-m,\ j-n] \tag{1}$$

Where p represents a pixel of outdoor space image feature information; m represents the variance of outdoor space image feature information; n represents the standard deviation of outdoor space image feature information; $B[m,n,k,\ j]$ represents Gaussian kernel function of outdoor space image feature information, and its calculation expression is as follows:

$$B[m,n,k,\ j]=\frac{\exp\left(-\frac{m^2+n^2}{2\sigma_\delta^2}-\frac{R[k-m,\ j-n]}{2\sigma_\xi^2}\right)}{R(k,\ j)} \tag{2}$$

Where σ represents the scale parameter of outdoor space image feature information.

According to the different data sources used, there are also differences in the corresponding processes of scene 3D information recovery. Image-based 3D scene modeling method uses collinear equation of camera photography, realizes the positioning and attitude determination of measuring equipment through backward intersection, and maps the measured values into 3D space through forward intersection to obtain the 3D model of the scene. The operation flow of CNN model for image segmentation is shown in Figure 2.

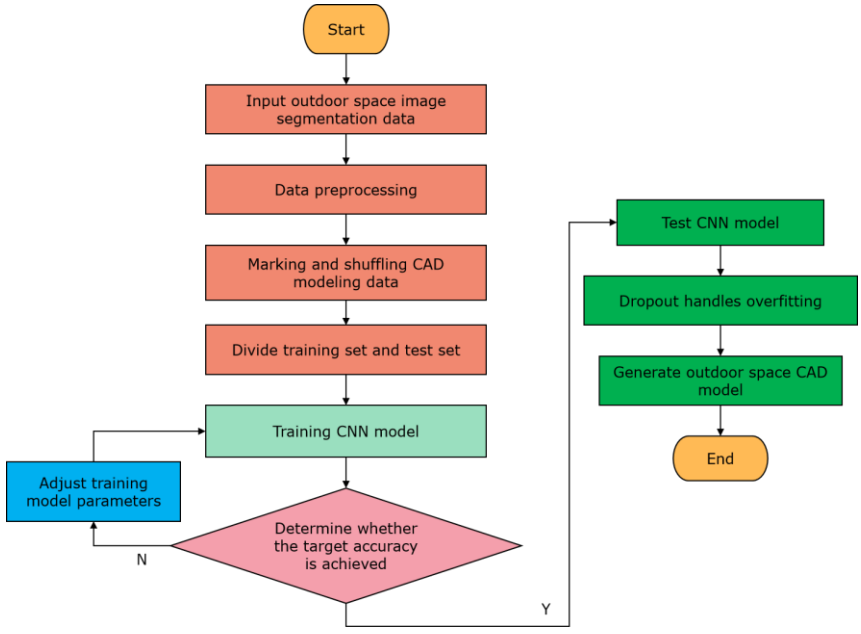

Figure 2: Operation flow of CNN model for image segmentation.

Image x_i represents the information of all pixels in a picture, and the category it represents is y_i. Through the scoring function (neuron) and activation function $f(x_i,W)$, the scoring s_j of different categories to which x_i belongs can be obtained. Then, the loss function of x_i for category prediction can be expressed as:

$$L_i = \sum_{j \neq y_i} \max\left(0, s_j - s_{y_i} + \Delta\right) \tag{3}$$

$\max(0,-)$ function is a threshold function about zero. The function in Softmax is defined as:

$$L_i = -\log\left(\frac{e^{f_{y_i}}}{\sum_j e^{f_{y_j}}}\right) \tag{4}$$

The derivative expression of one-dimensional function is:

$$\frac{df(x)}{dx} = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \tag{5}$$

4.2 3D Modeling of Outdoor Interactive Space CAD

In CNN model, attention mechanism has its unique importance, and most models will apply its attention mechanism characteristics to improve the performance of their own models. In this article, the attention mechanism is introduced into the multi-scale features of different layers, so that the network can adaptively focus on the salient feature information of objects at each level of the image, and can improve the understanding of multi-scale scenes to the object level. Finally, the feature maps of different scales obtained at different levels are adjusted to the same scale for fusion processing. The principle of image information fusion for outdoor space modeling is shown in Figure 3.

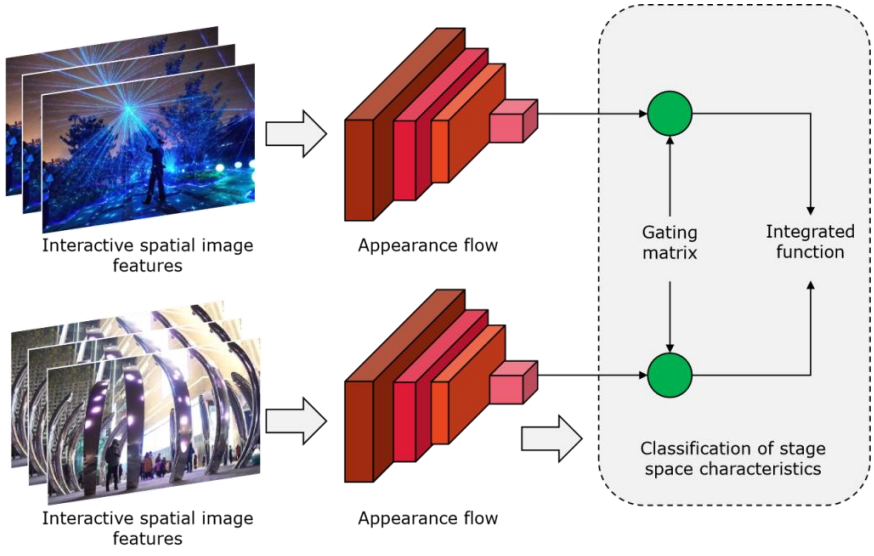

Figure 3: Image information fusion of outdoor space modeling.

The point cloud in the original image is preprocessed based on median filtering;

$$\psi_{i,j} = median\left[\Lambda_{i+m,j=n}; (m,n) \in w\right]\left\{\Lambda_{ij}; (i,j) \in Z^2\right\} \tag{6}$$

Where: m and n represent the size of the window in the horizontal and vertical directions respectively; w, Z^2 respectively represent the plane window specification and the serial quantity

of the two-dimensional data string; Λ_{ij} and $\psi_{i,j}$ respectively indicate that the point cloud coordinates on the image are the output values of (i,j) after median filtering.

In the 3D space, on the a-th image, the minimum calculation method of the square sum of the distance between the vertical projection point of the space point g and the pixel point $\hat{\omega}$ is as follows:

$$\min = \sum_{g=1}^{g}\sum_{a=1}^{A} v_{ga} d\left(E_a S_g, \hat{w}\right)^2 \tag{7}$$

The process of obtaining the attribute information of objects in the spatial data to be processed for analysis and classification is called feature extraction. Feature selection is an important data analysis process, an important step to realize the classification of objects in outdoor scenes, and a process to explicitly express imperceptible information hidden in discrete point clouds. Let the probability distribution of random variable set $X=\{X_1, X_2, \ldots, X_n\}$ be $P(X_1, X_2, \ldots, X_n)$. If all variables are taken as $\{0,1\}$, 2^n-1 parameters are needed to determine the joint distribution. Through Bayesian formula, the joint distribution can be written as:

$$\begin{aligned} P(X_1, X_2, \ldots, X_n) &= P(X_1)P(X_2|X_1)\ldots P(X_n|X_1, X_2, \ldots, X_{n-1}0) \\ &= \prod_{i=1}^{n} P(X_i|X_1, X_2, \ldots, X_{i-1}) \end{aligned} \tag{8}$$

For $\forall X_i \in X$, if there is $\pi(X_i) \subseteq \{X_1, X_2, \ldots, X_{i-1}\}$, the X_i assimilation $\{X_1, X_2, \ldots, X_{i-1}\}/\pi(X_i)$ condition is independent at a given $\pi(X_i)$, and the above formula can be changed to:

$$P(X_1, X_2, \ldots, X_n) = \prod_{i=1}^{n} P(X_i|\pi(X_i)) \tag{9}$$

For some outdoor objects with obvious characteristics such as artificial buildings, unsupervised classification can basically meet the requirements of classification accuracy. However, if the classification object is a complex outdoor scene, its typical feature is that the scene contains different kinds of ground information, such as different buildings, plants or complex ground conditions. Because the analysis and feature selection of the data to be processed will directly affect the subsequent effect of data processing, extracting the distinguishing features from the point cloud data to be processed will play a positive role in promoting the analysis and classification of the data.

5 RESULT ANALYSIS AND DISCUSSION

In order to verify the effectiveness of different algorithms, this article selects the classic outdoor scene 3D point cloud data set, tests the typical point cloud segmentation algorithm, and analyzes the effectiveness and applicability of the algorithm. For the outdoor interactive space image segmentation model based on DL and the traditional modeling method, a contrast experiment is set up to discretize the image data with different regional distributions, as shown in Figure 4.

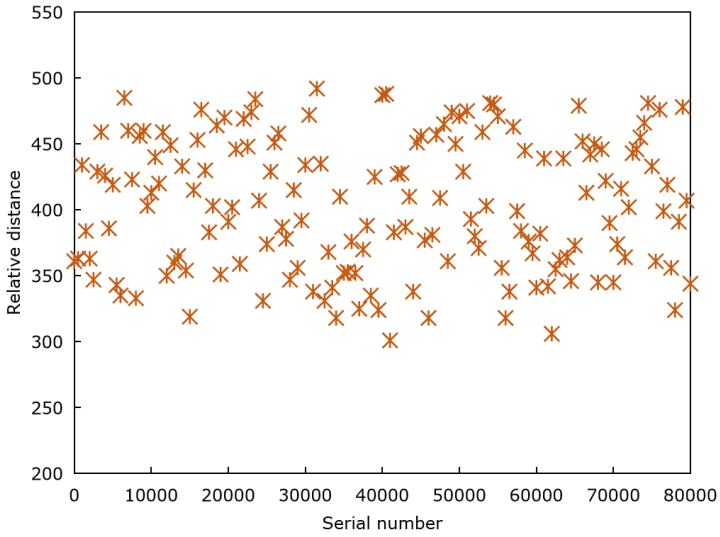

Figure 4: Interval discretization processing.

Because objects in outdoor scenes often present complex 3D states, this complexity usually stems from the non-uniformity of object characteristics, such as different ground objects with different sizes, shapes, densities and distribution laws. Therefore, this feature makes the classification of ground object point clouds in outdoor scene point cloud data more complicated than the segmentation of ground points. The modeling precision comparison results of this algorithm with particle swarm optimization (PSO) algorithm and ant colony optimization (ACO) algorithm are shown in Figure 5.

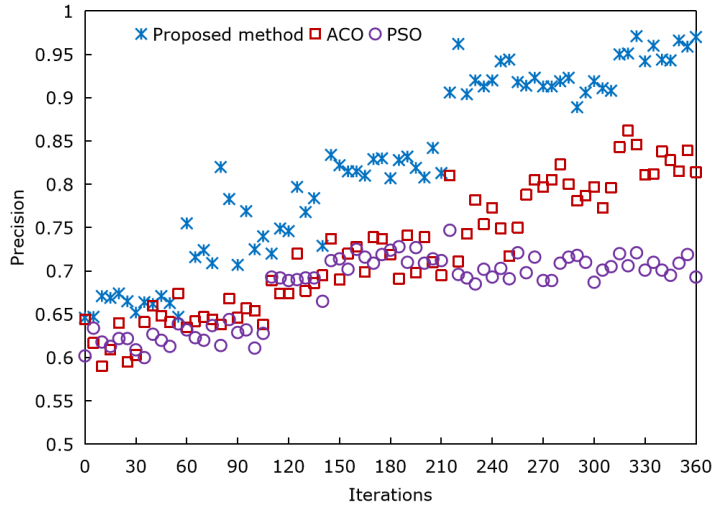

Figure 5: Precision comparison of modeling algorithms.

The spatial modeling precision of the algorithm in this article is better than the traditional modeling method after iteration, reaching more than 95%. For some outdoor objects with obvious characteristics such as artificial buildings, unsupervised classification can basically meet the requirements of classification accuracy. However, if the classification object is a complex outdoor scene, its typical feature is that the scene contains different kinds of ground information, such as

different buildings, plants or complex ground conditions. Because the analysis and feature selection of the data to be processed will directly affect the subsequent effect of data processing, extracting the distinguishing features from the point cloud data to be processed will play a positive role in promoting the analysis and classification of the data. Figure 6 shows the change of precision when the time factor is between 0 and 1.

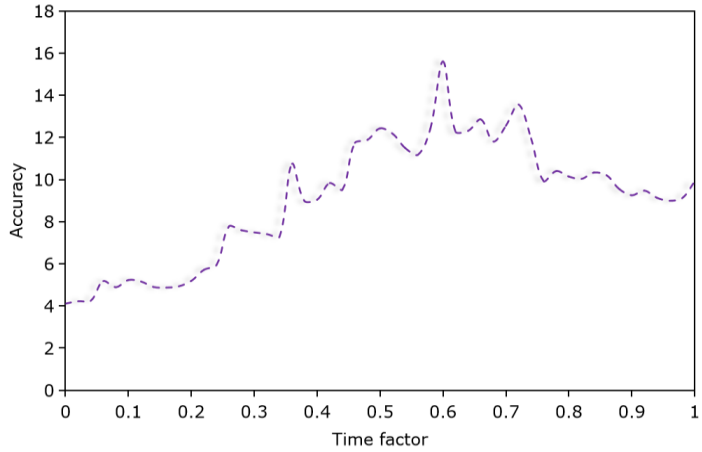

Figure 6: Relationship between time factor and precision.

For outdoor scenes, different types of point cloud data often show certain regularity at different scales, that is, different types of ground objects often have stable geometric dimension characteristics at different dimensions. In general, the minimum scale should be greater than the minimum density of point cloud data, and the maximum scale can be defined according to the actual size of vegetation. The size of the maximum scale starts from the minimum scale and increases according to the size of scale interval. Figure 7 shows the comparison of the recall between the proposed algorithm and the traditional algorithm.

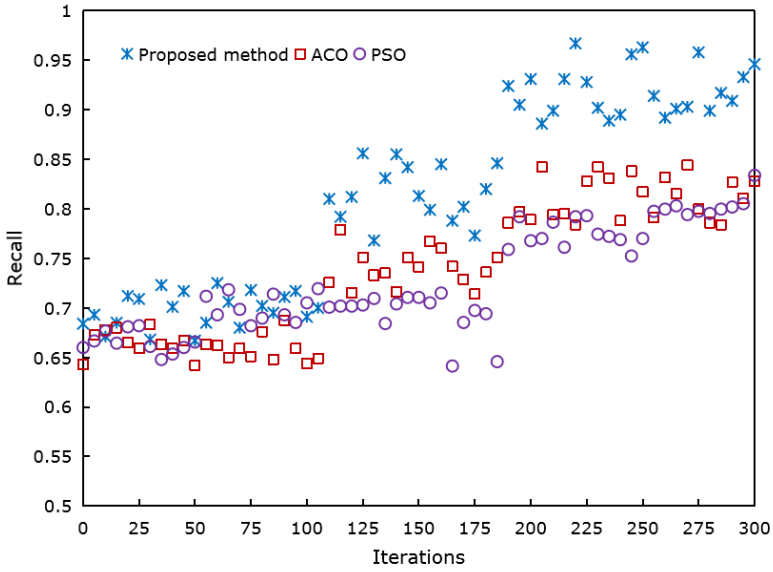

Figure 7: Comparison of recall of algorithms.

The comprehensive results show that the modeling precision and image segmentation algorithm recall of this method are improved to some extent compared with the traditional methods. The ultimate goal of design is no longer commodities, but users, which means that the design direction of exhibition design is no longer just exhibits, but should pay more attention to people's emotional experience, that is, the emotional communication between visitors and exhibits during the exhibition process. Through the development and application of this kind of CAD method, we can fully promote the audience's sensory interaction with outdoor space, stimulate the audience's sense of novelty and excitement, and effectively improve their reading and understanding ability of interactive content.

6 CONCLUSION

In the exploration of various new spaces, interactive space design has become a noticeable aspect in contemporary design. Outdoor space carrying complex information includes not only the communication between people in different spaces and at different times, but also the communication between people and things, people and the environment. With the increasing demand for 3D spatial information, 3D models should not only have high geometric accuracy and visual realism, but also provide richer scene knowledge and semantic information. In this article, an outdoor space CAD method is proposed based on the design concept of HMI and DL intelligent model. The results show that the modeling precision and image segmentation algorithm recall of this method are improved to some extent compared with traditional methods. Through the development and application of this CAD method, the sensory interaction between audience and outdoor space can be fully promoted. Because the point cloud data collection is affected by the collection perspective, most elements in the scene cannot be scanned completely, so the morphological structure of the segmented target needs to be improved before the key parameters are extracted. Although the region with strong similarity can be divided into a whole according to the spatial distribution characteristics of point clouds, the final segmentation and classification results still need to be optimized and improved semantically.

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