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Research and Implementation of Intelligent Interior Design Algorithms Based on Artificial Intelligence and Big Data

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***Abstract*—In the past few decades, interior design has relied on manual experience and designer intuition, during which time was consumed and the design results often failed to meet customer needs. Intelligent interior design is an emerging field based on artificial intelligence and big data technology, which aims to provide efficient and personalized interior design solutions through intelligent algorithms and data analysis. Therefore, this article's research on the application of intelligent design in indoor space has great practical significance and practical value. In this article, artificial intelligence and big data technology and their expansion of intelligent algorithms are analyzed with emphasis, and experiments and performance comparisons of several algorithms related to interior design are conducted. This article uses an interactive method to compare the running time of genetic algorithms, evolutionary algorithms and differential evolution algorithms. Experimental results show that the interactive evolutionary algorithm takes 56.2ms and the interactive genetic algorithm takes 33.6ms.**

Keywords—Artificial Intelligence, Big Data, Intelligent Algorithm, Interior Design

I. INTRODUCTION

Interior design is a must-have when people buy a new home, and it can be troublesome to choose a design that satisfies them. Therefore, we can first understand some design needs online, and then we can be more professional when looking for designers to design, and we can also put forward opinions that are more suitable for us. Intelligent computing is a branch of artificial intelligence that plays a huge role in computers. As new information technologies such as Internet technology and communication technology continue to develop and mature, people have put forward higher requirements for information processing. Intelligent interior design uses artificial intelligence and big data technology to analyze a large amount of interior design-related data, automatically generate design plans and carry out personalized customization.

The application of artificial intelligence and big data in the field of interior design provides interior designers and owners with more efficient and innovative design solutions. In terms of artificial intelligence, smart home systems can interact with users through sensors and smart devices, obtain user preferences and demand information in real time, and conduct personalized interior design based on the user's preferences and living habits. Virtual reality technology provides a brand-new design experience. Users can experience the design effect three-dimensionally through devices such as virtual reality glasses, making the design more intuitive and real. In terms of big data, we collect and analyze a large number of interior design case data, master various design plans with different styles and needs, and provide us with rich reference and reference. At the same time, big data analysis can also predict user demand trends and better meet user expectations.

This article first explains the development of artificial intelligence and big data in the first part, and briefly describes the background of smart interior design. In the second part, this article introduces in detail the research on interior design by other scholars, including the application of three-dimensional models, machine learning, digitalization, etc. in interior design. In the third part, this article first analyzes artificial intelligence and its role in interior design, and then introduces the application of big data, including Hadoop, Spark, Hive, etc. Subsequently, this article briefly discusses the intelligent interior design algorithm, lists relevant formulas, and then builds a recommendation system. In the fourth part, this article conducts experimental testing of the designed system.

II. RELATED WORK

In order to solve the problems of large color range, low structural similarity and poor objective evaluation index in the process of color transmission in interior design, Tiesheng Liu proposed a new method of color transmission in interior design based on machine learning. This method introduces the K-means algorithm to eliminate the range of uneven brightness of the target image. An initial grouping of target images is performed, and an iterative threshold segmentation method is used to obtain the final grouped accurate target images [1]. In order to improve apartment recommendation and user satisfaction, Guohui Fan and Chen Guo proposed a customized indoor style optimization algorithm based on local social networks, including obtaining (three dimension, 3D) model data, defining apartment attributes and exploring style associations. They analyzed user behavior, established

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corresponding user interest models, and combined location-based social network rule exploration algorithms to perform correlation analysis on interior design style 3D model data sets [2]. The interior design industry has evolved to promote advanced digital and interactive virtual reality technologies. Using a virtual configuration platform for marketing not only creates a positive image for the interior design company, but also allows customers to visually experience home design on a digital platform. Yuk-Ming Tang, Yui-yip Lau, and Uen Lam Ho investigated the relationship between the aesthetics, usability, and quality of information and consumer satisfaction in digital marketing [3]. Interior designers have an exceptional ability to generate innovative ideas and solutions. Sucheta Nigam, Vibha Kapoor believes that it is important to express the idea or communicate with the client effectively so that they can understand the project. Designers and architects believe that there are two ways of expressing ideas or communicating with clients: two-dimensional and three-dimensional presentations. Customers' experience and perception of these presentations depends on some elements they perceive. They compared 2D and 3D representations and the elements that shape customer experience with 2D and 3D representation trends [4]. There is a strong interest in the vocabulary of cultural heritage, which is the first pillar that determines the different intellectual trends in interior design schools, since these intellectual trends originate from human needs related to customs, traditions, religious culture and folk art that combine a group is distinguished from another group. Therefore, the research question is to identify the elements and determinants of cultural heritage in interior design, especially in contemporary interior design trends in design knowledge. The purpose of Hani Khalil Farran is to highlight the role and importance of cultural heritage vocabulary in influencing the education and education of various conceptual schools among intellectuals [5]. Priyanka Vashisht believes that the use of artificial intelligence technology to diagnose neurodevelopmental disorders and identify patterns and characteristics can improve the accuracy and efficiency of diagnosis [6]. Maxyn Leitner Developed a game-based high school artificial intelligence education method, aiming to improve students' interest in course teaching, combined game elements, designed interactive and interesting learning experience [7]. Avinash Agarwal Investigate the fairness scoring and process standardization in the AI system deeply. He proposed the evaluation framework, developed the evaluation indicators and the standardized process [8]. Hutan Ashrafian pointed out that algorithmic game theory and artificial intelligence enabled Rolls distributive justice, and he discussed [9] on the method of allocating resources and opportunities in commons. Michael Guerzhoy Put forward AI education, and envision the intelligent [10] of education through artificial intelligence. Ibrahim Elsiddig Ahmed Bank risk monitoring is crucial in avoiding and reducing losses. Therefore, he proposed the application of artificial intelligence to develop the bank risk index model, and to use the adaptive neural network fuzzy inference system for risk modeling and analysis of [11]. Hans-Christian von Herrmann explores the relationship between literature and artificial intelligence, [12]. Helen Piel, Rudolf Seising provides a comprehensive overview of the AI development in Europe from the perspective of artificial intelligence, and summarizes the current situation and future trend of AI in Europe, [13]. Vincent Charles studied the integration of blockchain and AI in the supply chain and critically analyzed [14]. Fariba Goodarzian Using the Internet of Things and artificial intelligence algorithms to design the integrated responsive green cold chain vaccine supply chain network [15].

By combining artificial intelligence and big data, we can deeply mine the data of user needs and design cases, apply machine learning algorithms for data modeling and training, and build intelligent decision-making engines and personalized recommendation systems to provide users with interior design solutions that meet their needs. We are expected to bring revolutionary changes to the interior design industry and create smart interior design methods that are more efficient, creative and user-friendly.

III. Design Algorithms of Artificial Intelligence and Big Data

A. Artificial Intelligence

Artificial intelligence refers to the use of computer intelligence technology to study human thinking, judgment and reasoning, and to complete work by simulating the human brain neural network model [6-7]. Its development is based on people, machines and information processing, automatically storing data through computers, and implementing algorithm operations in logical analysis [8-9]. Artificial intelligence has the capabilities of autonomous learning and self-control, and its core processor is usually supported by an expert system [10-11].

Interior design is based on meeting the needs of people and actual activities, and pays attention to the overall environment. Therefore, in the process, attention should be paid to the objects used, and cultural characteristics, styles, and the combination of science and artistry should be considered in advance. The interior design is based on three-dimensional reality technology and plays an important role in ergonomics. Ergonomics studies people's physical characteristics, behavioral habits, and perception of the environment. Therefore, interior design requires space layout, furniture placement, etc. to meet the physiological and psychological needs of the human body and provide a comfortable use experience. Virtual reality technology can simulate the real environment and evaluate the applicability of the design scheme by adjusting the size of the indoor space, the placement of furniture, and the illumination of light. As the demand in the interior design market continues to grow, traditional floor plans and hand-drawn renderings can no longer meet customer requirements. Customers prefer to understand and evaluate design solutions in a more intuitive and immersive way. 3D modeling software provides a wealth of tools and functions, and rapid modeling can improve design efficiency. This article uses 3D rendering technology to carry out material mapping, lighting settings and rendering of the three-dimensional model to generate high-quality renderings, intuitively display the appearance and atmosphere of the design scheme, add animation effects, better present the details of the design scheme, and improve user experience. 3D roaming allows users to freely browse the indoor space from a first-person perspective and better feel the atmosphere, spatial layout and material texture of the design.

B. *Application of Big Data*

In the era of big data, the functions of software platforms continue to develop, and various new technologies and applications emerge in endlessly [12-13]. Developing user-oriented customized products based on artificial intelligence and algorithm platforms is one of the current social development trends [14-15]. The application of big data analysis and mining in intelligent computing is a very important issue, which can improve our ability to predict, identify, extract and utilize the changing patterns of information volume [16-17]. Database technology is mainly used to process massive unstructured or semi-structured data collections, supports the use of web browsers/servers, which can realize interconnection between multiple computer systems and provide functions such as access resources required by different users to access the same physical hardware device at the same time, thus improving computing efficiency[18-19].

Big data technologies include Hadoop, Spark, Hive, MySQL (Structured Query Language, SQL) and Sqoop. Hadoop is an open source distributed computing platform used to process and store large-scale data sets [20]. It is based on the distributed file system and distributed computing framework MapReduce to realize data storage and processing, making the data highly reliable and fault-tolerant. Spark is a fast, general-purpose distributed computing system that supports large-scale data processing. It provides higher-level application programming interfaces (Spark Streaming, MLlib and GraphX) than Hadoop, making the processing process more flexible and efficient. Spark is faster because it can perform data calculations in memory. Hive is a data warehouse infrastructure built on top of Hadoop, providing a query language similar to structured query language to query and analyze large-scale data stored on Hadoop clusters. Hive converts structured query language statements into MapReduce tasks for execution, allowing analysts to use familiar structured query language syntax for data analysis. MySQL is a relational database management system that supports multi-user, multi-thread and multi-table operations. It is widely used in the field of big data in data storage and query scenarios that require high performance and reliability. It has a mature and stable open source community and rich ecosystem. Sqoop is used to transfer data between Apache Hadoop and relational databases. It supports importing data from relational databases into Hadoop clusters and exporting data from Hadoop to this library, providing a simple and easy-to-use command line interface and rich configuration options.

Data is generated mainly in the physical access module, backend and front-end embedded modules. After data collection and summary, in order to carry out subsequent enabling work (data visualization, machine learning modeling and other tasks), the data also need to be preprocessed. Common preprocessing operations include data cleaning (removing abnormal data, etc.), data missing value filling, data numericalization, data normalization and other operations. After the data is processed, various machine learning/deep learning models can be used for modeling, and then deployed online to provide various services.

C. *Intelligent Interior Design Algorithm*

The interactive evolutionary algorithm combines human-computer interaction and evolutionary computation, and its goal is to conduct optimization searches with users in an interactive manner to obtain the optimal solution. The interactive genetic algorithm is based on the genetic algorithm, simulates the process of natural selection and evolution, and introduces human subjective evaluation and feedback, making the optimization process more human-computer interactive. Compared with the interactive genetic algorithm, the interactive differential evolution algorithm uses the difference information between individuals and indirect population distribution scale information to improve the population through mutation, crossover and selection operations. During initialization, the initial population is generated:

$$\mathrm{a}_{k,i,0} = a_i^{\min} + (a_i^{\max} - a_i^{\min}) \times rand \quad \forall \mathrm{i} \in 1,...,\mathrm{F}; \forall k \in 1,...,\mathrm{M} \tag{1}$$

Among them, rand is a random number, and $\mathrm{a}_{k,i,0}$ is the i-th part of the gene of the k-th chromosome. The mutation operation relies on formula (2):

$$B_{k,s} = A_{k,s} + E_k \times (A_{pbest,s} - A_{k,s}) + E_k \times (A_{\mathrm{t}1,s} - A_{t2,s}) \tag{2}$$

Performing a crossover operation on the mutation vector and the parent vector, and after getting the test vector, choose the better one:

$$A_{\mathrm{k},s+1} = \begin{cases} A_{\mathrm{k,s}}, otherwise \\ V_{\mathrm{k,s}}, if \quad g(V_{\mathrm{k,s}}) \prec g(V_{\mathrm{k,s}}) \end{cases} \tag{3}$$

In interior design, furniture, decorations, etc. are placed reasonably so that the layout of the indoor space meets functional needs, aesthetic needs and ergonomic principles, and can maximize space utilization efficiency. This article uses optimization algorithms to generate the optimal functional area location and size to achieve the best layout effect in limited space.

D. *Construction of Recommendation System*

The intelligent design algorithm divides the indoor space design work into two parts: coordination and layout, and builds a segmentation network model and a layout network model respectively. The intelligent design system framework is shown in Figure 1:

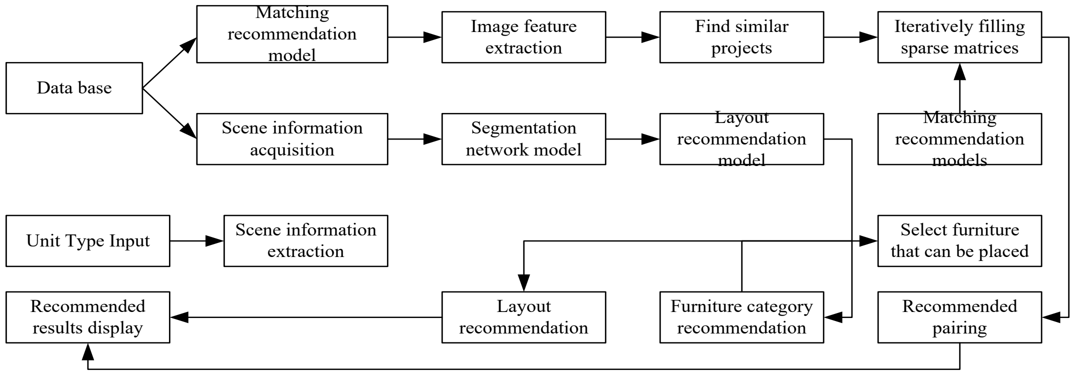

Figure 1. Intelligent design system framework

This article uses interior space design software to implement an intelligent decision-making engine and provide personalized design solutions based on recommendation algorithms. This article converts the layout problem into segmentation segments and house-type segments, digitizes the layout information, uses the embedding algorithm to successfully extract cross-features, and completes the layout recommendation model. The layout module extracts the scene information of the space to be laid out, and after screening, completely describes the house type information and obtains the recommended results. After determining the furniture category, the user can select appropriate furniture for placement. The layout module and the collocation recommendation module can be used individually or in combination, so the system is easy to expand and maintain.

IV. Experimental Testing of the Design System

A. *Simulation Environment Test*

In order to verify the effects of different algorithms compared with genetic algorithms in indoor layout design, experiments were conducted in a simulation environment. This article will pre-set the parameters on the premise that users cannot manually adjust features, have a clear overall understanding, and accurately select preferred pictures. The experimental templates are mainly kitchen, 3 bedrooms, living room, balcony, bathroom, and study room. The crossover probability of each iteration is 1/2, and the Euclidean distance between evolved individuals. In the experiment, the mutation operators were compared, divided into four control groups, and the experiment was conducted 4 times.

The learning rate determines the time and possibility of convergence to the minimum. This article selects 0.1 as the learning rate, draws the network model training, and adds the embedding layer before and after training for comparison. The experiment uses 2000 house layout data as a training model test set to test the accuracy of the network model. This article proposes to divide the test objects into four types: single household and whole house type before embedding and single house and whole house type after embedding. Four experimental trainings are carried out to obtain the data and make statistics.

B. *Analysis of Experimental Results*

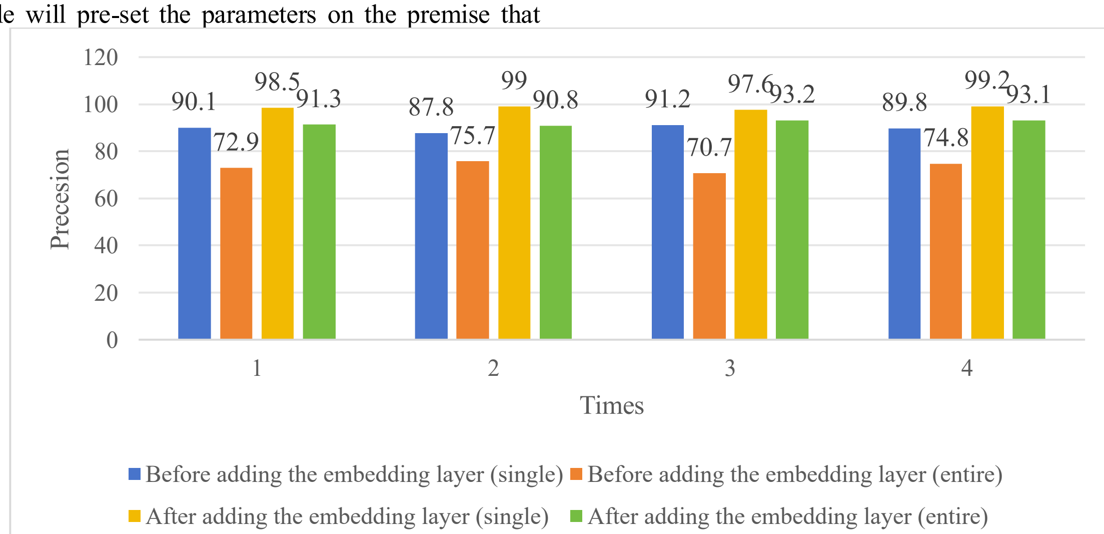

Figure 2. Test set accuracy

As shown in Figure 2, this article found that in the first test, the accuracy result obtained before adding the embedding layer (single) was 90.1%, and the accuracy before adding the embedding layer (whole) was 72.9%, the accuracy after adding the embedding layer (single) was 98.5%, and the accuracy after adding the embedding layer (whole) was even lower, only 91.3%. In the second test, the accuracy decreased before adding the embedding layer (single) and after adding the embedding layer (whole), and the accuracy improved before adding the embedding layer (whole) and after adding the embedding layer (single). The accuracy results obtained from these four tests are inconsistent, but in general, the highest accuracy before adding the embedding layer (single) was 91.2%, and the highest accuracy before adding the embedding layer (whole) was 75.7%, the highest accuracy after adding the embedding layer (single) was 99.2%, and the highest accuracy among the four indicators after adding the embedding layer (whole) was 93.2%.

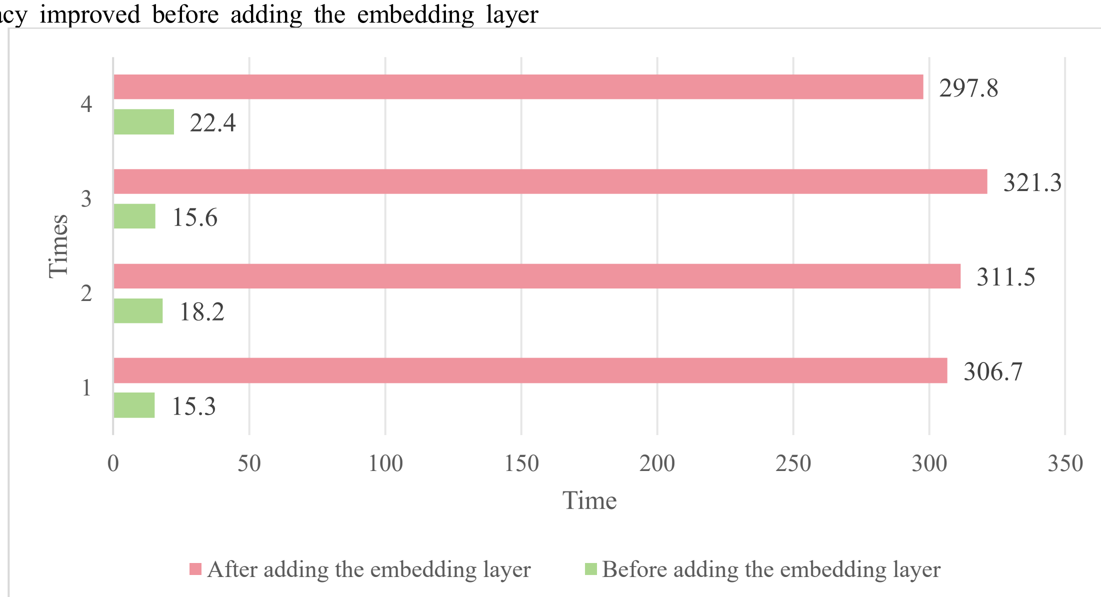

Figure 3. Test set running time

As shown in Figure 3, this article found that in this test set, the running time before and after adding the embedding layer differed greatly. For the first test, its running time took 15.3ms before adding the embedding layer and 306.7ms after adding the embedding layer. In the second test, the running time increased before and after adding the embedding layer. In the third test, the time before adding the embedding layer decreased compared to the second time, but the time after adding it increased. The running time obtained after the fourth test increased before adding the embedding layer, while the time after adding it was the least (297.8).

In addition, this article experimentally compares the placement running time of distance fields, placement fields, interactive evolutionary algorithms, interactive genetic algorithms, and interactive differential evolution algorithms. In the interior design system of this article, these five algorithms are used to test the system's operating capabilities, and its work efficiency is used as the evaluation criterion. As shown in Table 1, the distance field and the placement field take longer to run, with the distance field taking 532.5ms and the placement field taking 102.3ms. The interactive evolutionary algorithm, interactive genetic algorithm and interactive differential evolution algorithm all take less time, among which the interactive differential evolution algorithm takes 21.7ms to run.

TABLE 1. COMPARISON OF LAYOUT RUNNING TIME OF DIFFERENT ALGORITHMS

Layout algorithm	Layout running time
Distance field	532.5
Placement Field	102.3
Interactive evolutionary algorithm	56.2
Interactive Genetic Algorithm	33.6
Interactive Differential Evolution Algorithm	21.7

V. CONCLUSION

With the rapid development of artificial intelligence and big data technology, the field of interior design is gradually benefiting from the application of these innovative technologies. Artificial intelligence and big data provide designers with more possibilities and tools, allowing them to more accurately meet user needs and provide personalized interior design solutions. Therefore, this article aims to study and implement intelligent interior design algorithms based on artificial intelligence and big data to better improve the efficiency and quality of interior design. By combining artificial intelligence and big data technology, smart interior design algorithms can automatically process and analyze huge data, and build models based on machine learning algorithms to achieve smart interior design recommendation systems. This system can generate personalized design solutions based on the needs and preferences provided by users, and provide real-time feedback and optimization.

Designers can also use this algorithm to obtain data-driven design inspiration and improve design creativity and efficiency.

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