Multimedia Interaction and Intelligent Optimization Algorithm of CAD Model Based on Augmented Reality

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Abstract. In this paper, an interactive system prototype with real-time accuracy, scalability, and ease of use is constructed. Using advanced AR (Augmented Reality) technology, the system accurately integrates the CAD (Computer Aided Design) model into the real world and provides rich multimedia interactive means so that users can interact with the model in a more intuitive and efficient way. This paper utilizes diverse technical approaches and cutting-edge strategies. It achieves precise alignment and instantaneous updates of CAD models in the AR realm using precise tracking and registration techniques. Furthermore, it integrates intuitive interaction modes, such as gesture and voice recognition, elevating the user experience. Additionally, we've devised a robust user experience optimization framework that continuously enhances system performance through user feedback and data analysis. Experimental outcomes indicate exceptional system performance in real-time rendering, responsive interactions, and high user satisfaction. When compared to standard CAD software, user tests reveal a substantial boost in design efficiency and a more enjoyable user experience. User feedback further validates the system's usability and practicality.

Keywords: Augmented Reality; Computer Aided Design model; Artificial Neural Network; Multimedia; Intelligent optimization algorithm
DOI: https://doi.org/10.14733/cadaps.2024.S25.326-341

1 INTRODUCTION

With the rapid development of technology, technologies such as human-computer interaction, digital photogrammetry, visual programming languages, and augmented reality have been widely applied in the construction industry. Especially the technology based on scanning BIM (Building Information Modeling) models has brought revolutionary changes to building design and construction. Banfi and Previtali [1] use human-computer interaction technology to edit, optimize, and adjust models in virtual environments, achieving high integration with the real world. This human-computer interaction method not only improves work efficiency but also reduces design errors and construction risks. By overlaying virtual elements in the real world, AR enhances the user's interactive experience, making it more vivid and intuitive. Berseth et al. [2] analyzed interactive architectural design to explore diverse solutions. Exploring diverse solutions is an indispensable part of the practice of interactive building intelligent design. Due to the different characteristics, requirements, and constraints of each construction project, flexible and diverse solutions need to be developed for different situations. The system can detect safety hazards and performance issues on time through real-time monitoring and data analysis of various equipment inside the building, providing strong support for the operation and maintenance management of the building. The exploration of these diversified solutions not only promotes the development of interactive intelligent building design technology but also injects new impetus into the sustainable development of the construction industry.

Meanwhile, in modern product design, the accuracy and visualization of CAD models are crucial for improving design efficiency and quality. The assembly guidance and monitoring augmented reality system based on augmented reality multimedia projection is becoming an important tool to promote industrial upgrading and improve production efficiency. Chen et al. [3] used projection equipment to project assembly guidance information into actual assembly scenes in the form of virtual images, providing operators with intuitive and clear guidance. The assembly guidance and monitoring of augmented reality systems based on multimedia projection has many advantages. Chou et al. [4] explored the factors that affect the learning effectiveness of students applying artificial intelligence technology, with a focus on the mediating role of human-computer interaction experience. A good human-computer interaction experience can help students better understand and apply artificial intelligence technology, thereby improving learning efficiency. Therefore, integrating AR and CAD models for multimedia interaction and intelligent optimization has become an important theoretical and practical work. Dondi and Porta [5] discussed the principles, applications, and future prospects of gaze-based human-computer interaction technology for museums and exhibitions. The gaze-based human-computer interaction technology mainly achieves interaction by capturing and analyzing the audience's eye movements. By using cameras or other sensor devices, the system can track the audience's eye movements in real time, thereby determining their attention and interest in the exhibits. By processing and analyzing this data, the system can intelligently adjust the presentation of exhibits, provide relevant information, or trigger corresponding interactive functions to meet the personalized needs of the audience.

Gupta and Mukul [6] discussed multimedia retrieval based on deep learning models and their optimization methods in augmented reality applications. Deep learning models can learn the inherent patterns and features of large amounts of data by constructing deep neural networks. In the field of multimedia retrieval, deep learning models can automatically extract features of multimedia data and perform similarity matching and retrieval based on these features. Compared with traditional manually designed feature-based methods, deep learning models have stronger generalization ability and higher accuracy. Feature extraction refers to extracting representative feature vectors from multimedia data, which can reflect the inherent attributes and features of the data. Kim et al. [7] conducted a systematic evaluation of virtual reality systems from the perspective of user experience and delved into the role of human-computer interaction in them. A good user experience can enhance user immersion and engagement, thereby enhancing the attractiveness and market competitiveness of the system. In digital art design, designers need to process a large amount of multimedia data, such as images, audio, and video, and big data technology can help designers effectively store, manage, and analyze this data. By mining and analyzing data, Li [8] can more accurately grasp user needs and market trends, providing strong data support for design. Interactive virtual technology has brought a more realistic visual experience to digital art design.

The aim of this study is to investigate multimedia interaction methods using AR-based CAD models and explore the application of intelligent optimization algorithms in this area. By constructing a multimedia interaction system, this study achieved 3D visualization, dynamic simulation, and enhanced user interaction of CAD models, thereby improving the intuitiveness and efficiency of the design process. In addition, the introduction of intelligent optimization algorithms has improved the accuracy and performance of CAD models. This study contributes to the integration and development of AR and CAD technologies, paving the way for innovative solutions in areas such as product design, education, training, and medical diagnosis.

The main contents of this study include: (1) Research the multimedia interaction method and technology of CAD model based on AR; (2) Explore the application of intelligent optimization algorithm in CAD model; (3) Build a multimedia interactive system of CAD model based on AR, and conduct simulation experiments and performance evaluation.

The advancements presented in this paper are numerous: Firstly, we introduce a unique multimedia interactive approach for CAD models that leverages AR technology. This method enables 3D visualization, dynamic simulation, and seamless user interaction with the CAD model. Secondly, we incorporate an intelligent optimization algorithm to enhance the precision and performance of the CAD model. Lastly, we establish a comprehensive multimedia interactive system centred on AR-based CAD models and conduct simulation experiments along with performance assessments. These rigorous validations confirm the efficacy and superiority of our proposed methodology and algorithm.

This paper is divided into seven sections and comprehensively discusses the application of AR technology in CAD models and the realization and evaluation of intelligent optimization algorithms. The introduction part introduces the research background, present situation, content and innovation. Then, the paper expounds based on AR and CAD, and the application and realization of intelligent optimization algorithms in CAD. Based on this, a multimedia interactive system of CAD model under AR is designed, and the implementation scheme and technical details are described in detail. At the same time, the effectiveness of the algorithm and the practicability of the system are verified by simulation experiments and user tests. Finally, this paper summarizes the research achievements and shortcomings and puts forward prospects and suggestions for future research.

2 RELATED WORK

Li [9] explored a visual information enhancement method for multimedia human-computer interaction interfaces based on virtual reality technology. Visual information is one of the main ways for humans to obtain external information. For human-computer interaction interfaces, the presentation of visual information directly affects user experience and interaction effects. Therefore, by enhancing the clarity, richness, and interactivity of visual information, the usability and attractiveness of the interface can be significantly improved. Through high-precision 3D modelling and rendering techniques, realistic virtual scenes and objects can be created. Li et al. [10] explored the application and far-reaching impact of this technology in consumer behavior analysis and experiential education., Artificial intelligence-based human-computer interaction technology can also recognize and analyze consumer emotions. By capturing subtle changes in consumer voice, facial expressions, and posture during the interaction process, people can evaluate their emotional state, and understand their satisfaction and feedback with the product or service. This sentiment analysis technique helps businesses to promptly identify potential problems, improve products and services, and increase consumer satisfaction and loyalty.

Deep learning, as an important branch of artificial intelligence, provides strong technical support for intelligent human-computer interaction. Lv et al. [11] explored the exploration and practice of intelligent human-computer interaction using deep learning technology in the field of applied science. Intelligent human-machine interaction aims to achieve natural and efficient interaction between humans and machines, while deep learning simulates the working mode of human brain neural networks, enabling machines to understand and process complex information. Mao and Chen [12] discussed the application of 3D content augmented reality in general image training systems and its relationship with human-computer interaction. Traditional image training systems mainly rely on two-dimensional images for display and training. This method is simple and intuitive, but often cannot accurately reflect the three-dimensional features and spatial relationships of objects. The augmented reality technology of 3D content can combine elements such as 3D models and scenes with the real environment, presenting users with more realistic and three-dimensional visual effects.

Mourtzis and Angelopoulos [13] conducted in-depth research on the construction and application of this intelligent framework. Using AR technology to construct 3D visualization models in augmented reality-based artificial neural network modelling helps to better understand the structure and working principle of neural networks. Meanwhile, by utilizing the learning and processing capabilities of artificial neural networks, we can train and optimize them to improve their performance.

The integration of artificial intelligence and art has become a remarkable field. Nie et al. [14] analyzed the application of human-computer interaction systems based on machine learning algorithms in artistic visual communication, bringing unprecedented possibilities for artistic creation and appreciation. Human-computer interaction system is a technology that allows for bidirectional communication and interaction between humans and machines. It achieves a more intelligent and natural interactive experience by understanding the user's intentions and responses. Machine learning algorithms are the core of human-computer interaction systems, enabling machines to make autonomous decisions and optimizations through analysis and learning of large amounts of data. In time-critical resource management scenarios, due to the high complexity and urgency of tasks, the inherent cognitive load is often high. Therefore, designers and researchers need to optimize the human-computer interaction interface to reduce external cognitive load and alleviate the overall cognitive burden on users [15]. The design of a gesture recognition system is a key link in achieving human-computer interaction. The system mainly includes modules such as data collection, feature extraction, classification and recognition. The data acquisition module captures user gesture information through sensors or other devices and converts it into signals that can be processed by computers. The feature extraction module extracts key features of gestures, such as shape and motion trajectory, from the collected data. Tsai et al. [16] used machine learning algorithms to classify and recognize gestures. When designing a gesture recognition system, multiple factors such as recognition accuracy, real-time performance, and robustness need to be considered. In order to improve recognition accuracy, multi-mode fusion technology can be used to combine various sensor information for gesture recognition. Meanwhile, in order to ensure real-time performance, it is necessary to optimize algorithms and reduce computational complexity. In addition, gesture recognition systems should have a certain degree of robustness and be able to cope with gesture changes in different environments and users.

The application of computer-aided interaction technology enables visual elements to be more flexibly combined and presented, bringing users an unprecedented visual feast. Wang [17] created more creative and expressive visual works by using technologies such as 3D modelling, animation design, and virtual reality, making artistic expression more diverse. Meanwhile, computer-aided interaction technology also provides artists with a broader creative space. In addition, through computer-aided interaction technology, artists can also achieve real-time interaction with the audience, allowing them to participate in the process of creating and appreciating artworks, enhancing the participation and interactivity of artworks. Zhang [18] discussed the design and application of computer-aided human-computer interaction in visual communication, as well as its profound impact on the design industry. Computer-assisted human-computer interaction is a method of using computer and human-computer interaction technology to assist designers in design. At the same time, the application of human-computer interaction technology also enables designers to have a more intuitive understanding of user needs and feedback, thereby adjusting and optimizing design solutions. In advertising design, through human-computer interaction technology, designers can simulate the user's viewing experience, predict the effectiveness of advertisements in different scenarios, and thus develop more accurate advertising strategies. Zhao [19] must explore a new model based on artificial intelligence to cultivate talents in human-computer interaction art and design. The core of the new model for cultivating talents in human-computer interaction art and design based on artificial intelligence lies in combining artificial intelligence technology with art and design education, cultivating new talents who possess both art and design abilities and are familiar with artificial intelligence technology. This new model aims to break the limitations of traditional art and design education and provide students with broader design ideas and creative space.

3 AR TECHNOLOGY, CAD MODELS, AND INTELLIGENT OPTIMIZATION ALGORITHM FOUNDATION

3.1 AR Technology Overview

Currently, research efforts primarily concentrate on the utilization of AR technology for visualizing CAD models and optimizing them through intelligent algorithms. While initial progress has been noted, numerous pressing issues and challenges still require urgent attention. These include challenges such as accurately registering and rendering CAD models in real-time within AR environments, enhancing the naturalness and efficiency of user interactions, and selecting/designing intelligent optimization algorithms tailored for CAD models.

Looking ahead, as AR technology continues to evolve and mature, and as intelligent optimization algorithms undergo continuous innovation and refinement, the focus on multimedia interaction and intelligent optimization of CAD models within AR is poised to emerge as a significant research trend. It is anticipated that this domain will witness further theoretical advancements and technological breakthroughs, thereby providing robust support for advancements in product design and beyond. AR technology is a technology that superimposes virtual information into the real world and interacts with users through computer-generated images, sounds, words, and other multimedia elements. Through the perception and understanding of the real world, it integrates virtual objects with the real environment, creating a sensory experience beyond reality for users. The core of AR technology lies in the realization of key technologies such as real-world perception, tracking registration, virtual rendering, and user interaction.

Perception technology is the basis of the AR system, which provides an accurate reference for the superposition of virtual objects by acquiring and processing information such as images, sounds, and positions in the real world. Tracking registration technology is the key to realizing the alignment of virtual objects with the real environment. It can calculate the position and posture of virtual objects in the real world in real-time by tracking the user's head, hands, and other parts. Virtual rendering technology is responsible for presenting virtual objects in front of users in a realistic way, including the processing of details such as illumination, shadow, and texture. User interaction technology is a bridge that allows natural interaction between users and virtual objects. It can seamlessly connect users with the virtual world through gesture recognition, voice recognition, and eye tracking.

3.2 CAD Model and Its Application in AR

CAD model is an important tool for product design, which uses computer technology to assist designers in product modeling, analysis, and optimization. CAD model has the advantages of high accuracy, good visualization effect, and easy modification, and is widely used in machinery, architecture, automobile, aerospace, and other fields.

In the realm of AR, the CAD model occupies a pivotal position. Designers can effortlessly visualize and revise the 3D product structure within the actual world by integrating the CAD model into the AR system, subsequently elevating both the efficiency and quality of the design process. Simultaneously, AR technology showcases the CAD model's dynamic attributes visually, aiding designers in comprehensively grasping the product's functionality and motion patterns. Moreover, the amalgamation of CAD models in AR applications extends its utility to product demonstrations, educational endeavours, training sessions, maintenance guides, and beyond, bestowing upon users a more engaging and intuitive interactive experience.

3.3 Realization of Multimedia Interactive Technology in CAD Model

Multimedia interaction technology is an important means of realizing the interaction of CAD models in AR. It provides users with a more intuitive and natural way of interaction by combining multimedia elements such as images, sounds, and characters with CAD models. For example, users can rotate, scale, and move CAD models through gesture recognition technology; command control of CAD models is realized by speech recognition technology, and rapid switching of CAD model views is realized by eye tracking technology.

In order to realize the application of multimedia interactive technology in the CAD model, a series of key technical problems need to be solved. First of all, it is necessary to establish the mapping relationship between the CAD model and multimedia elements and realize the synchronous update and interactive response between them. Secondly, it is necessary to design a reasonable user interaction interface and process to ensure that users can complete the interaction tasks conveniently and quickly. Finally, it is necessary to process and analyze the data in the process of interaction in real-time to provide accurate feedback and response.

3.4 Intelligent Optimization Algorithm and its Application in CAD Model

Intelligent optimization algorithms are search and optimization techniques inspired by natural phenomena or human intelligence. These algorithms tackle intricate optimization challenges by mimicking optimization processes found in nature or social behaviours. When compared to conventional optimization methods, intelligent optimization algorithms excel with their robust global search capabilities, resilience to initial solutions, and parallel computing feasibility. As a result, they have found widespread applications in engineering optimization, machine learning, data mining, and beyond. Some common intelligent optimization algorithms include genetic algorithms, particle swarm optimization, ant colony algorithms, and ANN.

Genetic algorithms seek optimal solutions by simulating the selection, crossover, and mutation processes observed in biological evolution. Particle swarm optimization achieves global optimization by emulating the collective behaviour of social animals like birds or fish schools. Ant colony algorithms address combinatorial optimization problems by mimicking ants' pheromone updates and path selection during foraging. Lastly, ANNs can handle and classify intricate data by simulating the connections and signal transmission processes of human brain neurons.

Optimizing CAD models presents a multifaceted challenge due to numerous design variables and constraints, often rendering traditional optimization techniques inadequate. Intelligent optimization algorithms, with their robust global search capabilities and ease in handling multi-objective optimization problems, hold significant value in CAD model optimization. Specifically, intelligent optimization algorithms can be used in shape optimization, structure optimization, material optimization and other aspects of CAD models. For example, in shape optimization, the shape change can be controlled by adjusting the parameters of the CAD model, so as to optimize the product performance; In structural optimization, an intelligent optimization algorithm can be used to search the optimal structural layout and connection mode to improve the structural strength and stability of products. In material optimization, intelligent optimization algorithms can be used to select the best material combination and distribution mode to meet the performance requirements and cost constraints of products.

4 DESIGN OF MULTIMEDIA INTERACTIVE SYSTEM FOR CAD MODEL BASED ON AR

The primary goal of designing multimedia interactive systems of CAD models based on AR is to provide an intuitive, efficient, and user-friendly interactive environment so that designers can seamlessly interface with CAD models in the real world, thus improving design efficiency and quality. The system design shall follow the principles in Table 1.

Principle	*Related Description*
Real-time	The system should be able to capture user input in real-time and give feedback in the shortest time to ensure a smooth and natural interaction between users and CAD models.
Accuracy	The system should ensure the accurate alignment of the CAD model in the AR environment with the real world, and avoid the influence of the position deviation on the user experience.
Expandability	The system design should consider the requirements of future technical development and function expansion, and it is easy to integrate new multimedia

	interaction means and intelligent optimization algorithms.
Usability	The user interface should be concise, conform to the user's operating habits, provide necessary help and guidance, and reduce the difficulty of use.

Table 1: System design principle.

A Multimedia interactive interface is a window for users to interact directly with the system, and its design quality directly affects the user experience. In the interface design, it is necessary to make full use of multimedia elements such as images, sounds and words to provide intuitive and clear operation guidance and feedback. At the same time, the interface layout should be reasonable and conform to the user's operating habits, so as to ensure that the user can complete the interactive task quickly and accurately. In addition, the aesthetics and consistency of the interface should be considered to improve user satisfaction. In order to continuously optimize the user experience, this paper systematically establishes an effective user experience and feedback mechanism. By collecting information such as user behaviour data, operation records, and subjective evaluation, the system can analyze users' needs and preferences, and find existing problems and improvement points. At the same time, the system also provides convenient user feedback channels to encourage users to put forward valuable opinions and suggestions. This feedback will become an important basis for continuous improvement and optimization of the system.

The core functional modules of the multimedia interactive system of CAD model based on AR in this paper are shown in Table 2.

Functional module	*Describe*
AR module	Responsible for the integration of the virtual and real world, including key technologies such as image recognition, tracking and registration, rendering and display, to ensure the accurate presentation of CAD models in a real environment.
CAD model processing module	Responsible for the import, analysis, optimization and other operations of CAD model, as well as data interaction with AR module to realize the visualization and interaction of CAD model in AR environment.
Multimedia interactive module	Integrate images, sounds, words and other media elements to realize rich interaction between users and CAD models, including gesture recognition, voice control, eye tracking and other interactive means.
User experience optimization module	Collect user feedback, analyze user behaviour, and adjust system parameters and functions to continuously improve user experience.

Table 2: Core function module of CAD model multimedia interactive system based on AR.

The above modules together constitute the overall architecture of the system, and the multimedia interaction function of the CAD model based on AR is realized through efficient data exchange and cooperation among the modules.

5 REALIZATION AND SIMULATION OF INTELLIGENT OPTIMIZATION ALGORITHM IN CAD MODEL

5.1 Concrete Application of Algorithm in CAD Model

The realization of intelligent optimization algorithms in CAD models needs to rely on specific programming environments and tools. Common programming environments include Python, MATLAB, C++, etc. These environments provide rich mathematical libraries and algorithm libraries, which are convenient for realizing various complex optimization algorithms. At the same time, it is necessary to integrate the optimization algorithm with the CAD model using an API interface or plug-in mechanism provided by CAD software.

ANN is a computational model that mimics the structure and functionality of the human brain's neurons. Consisting of numerous interconnected simple processing units, it can process and acquire information through the adjustment of its connection weights. ANN has adaptability, fault tolerance and parallel processing ability, and is suitable for dealing with complex nonlinear problems. Using the ANN algorithm, the model can be trained to learn excellent interface layout cases, thus automatically generating an interface layout that conforms to design principles and user habits. By defining the input layer (such as screen size, number of elements, etc.), hidden layer and output layer (location and size of elements, etc.), the neural network can gradually optimize the layout scheme until it reaches the ideal user experience standard. In ANN, forward propagation is used to calculate the network output under a given input. For each layer, its output can be expressed as:

$$a^{l} = f\left(z^{l}\right) \tag{1}$$

$$z^{l} = W^{l} a^{l-1} + b^{l} \tag{2}$$

Where a^{l} represents the activation value of the layer; f is an activation function; z^{l} is the weighted input of layer l ; z^{l} is the weight matrix of the l layer; b^{l} is the bias vector of the l layer; a^{l-1} is the activation value of the previous layer.

Backpropagation computes the gradient of the loss function concerning the weights, enabling weight updates via gradient descent. Specifically, for the output layer, its gradient is represented as:

$$\delta^{L} = \nabla_{a^{L}} J \bullet f'\left(z^{L}\right) \tag{3}$$

For the hidden layer, the gradient can be recursively calculated as:

$$\delta^{l} = \left(W^{l+1}\right)^{T} \delta^{l+1} \bullet f'\left(z^{l}\right) \tag{4}$$

Where δ^{l} is the error term of the l layer; J is the loss function; f' is the derivative of the activation function. The output of the fully connected layer is calculated as:

$$z = Wx + b \tag{5}$$

$$a = f \ z \tag{6}$$

Where x is the input vector, W is the weight matrix, b is the offset vector and f is the activation function.

Firstly, collect the historical interaction data of users, including clicking, sliding, scrolling, staying time, visiting frequency, etc. These data can be obtained through user behaviour logs, event tracking and other technical means. The collected raw data need to be cleaned, denoised and formatted to ensure the quality and consistency of the data. A simple denoising method is to use a moving average filter, and its formula is:

$$y_t = \frac{1}{k}\sum_{i=0}^{k-1} x_{t-1} \tag{7}$$

Where y_t is the denoised value at a time t ; x_{t-1} is the original value at the time $t-1$; k is the window size of the filter? The standardized formula is:

$$z = \frac{x-\mu}{\sigma} \tag{8}$$

Where z is the normalized value; x is the original value; μ is the mean; σ and is the standard deviation?

Extract key features from preprocessed data, such as user behaviour sequence, page residence time distribution, etc. These features can be represented by data structures such as vectors, matrices, or tensors so as to be input into the neural network model.

A neural network model tailored for processing sequence data, as depicted in Figure 1, is established. The model's parameters undergo continuous refinement through the application of the backpropagation algorithm and gradient descent optimizer, aiming to minimize prediction errors.

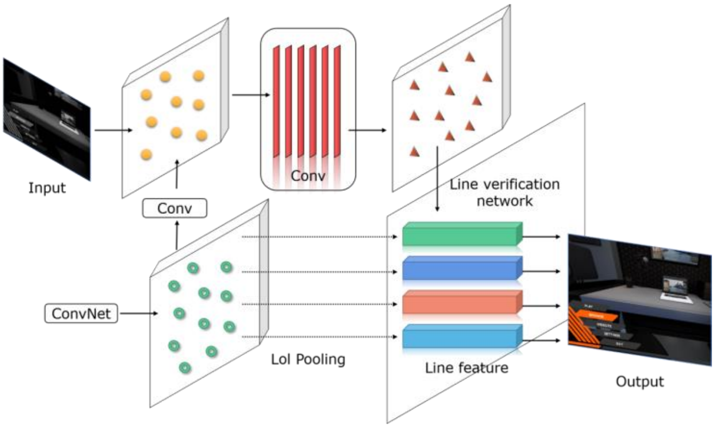

Figure 1: ANN model.

In this paper, the extracted features are used as input, and the corresponding color-matching scheme and style guide are used as output to train the model. By adjusting the parameters and structure of the model, the difference between the generated results and the real samples is minimized. In this paper, gradient descent is used to update weights and offsets:

$$W^{l} = W^{l} - \alpha \sum_{i} \delta_{i}^{l} \left(a_{i}^{l-1}\right)^{T} \tag{9}$$

$$b^{l} = b^{l} - \alpha \sum_{i} \delta_{i}^{l} \tag{10}$$

Where a is the learning rate, which controls the step size of the weight update?

The trained neural network model can generate a matching colour matching scheme and style guide according to the input provided by users. Designers can refer to these generated results for inspiration and reference to meet the individual needs of users.

In the implementation of the ANN algorithm, the problems of data processing and storage are mainly considered. In this paper, tools such as databases or file systems are used to manage the data of the CAD model efficiently to ensure that the algorithm can read and process the model data quickly and accurately. In addition, this paper also uses visual tools to show the running process and results of the algorithm to help users better understand the working principle and optimization effect of the algorithm.

5.2 Performance Evaluation and Result Analysis of the Algorithm

To validate the efficacy and advantages of intelligent optimization algorithms within CAD models, a simulation experiment design is essential. This simulation mimics the actual design environment and workflow, assessing the algorithm's performance and impact. Various design variables and constraints are introduced to challenge the algorithm's optimization capabilities and stability across diverse scenarios. Evaluating an algorithm's performance is crucial for gauging its effectiveness within CAD models. Metrics such as solution accuracy, convergence rate, and robustness are considered. By juxtaposing the performances of distinct algorithms on the same task, their respective strengths and weaknesses become apparent.

Illustratively, Figure 2 depicts the solution accuracy achieved by the algorithm presented in this study, while Figure 3 offers a comparative analysis of the solution accuracies among different algorithms.

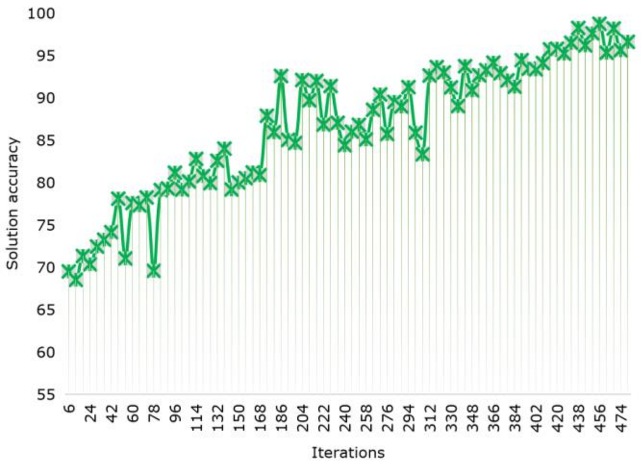

Figure 2: The accuracy of the algorithm in this paper.

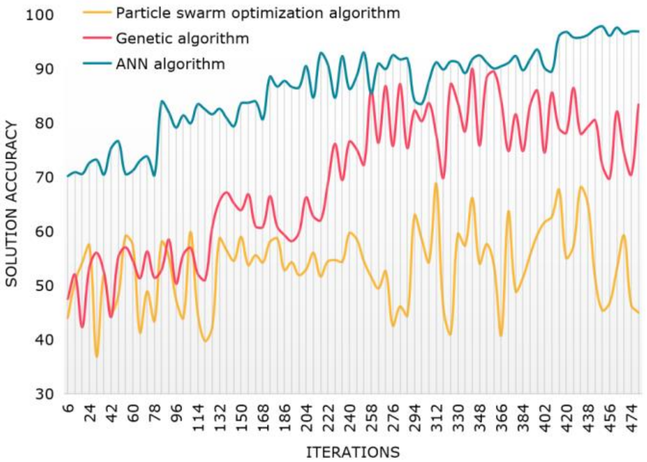

Figure 3: Comparison of solution accuracy of different algorithms.

Upon observation of Figure 2, it is evident that as the iteration count varies, the algorithm's solution accuracy remains consistently high or experiences gradual improvement. This underscores the robustness and adaptability of the algorithm presented in this study when tackling intricate challenges. Meanwhile, a comparative analysis of Figure 3 reveals that, in most instances, our algorithm exhibits superior accuracy. This is indicative of its notable superiority in terms of solution quality.

Beyond accuracy, assessing an algorithm's efficiency is equally crucial. This study empirically examines our algorithm's operational performance. Specifically, Figure 4 illustrates the execution time of our algorithm, while Figure 5 compares the runtimes of different algorithms.

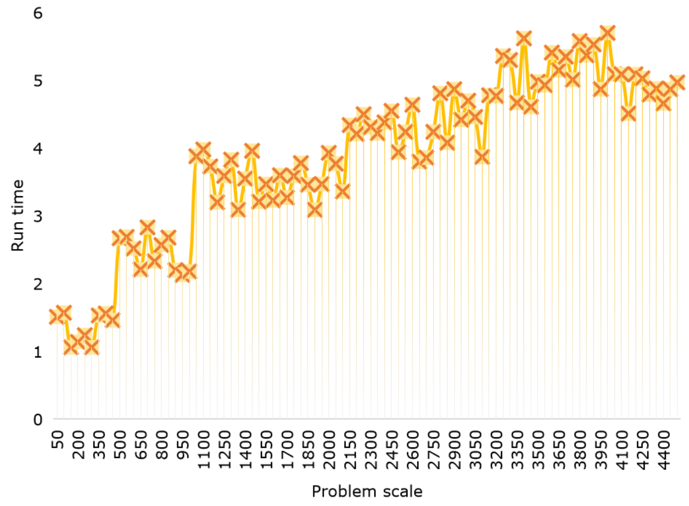

Figure 4: The running time of this algorithm.

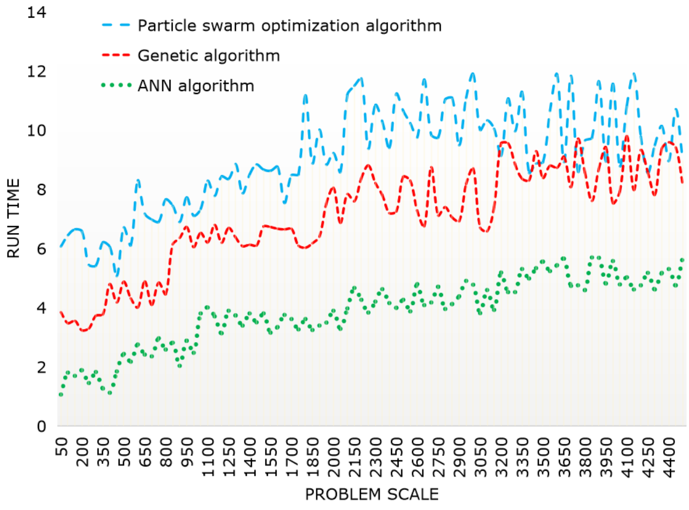

Figure 5: Comparison of running time of different algorithms.

Upon examination of Figure 4, it becomes apparent that as the problem's scale escalates, the algorithm's running time also rises commensurately. However, the increase is relatively gradual, indicating that the algorithm presented in this paper possesses optimization and control capabilities in terms of efficiency. A comparative analysis of the data depicted in Figure 5 further reveals that, under similar problem scales, our algorithm typically exhibits a shorter running time. This signifies its superior computational speed and efficiency, which are particularly advantageous when addressing large-scale problems or scenarios demanding high real-time performance.

The stability test results of the algorithm are shown in Figure 6.

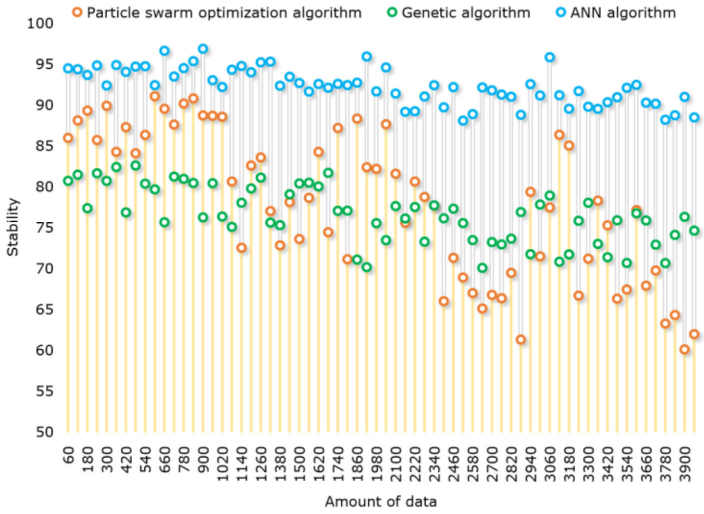

Figure 6: Stability test results of the algorithm.

It is obvious from Figure 6 that with the increase in data volume, the stability of particle swarm optimization and genetic algorithm begins to decline, and the performance fluctuation increases. This is because these methods are affected by computing resources, memory limitations or the complexity of the algorithm itself when dealing with large-scale data, resulting in unstable performance. In contrast, the method proposed in this paper can still maintain more than 90% stability in the case of large data. This shows that this method has better robustness and reliability when dealing with large-scale data.

6 REALIZATION AND TEST OF MULTIMEDIA INTERACTIVE SYSTEM OF CAD MODEL BASED ON AR

6.1 System Development Environment and Key Technologies

In the process of realizing the multimedia interactive system of CAD model based on AR, it is necessary to build a stable development environment at first. This usually includes high-performance computer hardware to support complex graphics rendering and real-time data processing. In terms of software, we need to use game development engines such as Unity and Unreal Engine, which provide rich graphics rendering, physical simulation and user interaction functions. In addition, you need to use the API of CAD software to import CAD models into the AR environment.

For development tools, this study utilizes programming languages including C#, C++, and Java, alongside integrated development environments like Visual Studio and Eclipse. In order to realize multimedia interaction, we also need to use audio and video processing libraries, such as FFmpeg and OpenCV.

In the process of realizing the system, some key technologies and difficulties will be encountered. For example, how to ensure the accurate alignment and real-time update of CAD models in an AR environment requires the research and application of advanced tracking and registration technology. In addition, it is also a challenge to realize natural and intuitive user interaction, which needs to be combined with gesture recognition, voice control and other interactive means. In order to overcome these difficulties, this paper carries out in-depth technical research, prototype development and experimental verification; The performance of different tracking and registration technologies is tested through well-designed experiments, and the usability and user satisfaction of different interactive means are evaluated through user tests.

6.2 System Testing and Result Analysis

Once the system has been developed, it is imperative to conduct a thorough test to guarantee that its functionality and performance align with the established requirements. This testing encompasses unit testing, integration testing, and system testing. Unit testing involves assessing each individual module within the system to verify their proper operation. Integration testing, on the other hand, emphasizes the examination of interfaces and the collaboration among modules. Lastly, system testing evaluates the entire system to confirm its adequacy in meeting user needs. The detailed outcomes of these tests are presented in Tables 3, 4, and 5.

Module name	*Number of test cases*	*Success number*	*Number of failures*	*Success rate*
AR module	20	19	1	95%
CAD model processing module	30	28	2	93.3%
Multimedia interactive module	15	14	1	93.3%
User experience optimization module	10	9	1	90%

Table 3: Unit test results.

Module combination	*Number of test cases*	*Success number*	*Number of failures*	*Success rate*
AR+CAD model processing	15	14	1	93.3%
Multimedia interaction+user experience optimization	10	9	1	90%
Full module integration	20	18	2	90%

Table 4: Integration test results.

Test item	*Number of test cases*	*Success number*	*Number of failures*	*Success rate*
Function needs/requirement	50	47	3	94%
Performance requirements	20	18	2	90%
Compatibility test	10	9	1	90%
Stability test	15	14	1	93.3%

User experience test	10	8	2	80%

Table 5: System test results.

As shown in the above table, although the overall test results of the system are good, there are still some problems and shortcomings. According to the test results, targeted repair and optimization work will be carried out to improve the quality of the system and user experience.

In addition to internal testing, it is also necessary to collect user feedback to understand the actual use of the system. User feedback includes problems, suggestions and suggestions for improvement during use. These feedbacks are very important for the continuous improvement and optimization of the system. In order to collect user feedback, this paper designs user questionnaires, conducts user interviews or sets up online feedback channels. As shown in Figure 7, the user rating results are shown in detail.

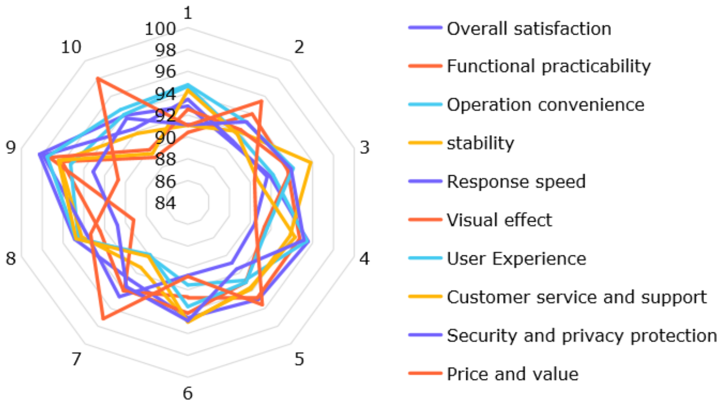

Figure 7: User rating results.

The user rating results depicted in Figure 7 unveil both the strengths and weaknesses of the system across various aspects, including overall satisfaction, functional practicality, operational convenience, stability, response speed, visual appeal, user experience, customer service and support, security and privacy measures, as well as pricing and value. These insights offer invaluable guidance for refining the system's quality and better catering to users' needs.

7 CONCLUSIONS

This research focuses on designing and implementing an AR-based multimedia interactive system for CAD models. Through meticulous examination of AR technology, CAD model manipulation, and multimedia interaction techniques, we've created an interactive system that excels in real-time performance, precision, scalability, and usability. This system not only faithfully represents CAD models within the AR environment but also incorporates a range of multimedia interaction features, enabling more intuitive and efficient user interaction with CAD models.

During our research, we tackled various technical challenges, including precise tracking and registration, real-time rendering optimization, and intuitive interaction design, among others. These accomplishments form the cornerstone of our system's successful deployment. Additionally, we continuously refined the system's performance and enhanced the user experience through user testing and feedback solicitation.

The primary accomplishments of this endeavour comprise a fully operational prototype of an AR-based multimedia interactive system tailored for CAD models, along with an array of supporting technical investigations and empirical validations. This system stands out in terms of its real-time capabilities, precision, scalability, and ease of use, offering a novel approach to CAD model design and interaction. Looking ahead, the potential applications of this AR-driven multimedia interactive system for CAD models are vast and varied, spanning engineering design, educational training, product demonstrations, and beyond. As such, we must remain attuned to the evolving landscape of emerging technologies and explore their integration with AR and CAD models.

8 ACKNOWLEDGEMENT

This work was supported by the Integration projects of industry and education of University of Sanya, China (No. USY-CJRH2329); the Education Department of Hainan Province project number: Hnjg2023ZD-46.

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