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Computer-Aided Design AND APPLICATIONS

Optimization Strategy for Animation Character Design Utilizing CAD and Multi-Agent Systems

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Abstract. This article delves into the optimization tactics of animation image design by amalgamating computer-aided design (CAD) with the multi-agent system (MAS). The prime focus is on the utilization of the ant colony optimization (ACO) algorithm and its hybrid variant, the genetic algorithm-aided ACO (GA-ACO), in resource allocation and task scheduling. To achieve an efficient and innovative animation design workflow, the study examines the current standing of CAD technology in this domain and explores how MAS can usher in automation and intelligence through optimization techniques like the ACO algorithm. In the experimental phase, a comparative analysis is conducted to assess the performance of the standalone ACO algorithm, the genetic algorithm (GA), and the combined GA-ACO approach in task scheduling and resource allocation. The findings reveal that the GA-ACO algorithm outshines the others in terms of convergence speed, task completion time, system load balancing, and resource utilization. It is emphasized that the optimization approach for animation image design, grounded in CAD and MAS, particularly the GA-ACO algorithm, holds immense potential to elevate design performance and usher in groundbreaking advancements in the realm of animation design.

Keywords: CAD; Multi-Agent; Animation Image Design; Ant Colony Algorithm; Genetic Algorithm
DOI: https://doi.org/10.14733/cadaps.2024.S26.187-201

1 INTRODUCTION

Computer graphics technology has been widely applied in the field of animation production. On the one hand, digital technology has revolutionized the traditional concept and methods of animation production, breaking the traditional frame-by-frame shooting method. Abdrashitov et al. [1] used digital image data to create animations, transforming traditional brushes into "digital brushes" to make the animation more realistic. On the other hand, CG technology subverts and reinterprets the original definition of animation ontology, blurring the boundary between animation art itself and the generalization of CG technology. Currently, digital animation technology has become the mainstream of the animation industry worldwide. Compared to handmade animation, its production cost is lower, but it also suppresses the market space and aesthetic exploration space of handmade animation. By examining the development history of animated films, it was found that digital animation technology has had a profound impact on the animation industry. By examining the media, aesthetic, and ontological characteristics of handcrafted animated films, we have considered their unique value in current global animated films. And combined with the script "The Kingdom of Divine Painting", explore the cultural connotations and aesthetic values of handmade animated films. The purpose of Aberman et al. [2] is to explore the key technologies of the two in their respective development and application processes, starting from the principles and characteristics of this CAD technology. Through the case study of the application of two technologies in 3D animation scene modelling and virtual studio technology, the advantages of 3D animation and virtual reality technology in the field of business are further demonstrated from both theoretical and technical perspectives. It is clarified that in the future stage, the theoretical research of 3D animation and virtual reality technology is the fundamental guarantee for both to advance in the field of technological application. Finally, the interaction between the two technologies in 3D scene creation and motion capture techniques for virtual animated characters is discussed. The feasibility analysis and research, elucidated the main research content of virtual reality technology in virtual scene construction in the next stage. The significant role of computer software and hardware technology in promoting the development of 3D animation technology cannot be ignored. This points out the research direction for future theoretical research on 3D animation and virtual reality technology [3].

The application scope of intelligent CAD algorithms is wide, including multiple fields such as architectural design, mechanical manufacturing, animation production, etc. By integrating MAS into animation image design, the design process can achieve a higher level of automation and intelligence through collaborative and competitive interactions among agents, ultimately elevating the creativity of animation designs. In the digital age, animation, as a unique art form, has penetrated into people's lives. However, compared to real-world facial recognition technologies, facial recognition and logo extraction techniques for animated characters still face many challenges. With the rapid development of deep learning, big data, and cognitive computing technologies, significant progress has been made in research in this field. Bodini [4] reviewed the techniques of using deep learning to extract facial features of animated characters in 2D images and videos. And explore the roles of big data and cognitive computing in this process. For the extraction of facial features in animated characters, deep learning models can automatically recognize and locate key facial feature points by learning a large amount of annotated data. These feature points usually include key parts such as the eyes, nose, and mouth, which are the basis for facial expression recognition and animation production of animated characters. Nonetheless, the effective integration of CAD technology with MAS and its subsequent application to optimizing animation image design remains a challenging and unexplored research area.

In recent years, the landscape of animation image design has undergone significant changes, driven by advancements in computer graphics, artificial intelligence, and distributed computing. Scholars and research institutions alike are dedicated to exploring cutting-edge techniques for more efficient and intelligent animation generation and design. In the digital age, cartoon character images, as a widely popular art form, have penetrated into people's daily lives. Among them, cartoon characters with different styles are deeply loved by the public due to their cute and cute characteristics. However, emotion recognition of these cartoon character images, especially the classification of bipolar emotions such as happiness and sadness, remains a challenging task. Cao et al. [5] applied deep learning to bipolar emotion classification of cartoon character images with different styles. It utilizes deep learning techniques to construct an emotion classification model. This model can use Convolutional Neural Networks (CNN) as the basic structure to automatically extract feature information from cartoon character images through multi-layer convolution and pooling operations. At the same time, in order to better capture emotion-related features, we can also introduce advanced technologies such as attention mechanisms, so that the model can pay more attention to regions related to emotional expression. Traditional animation 3D pose recognition methods often rely on complex manual feature extraction and model design, and their recognition speed and accuracy are often difficult to achieve ideal results. Ding and Li [6] discussed the high speed and accuracy of animation 3D pose recognition based on an improved deep convolutional neural network. Deep convolutional neural networks can automatically learn and extract advanced features from images by simulating the hierarchical structure and connectivity of human brain neural networks. In animation 3D pose recognition, DCNN can effectively extract character pose information from animation frames and gradually abstract more refined and representative feature representations through layer-by-layer convolution and pooling operations. 3D modelling and animation methods often require tedious operations and complex processes, making it difficult for ordinary users to get started easily. To solve this problem, a single-view method for leisure 3D modelling and animation based on CAD and multi-agent systems has emerged, Dvorožňák et al. [7] provide users with a simple and efficient solution. CAD technology, as a core tool in the field of modern design, can accurately construct three-dimensional models and provide high-quality materials for animation production. Multi-agent systems can simulate and process complex tasks, achieving intelligent operations. By combining these two technologies, it is possible to achieve leisure 3D modelling and animation based on a single view.

With the introduction of the concept of the metaverse, research on animated digital humans has also received attention from researchers. The most important part of the generation process of digital humans is the expression of digital human expressions. Studying how to generate highly realistic animated 3D digital human expressions is of great significance. Moreover, the study of highly realistic facial expressions has a wide range of application scenarios. In areas such as AR/VR, virtual broadcasters, and game production, using highly realistic facial expressions can provide users with a more realistic experience. Feng et al. [8] proposed a precise facial expression modelling method based on high-precision 3D facial models, which uses a high-precision structured light system to capture highly realistic 3D facial models. Parameterize the representation of the obtained high-precision facial model. Using facial driving parameters obtained from two-dimensional facial videos to drive parameterized facial models. Huang et al. [9] studied a structured light-based 3D reconstruction algorithm and built a high-precision structured light-based facial data acquisition system. Use this system to collect three-dimensional point cloud data of facial expressions from multiple angles. It uses registration algorithms to concatenate the collected point cloud data; And perform grid operation on the spliced point cloud. Finally, map the 3D model to the 2D texture. On the basis of the structured light system, a DSLR camera has been added for the collection of facial textures in 3D models. The high-resolution 2D images collected are mapped onto the 3D model as textures. Jing and Song [10] proposed a method to obtain two-dimensional facial expression coefficients by using a linear combination of three-dimensional facial expression data. Use this method to automatically annotate the expression coefficients of two-dimensional expressions, in order to obtain a training set of expression coefficients with sufficient samples. A deep learning model was designed to train using two-dimensional images from the training set and the obtained expression coefficients, in order to obtain an expression-driven model with high robustness and recognition efficiency. This model can be used to drive highly realistic 3D virtual expressions based on 2D videos. Through precise modelling and rendering, the skin texture, clothing materials, and lighting effects of animated characters can be realistically reproduced, greatly enhancing the audience's immersion and immersion.

This article aims to investigate an optimization strategy for animation image design through the integration of CAD and MAS. It examines the current utilization of CAD technology in animation image design and explores the algorithmic benefits of MAS in optimization processes. Based on this analysis, the article proposes a framework that combines CAD and MAS for enhanced animation image design optimization. The framework takes CAD technology as the basic tool of design, realizes the automation and intelligence of the design process by using MAS, and achieves the purpose of improving design efficiency and creativity through cooperation and competition among agents. The research not only has important theoretical value but also will promote the innovation and progress of the animation industry. Specifically, this article has the following innovations:

(1) This article puts forward the strategy of combining the accuracy of CAD technology with the intelligence of MAS to optimize the animation image design.

(2) This article designs an optimization algorithm based on MAS, which is used to automatically generate animation images that meet the design requirements. The algorithm can find the global optimal solution through cooperation and competition among agents according to the optimization objectives and constraints set by designers.

(3) By combining CAD technology and MAS, this article realizes the automation and intelligence of animation image design. This not only greatly reduces the designer's manual operation and time cost, but also can automatically generate high-quality animation image design schemes according to the designer's needs.

This article first analyzes the role of CAD technology in key links such as animation modelling and rendering and then puts forward an optimization strategy of animation image design combining CAD technology with MAS, which includes key steps such as data preprocessing of CAD model, MAS modelling, optimization algorithm design and performance assessment. The research of this article, can not only provide a new optimization strategy and methodology guidance for the field of animation image design but also promote the application of CAD technology and MAS in a wider field. In future research, we can further expand the methodological framework of this article and explore its potential value in architectural design, industrial design and other fields.

2 RELATED THEORY AND TECHNICAL BASIS

In the field of computer-aided animation character design, cubic B-spline curves play a crucial role as an important mathematical tool. It provides more flexible and precise methods for the design of animated characters with unique properties such as continuity, smoothness, and local adjustability. At present, the most commonly used method for generating 3D virtual expressions in film, television, and animation games is to attach marker points on the actor's face. Li [11] used special equipment to capture the facial expressions and movements of actors, thereby creating virtual characters. The expression of game characters in Final Fantasy XV is a classic animated image created based on marker point capture. In the field of virtual broadcasters, the study of highly realistic 3D expressions also plays a very important role. Virtual anchor technology usually controls the image of a virtual 3D cartoon character through animated videos, and the facial expressions are not particularly rich. If high-realism 3D expressions are applied in the field of virtual anchors, it will greatly improve the effectiveness of live streaming. In the field of medical beauty, high-precision 3D animation reconstruction technology is used to reconstruct faces. Then attach different expressions to the scanned 3D face, allowing the beauty seeker to experience the postoperative effect before surgery. At the same time, accurately expressing one's intention to undergo plastic surgery to the doctor can form more effective communication. As mentioned above, highly realistic 3D animated facial expressions can greatly improve the user experience in fields such as film and television, gaming, medical beauty, etc., and also play a very important role in the generation process of virtual humans. Li and Li [12] proposed a series of innovative algorithms for the precise modelling of high-precision and highly realistic 3D animated facial models. We have conducted in-depth and systematic research on virtual human expression generation to help people quickly and accurately model expressions. In the above research plan, facial reconstruction technology and facial animation technology are both independent of each other. The research on facial recognition technology is based on experiments conducted on existing facial databases. The experimental plan must be implemented based on the characteristics of the facial database. Such facial animation technology will be limited by factors such as the accuracy of emotion recording and the richness of facial expressions in the facial database [13].

The three-dimensional reconstruction technology of the face and the animation technology of the face is important research in the field of computer graphics. Traditional facial 3D reconstruction technology mainly relies on expensive 3D scanning equipment and a large amount of time-consuming post-processing and requires the scanned subject to maintain a fixed posture for a considerable period of time. In recent years, the development of large-scale computing power in computer-related hardware, especially GPUs and distributed computing, has made it possible to come up with a real-time and efficient solution. At present, the main methods used domestically and internationally can be roughly divided into the following types: traditional 3D facial reconstruction methods, 2D image-based 3D facial reconstruction, depth camera-based 3D reconstruction, and end-to-end 3D facial reconstruction methods [14]. The complex three-dimensional spatial structural features and rich subtle facial features make facial 3D reconstruction and related facial animation technologies the main challenges in the field of computer graphics. Mori and Bao [15] studied the mapping relationship between key points in 2D facial images and key points in 3D facial models. And calculate the changes in three-dimensional space based on two-dimensional key points, in order to reconstruct and gradually optimize the three-dimensional model of the face. Another exploration content of this paper is facial animation technology, mainly through customized bone point-driven methods and the calculation of individual coefficients and expression coefficients through blend shape. Najafi et al. [16] studied and developed corresponding directly operable applications based on the above methods and algorithms to showcase their research results. This program not only reconstructs the facial model, but also adds custom textures, even refining the eyeball, different skin tones, different hairstyles, and different lighting. At the same time, based on the reconstructed facial model and combined with BlendShape technology, more subtle pose expressions can be set for the facial model to build a database of the same subject. On the premise of enriching the breadth of the original data, this database can provide convenient and practical data for facial-related film and television, game production, virtual reality, medical beauty and other development fields. Combining computer graphics-related technologies to enrich the research of faces in two-dimensional and three-dimensional spaces. The research content of this paper mainly includes the following parts: research on three-dimensional facial reconstruction based on two-dimensional images, improvement of blend shape technology, and exploration of facial animation.

Facial 3D reconstruction and facial animation are two important research areas in the field of computer graphics. Due to the complex spatial structure and rich subtle features of 3D models, facial 3D reconstruction and facial animation technology have become the main challenges in the field of computer graphics. The current research in the field of facial recognition can achieve good results to a certain extent. However, in practical applications, various problems are often encountered. For example, the angle, posture, makeup, and lighting of the face have a significant impact on the recognition effect, which is worrying. In order to avoid the unnecessary impact of these factors on facial recognition and improve recognition accuracy, Paier et al. [17] adjusted the parameters of the animation based on these features. 3D facial reconstruction is also playing an increasingly important role in the research of facial recognition. In order to reconstruct 3D models with detailed features of characters and achieve more realistic facial animation technology, many research methods have been proposed by the academic and industrial communities and have been applied in fields such as cartoon animation production, film and television special effects production, medical visualization, virtual reality (VR), etc. At the same time, it meets the growing demand for 3D facial models, making 3D facial reconstruction and related animation technologies gradually mature. High-quality facial-driven animation technology requires capturing the facial expressions and semantic information of actors and reproducing this information on virtual character models such as cartoons. By using advanced 3D scanning and facial expression motion capture devices, realistic facial animation effects can be created in movies and game production. Therefore, ultra-realistic facial expression animation technology is gradually being applied in film and television special effects production. The related film and television have sparked a wave of application of 3D facial models and facial animation technology. For example, movies such as Avatar and The Lord of the Rings capture facial expressions and actions of actors through cameras and sensors located on the face, further driving the target model [18].

When it comes to computer graphics, the most easily associated application field is 3D games, where modelling, animation, and rendering techniques from computer graphics are widely used to achieve super-realistic effects. The facial images of characters in traditional 2D flat games are relatively fixed. In contrast, in 3D games, custom facial contouring can be performed, and many super realistic game protagonists have built 3D facial models based on celebrities, which are becoming increasingly realistic [19]. Rathore et al. [20] implemented a regression-based method for reconstructing a single-face image. This method establishes a mapping relationship between the feature points of a 3D facial model and the facial features of a 2D facial image. It can calculate the changes in feature points in three-dimensional space based on the changes in feature points in two-dimensional facial images. At the same time, further adjustments were made based on the projection mapping of feature points in three-dimensional space on two-dimensional space, achieving good results.

3 FUSION STRATEGY OF CAD AND MAS

In animation image design, it is the key to improving the design efficiency and quality to realize the effective integration of CAD technology accuracy and MAS intelligence. This section will elaborate on the fusion strategy of CAD and MAS in detail, especially how to introduce the ACO algorithm into this fusion process to build an efficient and intelligent animation image design optimization model.

3.1 Data Preprocessing of CAD Model

In the fusion strategy, it is necessary to preprocess the data of the CAD model in order to provide suitable input for MAS. The preprocessing process includes data cleaning, format conversion, feature extraction, and dimension reduction. Data cleaning is mainly to remove redundant information and noise data in the CAD model to ensure the accuracy of subsequent processing. Format conversion is to convert CAD data into a format that MAS can handle, such as converting a three-dimensional model into a two-dimensional grid or point cloud data. Feature extraction and dimensionality reduction aim to extract key design features from CAD models, such as shape, size, and proportion, and reduce the dimension of data so as to reduce computational complexity and improve processing efficiency.

3.2 MAS Modeling

In animation image design, the modelling of MAS is the core link to realize the integration of CAD and MAS. First of all, it is necessary to divide the animation image design process into multiple subtasks according to the design task and define one or more agents for each subtask. The agent's definition should consider its autonomy, reactivity, sociality, and initiative so that it can independently complete tasks and cooperate effectively with other agents in the design process.

The behaviour rules and decision-making mechanism of agents are the key to MAS modelling. Behaviour rules define the behaviour choice of agents in a specific state, while the decision-making mechanism determines how agents make optimal decisions according to the current state and goals. In order to realize the integration of CAD and MAS, we need to introduce the data characteristics and constraints of the CAD model into behaviour rules and decision-making mechanisms.

The context of the issue involves considering agents from set n and tasks from set n. Tasks can be delegated to any agent, with varying costs for each agent to fulfil each task. Given a specific arrangement $\pi \in P_n$ within the collection P_n, its associated weight $w(\pi)$ is determined by the aggregate of the corresponding weights of all the elements that compose that arrangement:

$$w(\pi) = \sum_{i=1}^{n} w(i, \pi(i)) \tag{1}$$

In this context, $\pi(i)$ denotes the value of the i bit within the configuration π. The objective is to identify the arrangement $\pi^* \leftarrow \arg\min \{ c(\pi') \mid \pi' \in P_n \}$ that exhibits the lowest weight within the set P_n.

Considering the complexity of animation image design, it is needed to design an effective cooperation mechanism to realize the cooperative work among multiple agents. This cooperation mechanism should be able to ensure the coordination and information sharing among agents in the design process.

3.3 Optimization Algorithm Design of ACO Based on GA-ACO Algorithm

ACO algorithm is an optimization algorithm that simulates the foraging behaviour of ants in nature and has strong global search ability and robustness. In the optimization algorithm design based on ACO, the animation image design problem is transformed into a problem of finding the optimal path. Each "and" represents a potential design scheme, and they search in the design space and construct an animated image that meets the requirements. In the process of searching, ants will choose the next moving direction according to the pheromone concentration and visibility of the current position. Pheromone concentration and visibility represent the advantages, disadvantages, and feasibility of the design scheme, respectively.

The implementation process of the fusion strategy of CAD and MAS is as follows: firstly, the data of the CAD model is preprocessed to extract key features and constraints. Then, according to the design task division and agent definition, the MAS model is constructed. Then, an optimization algorithm based on ACO is designed, and the data characteristics and constraints of the CAD model are introduced into the algorithm. Finally, through iterative calculation and pheromone update, the optimal design scheme is found.

Figure 1 depicts the basic mechanism of the ACO algorithm; that is, ants will release a special smell in the process of marching, which is called pheromone, and it provides clues for subsequent ants to choose their paths. When ants crawl a unit distance, the amount of pheromones they leave is constant. In the initial state, if the pheromone concentration of the two paths is the same, then the possibility of ants choosing these two paths is equal only based on the pheromone factor. In this way, the ACO algorithm simulates the foraging behaviour of ants and finds the optimal path.

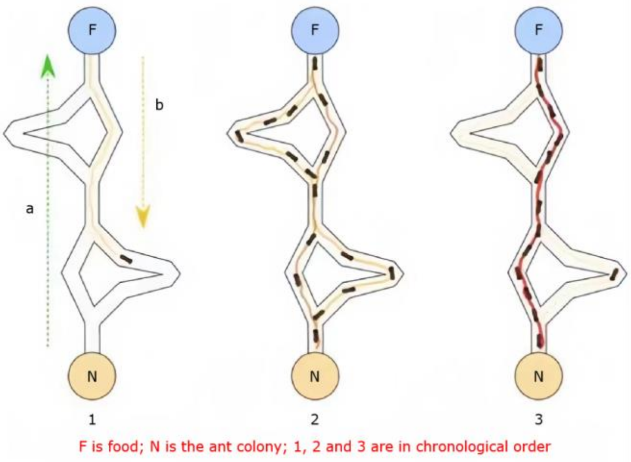

Figure 1: Schematic diagram of ACO algorithm.

The likelihood of an ant selecting its subsequent step (ensuring that this intermediary point is not listed in the tabu list S is influenced by multiple factors: the pheromone intensity ξ_{ij} on the route, the magnitude η_{ij} of heuristic data, the significance a of pheromone levels and the relevance β of heuristic information. The precise probability of selection is determined as follows:

$$p(i,j) = \frac{[\xi_{ij}]^{\alpha} [\eta_{ij}]^{\beta}}{\sum_{h \notin S} [\xi_{ih}]^{\alpha} [\eta_{ih}]^{\beta}} \tag{2}$$

Excessive pheromone residue on a path (i,j) can lead to the burial of heuristic information by residual data, impeding effective path selection in subsequent cycles. To prevent this scenario, artificial ants emulate the storage mechanism of human brain information. This means that as new information is stored, older memories gradually become less distinct or are erased over time. Consequently, after completing a cycle (comprising C elements from the feasible set n, the artificial ants update and refine the pheromone levels on each path.

Between time t and time $t+n$, the pheromone intensity on path (i,j) undergoes updates and adjustments based on a set of predefined rules.

$$\tau_{ij}(t+n) = \rho \cdot \tau_{ij}(t) + \Delta\tau_{ij}(t) \tag{3}$$

$$\Delta\tau_{ij}(t) = \sum_{k=1}^{m} \Delta\tau_{ij}^{k}(t) \tag{4}$$

In this context, ρ designates the pheromone residual coefficient, which falls within the range denoted by $\rho \in (0,1)$.

In order to introduce the data characteristics and constraints of the CAD model into the ACO algorithm, we can improve the pheromone update rules and visibility calculation methods. Specifically, we can add the data characteristics of the CAD model to the pheromone update rules so that excellent design schemes can accumulate more pheromones. Furthermore, the constraint conditions of the CAD model are considered in the visibility calculation method to ensure that the generated design scheme meets the design requirements. Figure 2 shows the algorithm's optimization process.

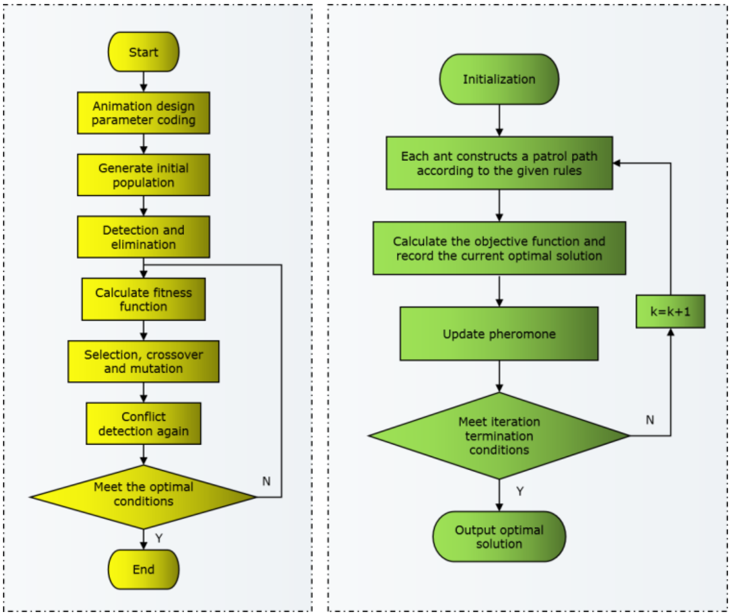

Figure 2: Algorithm optimization process.

In the recently revamped system, a combination of global and local update strategies is employed. The aim of global updating is to enhance the guidance provided during the search process. This update occurs once all ants have concluded their search, utilizing the following formula to establish the path for updating:

$$\tau(r,s) \leftarrow (1-\rho)\cdot\tau(r,s) + \rho\Delta\tau(r,s) \tag{5}$$

$$\Delta\tau(r,s) = \begin{cases} (L_{gb})^{-1} & If\ (r,s)\ is\ the\ global\ optimal\ path \\ 0 & otherwise \end{cases} \tag{6}$$

In this context, ρ represents the pheromone evaporation parameter, whose value is set based on the previously analyzed parameter progression. Meanwhile, L_{gb} denotes the currently identified global optimal path. The formula indicates that the pheromone reinforcement increases with the weight value attained on the shortest path.

When tackling real-world problems, solutions are often scarce and unevenly distributed, resulting in minimal differences among the obtained solutions. Consequently, during the iterative process, it's crucial to incorporate the aforementioned random operator to ensure a uniform and diverse distribution of solutions. This enhances the problem-solving capabilities of the ant colony algorithm:

$$r = \max(rand(\ ), 0.602) \tag{7}$$

$$x' = LB + r*(UB - LB) \tag{8}$$

In this context, x' represents a new individual resulting from crossover and mutation operations, while UB and LB are matrices composed of ceiling and floor values respectively, known as h matrices.

To enhance the search quality and global reach of the ACO algorithm, ensure robust diversity and randomness, and prevent premature convergence, it is crucial to impose limits on pheromone intensity after each update. Additionally, the pheromone threshold should align with the max-min ant system for optimal performance:

$$\tau_{ij} = \begin{cases} \tau_{\min} & \tau_{ij} < \tau_{\min} \\ \tau_{ij} & \tau_{\min} \le \tau_{ij} \le \tau_{\max} \\ \tau_{\max} & \tau_{ij} \ge \tau_{\max} \end{cases} \tag{9}$$

By imposing limits on the pheromone intensity of each node, we can maintain a consistent range $[\tau_{\min}, \tau_{\max}]$ of pheromone levels across all paths. This approach helps to concentrate pheromone intensity on more promising paths while also preventing the intensity from becoming too low, which might hinder the discovery of alternative routes. Furthermore, it avoids excessive pheromone accumulation that might lead to premature convergence of the algorithm, thereby ensuring a more effective search for the global optimal solution.

Figure 3 is a composite image obtained by using the animation image style migration method. Drawing from the aforementioned satisfactory outcomes, diverse style models were created to cater to distinct style target images. Consequently, the stylized images produced during the testing phase exhibited varied hues, yielding comparable yet distinctive styles. Illustrations of some of these results can be found in Figure 4.

According to the characteristics of animation image design, it is necessary to design an effective decoding method to convert the ant path into the actual design scheme. The decoding method should be able to restore the characteristic parameters and attribute values of the CAD model according to the path information of ants so as to generate an animated image that meets the design requirements.

Figure 3: Style migration.

Figure 4: Migration effect of different styles.

4 ALGORITHM IMPLEMENTATION AND PERFORMANCE ASSESSMENT

4.1 Experimental Design

The purpose of the experiment is to comprehensively evaluate the performance of the original ACO algorithm, GA, and the improved GA-ACO algorithm, which combines them in the field of task scheduling and resource allocation. The experimental environment is based on the Matlab programming platform, which ensures that the algorithms can be compared fairly under the same conditions. By setting the number of iterations to 100, the population size to 40, and the number of server nodes to 20, and testing in the range of 20 to 200 tasks, the performance of the algorithm in different scenarios is comprehensively investigated.

During the experiment, each algorithm needs to complete task scheduling and resource allocation and record key indicators such as task completion time, system load balance and resource utilization. These indicators will directly reflect the performance and efficiency of the algorithm in practical application. By comparing these indicators, we can clearly see the advantages and disadvantages of each algorithm and the performance changes under different task scales.

4.2 Experimental Result

Figure 5 shows the running results of the original ACO algorithm and the improved algorithm (GA-ACO) combining ACO and GA on task scheduling and resource allocation. On the premise of meeting the requirements of animation design, the GA-ACO algorithm is faster and more efficient than the original ACO algorithm in finding the best resource combination.

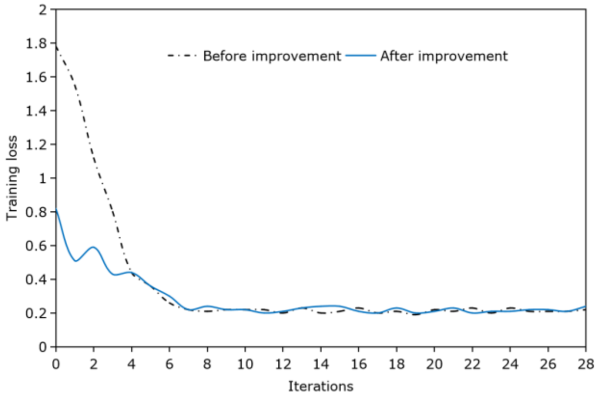

Figure 5: Schematic diagram of ACO algorithm evolution.

GA-ACO algorithm makes full use of the global search ability of ant colony and the flexible parallel mechanism of GA by combining the advantages of ACO and GA. This enables the algorithm to find the potential optimal solution more quickly in the search process, thus accelerating the convergence speed. Compared with the original ACO algorithm, the GA-ACO algorithm can approach or reach the optimal solution more quickly in the same number of iterations, which significantly improves the solution efficiency.

Task completion time, that is, the total time required from the first task assigned to the computing node to the completion of the last task. In this experiment, there are 20 server nodes, and the number of tasks is set between 20 and 200. See Figure 6 for the comparison results of task completion time.

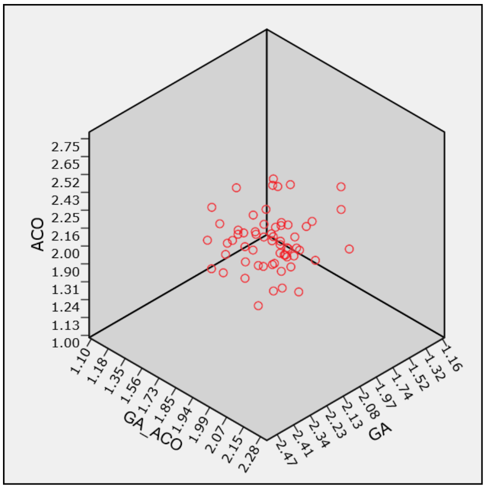

Figure 6: Comparison of task completion time.

Compared with the GA algorithm, the ACO algorithm and GA-ACO algorithm are better in task execution time. This is mainly because they successfully introduce the server load factor so that they can preferentially select the server nodes with lighter loads to perform tasks. On the contrary, when the number of tasks increases due to the lack of solving ability in the later stage of the GA algorithm, the completion time is also significantly prolonged. Therefore, the GA-ACO algorithm has better convergence speed and the shortest task execution time.

In order to evaluate the system load balancing performance of different scheduling algorithms more accurately, the standard deviation of resource node load is used as the assessment index. Based on different task scheduling algorithms, the load balance of the system with different task numbers is compared, and the results are shown in Figure 7.

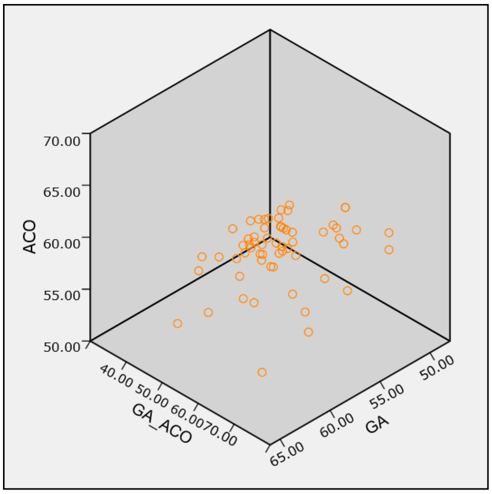

Figure 7: Comparison of system load balancing with different task numbers.

With the increase in the number of tasks, the load standard deviation of all resource nodes in the system corresponding to all scheduling algorithms generally shows a downward trend, which indicates that the load balance of the system is continuously improving. This is mainly because when the number of scheduled tasks is small, there is a great randomness in task allocation, which has a certain impact on system load balance; However, with the increasing number of tasks, the resource allocation gradually becomes more reasonable, and then the load balance of the whole system is gradually improved. Among all the scheduling algorithms, the system load balancing level based on the GA-ACO task scheduling strategy is always the best. By skillfully combining the advantages of GA and ACO, the GA-ACO algorithm successfully avoids the problem of falling into the local optimal solution and improves the convergence speed by 5.45%. Furthermore, with the increasing task scale, the resource load rate of the algorithm is reduced by 22.76% on average compared with the standard ACO.

In order to further verify the effectiveness and feasibility of the improved ACO optimization algorithm, the performance of GA-ACO and standard ACO is compared through the index of resource utilization. Figure 8 shows the comparison results of the two algorithms in terms of resource utilization.

In terms of resource utilization, the improved algorithm proposed in this article also performs well compared with the standard ACO. This is due to the fact that the algorithm makes full use of the global search ability of the ant colony and provides a stable connection, thus ensuring high resource utilization and making the algorithm more efficient. Furthermore, the main difference between GA and traditional algorithms in practical application lies in its improved parallel mechanism based on genetic analysis. GA can judge the pre-gene in the route randomly, which increases the flexibility.

GA-ACO algorithm can ensure the efficient distribution of computer communication network traffic to the greatest extent so as to maximize the performance of the computer network.

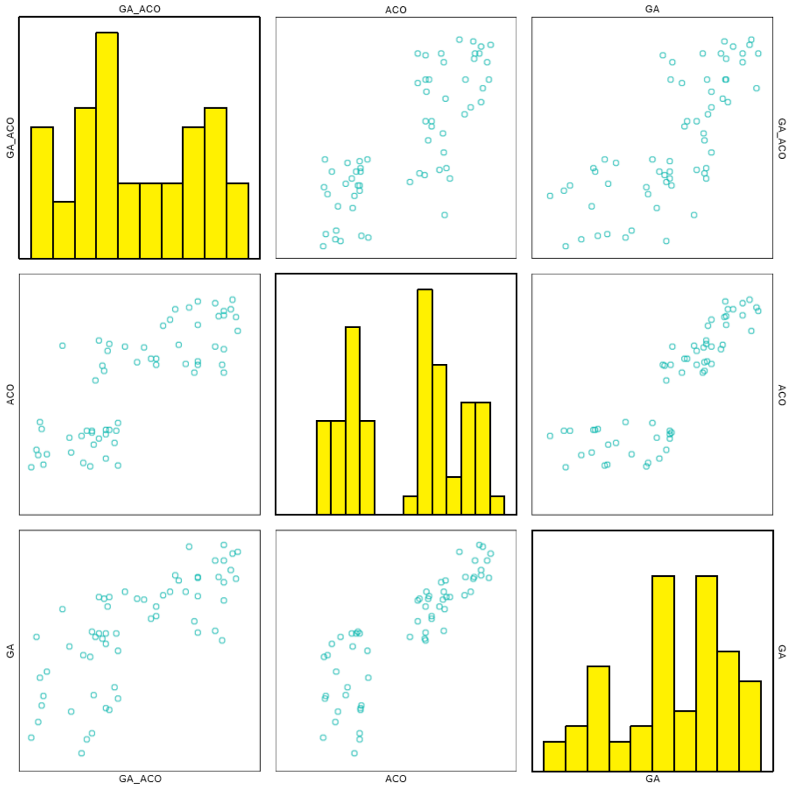

Figure 8: Comparison of resource utilization rate.

Figure 9 shows the maximum occupancy rate of resources allocated by each algorithm under a different number of simulation models. This index is a key parameter to measure the performance of the algorithm in resource allocation. The smaller its value, the higher the efficiency of the algorithm in resource allocation and the better its performance.

5 CONCLUSIONS

As computer graphics, artificial intelligence, and distributed computing undergo rapid advancements, the realm of animation image design is constantly evolving. This article delves into an optimization approach that blends CAD with MAS for animation image design. Through rigorous experiments, we validate the efficacy and superiority of this proposed strategy.

CAD technology, as the cornerstone of animation image design, equips designers with robust modelling and rendering capabilities. The integration of MAS further elevates the design process, introducing automation and intelligence. By establishing an optimization framework centred on CAD and MAS, this study effectively incorporates the collaborative and competitive dynamics of agents into the design optimization process. The findings reveal that this framework notably enhances design efficiency and fosters creative inspiration among designers. The collaborative aspect of agents facilitates efficient information exchange and resource sharing, while the competitive element challenges agents to explore fresh design concepts, driving innovation.

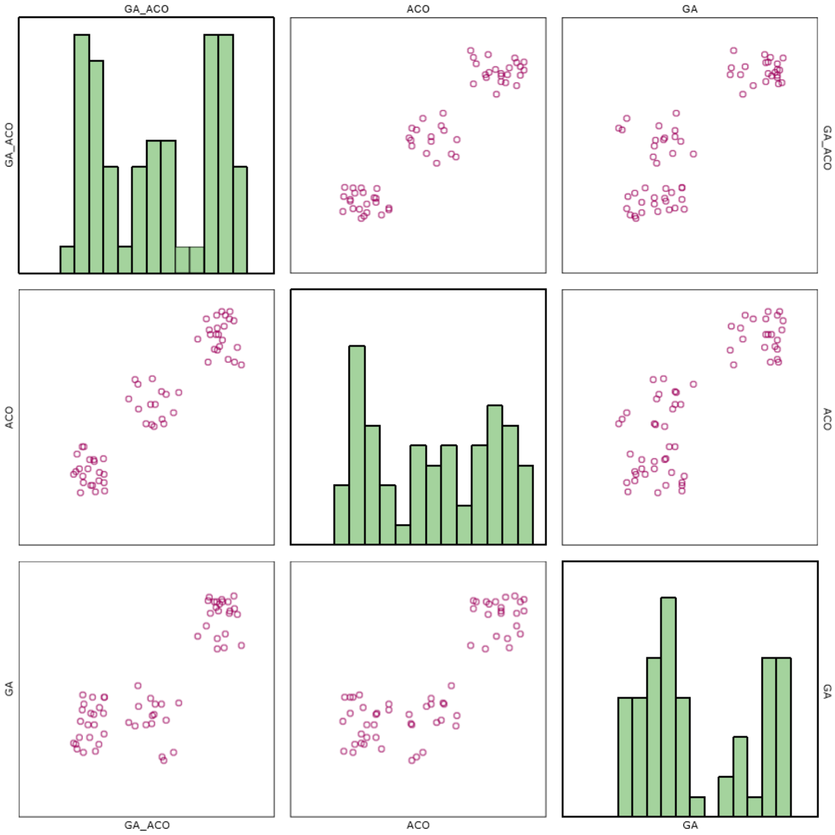

Figure 9: Comparison of the maximum occupancy rate of algorithm resources.

Beyond enhancing design efficiency, the optimization strategy presented in this article elevates the overall creativity of designs. It offers novel perspectives and techniques for advancing animation image design, paving the way for continued innovation and progress in this thriving field. Looking ahead, we are committed to further exploring the synergistic application of CAD technology and MAS, aiming to unlock even more breakthroughs in animation image design.

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