Hindawi
Scientific Programming
Volume 2022, Article ID 1171905, 9 pages
https://doi.org/10.1155/2022/1171905

Research Article

Online Optimization of Animation Art Design User Virtual Perception in Mobile Edge Computing Environment

Guozhu Liu [1] **and Sang-Bing Tsai** [2]

[1]*School of Art and Archaeology, Zhejiang University, Hangzhou 310028, China*
[2]*Regional Green Economy Development Research Center, School of Business, WUYI University, Nanping, China*

Correspondence should be addressed to Guozhu Liu; lgzzju@163.com

Received 13 January 2022; Revised 17 February 2022; Accepted 22 February 2022; Published 25 March 2022

Academic Editor: Sheng Bin

Animation art design is widely used in all levels of social life and has become an important part of modern social visual culture. Driven by new technologies, it is integrated with relevant application fields, resulting in new media forms and art categories. The development course of animation art design is sorted out, focusing on the analysis of the technical basis of animation art design and art form, social function and cultural form, creative practice, and theoretical research. This paper puts forward the concept of dimension composition of animation art design and analyzes and studies the dimensions of technology and art, cognition and experience, economy, and culture in animation art design and artistic creation based on this concept. The modeling of edge devices and services is proposed to abstract resources and provide a unified formal description of user virtual perception for animation art design of various sensing types. All related attributes are described uniformly, and the device model and task model are given. Users can customize services based on predefined attributes. According to the development demand of multiuser shared virtual environments, the characteristics and limitations of the previous perception management scheme are analyzed and a two-layer perception management scheme is designed to adapt to the development of new multiuser shared virtual environment of animation art design.

1. Introduction

By pushing computing, network control, and storage to edge nodes, mobile edge computing enables computing intensive and delay-sensitive service scenarios to be applied to resource-constrained mobile edge devices. For example, city traffic surveillance cameras are responsible for monitoring and tracking vehicles that violate regulations, and they need to collect license plate information. In the current architecture of cloud computing, the image needs to be transmitted to the cloud service center for processing and then the response is sent back to the camera. In the framework of edge computing, the camera can use the edge node with the closest geographical location to carry out image recognition processing and obtain analysis results more quickly, as long as the results are transmitted to the service center [1].

In a collaborative virtual environment, especially in a multiuser virtual environment with relatively concentrated participants, real-time interaction between users and operation changes of users to the virtual environment happen at any time, which puts forward certain requirements on computer processing capability, VR engine, and network broadband of the server and client [2]. The server must be able to deal with real-time operation and cooperative interaction in the virtual scene in a timely manner, accept random requests from users, process scene data updates according to users' requests, then obtain the information needed by users, and transmit it to them. The client should be able to process the data in a timely manner once it receives the information, be able to portray a good-quality shared virtual world, and be able to respond quickly enough to the actions and other behaviors of participants. Based on a mobile group of mental awareness on the edge of the

network, how to effectively resource schedule so as to optimize cost awareness is a key problem [3], for example, how to deploy and configure the edge server and how to develop the appropriate data for mobile users' upload strategy, direct users to the corresponding edge server, upload sensory data, and reduce the cost of perception.

The technical and artistic characteristics and their changes in the development of online optimization design for animation art design user virtual perception are discussed. This paper analyzes the core issues involved in the process of online optimization of animation art design user virtual perception. This paper analyzes the significance and function of dimension expansion and compression in online optimization design of animation art design user virtual perception. Taking the above content as the starting point, the theoretical framework of online optimization design of animation art design user virtual perception is constructed. Based on the concept of dimension composition, this paper analyzes the application of spatial dimension expansion and compression in creation from the perspective of creators and provides a basis for discussing the inevitable relationship between the technical foundation and art form of online optimization design for animation art design user virtual perception. From the perspective of the audience, this paper analyzes the cognition and experience dimensions of animation art design users to network optimization design and probes into the internal influence of animation art design users' visual principles and aesthetic psychology to network optimization design on art creation. We analyze the relationship between commercial economy and cultural phenomena in the development of online optimization design. In the study of optimization design of animation art design user virtual perception online, the concept of virtual users online optimization design dimensions can be divided into different angles and levels to clarify the animation art design user virtual online optimization design technology, the construction of the artistic skill and the basic theory, and the relationship between the vital elements, for animation creative practice and theoretical research has a vital significance. Section 1 is an introduction, Section 2 is related work, Section 3 is optimization of virtual user perception for animation art design based on moving edge computing, Section 4 is mobile edge animation art design user virtual online optimization, Section 5 is example verification, and Section 6 is conclusion.

2. Related Work

At present, the research on edge computing is unloading, that is, using edge servers to undertake part of the computing tasks of edge devices. A mobile sensing framework (MSF) is proposed, in which all the preprocessing and calculations are completed in smartphones [4], but complex algorithms may need a long time to run on low-end processors and consume a lot of energy. An end-to-end solution is proposed for this situation, which aims to balance network overhead and CPU overhead. Specifically, it is to divide processing tasks between mobile devices and the cloud. Mobile devices will process the preprocessing unit and minimize unnecessary information to reduce the amount of data transmitted [5]. Task division helps to reduce network overhead, but the advantages of mobile edge computing are not fully utilized. The premise of the solution is a good network connection, which cannot adapt to dynamic and changeable network conditions in practice [6]. The virtual environment is divided into regions, and the boundaries of each region define different levels of penetration in response to different user perceptions. For example, the boundaries of an area can attenuate audio information but allow visual information to pass through unimpeded. A region can also provide an overall depiction of the internal object set and move around the virtual environment as its internal objects move [7]. For example, a region can move in the virtual environment with the movement of the internal group of participants, so that only the movement of the group as a whole can be seen when observed at a certain distance, thus greatly reducing the description information for the data update of participants. In a multiuser shared virtual environment, participants are distributed independently in different locations and they participate in the system as avatars. As the subject of perception, the surrogate can perceive the change information of objects in the virtual environment in real time [8]. The avatars roam freely in the space information provided by the scene and operate the virtual objects by triggering the events of the virtual objects. Avatars communicate with each other through the tools and methods provided by the virtual environment. In a multiuser shared virtual environment, due to the participation of multiple people, the scene or object information will be exchanged with users when it is changed. Also, communication between multiple people is accomplished through real-time interactive information.

From the perspective of users, user selection usually refers to selecting some mobile users to perform perceptual tasks under budgetary constraints, so as to maximize the optimization objectives such as perceptual task quality and platform revenue [9, 10]. Firstly, a user recruitment algorithm is proposed to recruit as few users as possible while ensuring the quality of task completion, and then, a secure user recruitment protocol based on secret sharing is proposed [11]. Secondly, a semi-Markov model is proposed to determine the probability distribution of users' arrival at the point of interest, and then, the contact probability between users is obtained. Then, an effective prediction-based mobile swarm intelligence awareness user recruitment strategy is proposed [12, 13] to minimize data upload costs. The user recruitment strategy based on data quality is studied. First, by mining the historical data of users' task execution, compressed sensing is used to predict the data quality that users will achieve when performing tasks they have never performed before [14] and the predicted data quality is used to guide user recruitment. The authors consider both offline and online situations and propose a user recruitment method based on the greedy strategy. In order to recruit users with high credibility, this paper studies the trust evaluation mechanism based on user recruitment and proposes a new trust model called "empirical credibility" [15, 16], which is used to evaluate the trust relationship between any two mobile users. Based on these trust

relationships, a new trust-based user recruitment scheme is proposed. Task recommendation refers to the user-centered design of a task recommendation mechanism based on user preferences and reliability. A reasonable task recommendation mechanism can improve the probability of users accepting tasks and the perceived task completion quality and also attract users to participate in the perceived task again. Logistic regression is used to estimate users' preferences, perform task recommendations based on preferences, and determine the payment to users [17]. A personalized task recommendation system is proposed to evaluate user preferences through implicit feedback in user's historical performance and to evaluate user reliability using a block coordinate descent algorithm [18]. Based on the user's behavior rule and the recommendations of interest preferences, the geographical social relation model is used to analyze the task clustering and then the Gaussian analysis of the Markov model is used to predict the users' next transfer time likely to reach the probability of each place [19].

Therefore, drawing lessons from and learning the design and scheduling of film shots are an inevitable part of animation production, but the composition elements and implementation means of animation shots and film shots are different [20]. Mainstream animation art design user virtual online optimization works are still dominated by feature films, and some experimental animation works also include hidden or potential narrative clues. In terms of picture composition principles, they all focus on the creation of picture ideograms and visual centers and pay attention to the dynamic balance of the picture. The development of digital technology has brought revolutionary progress to the film industry [21, 22]. Animation art design user virtual online optimization are widely involved in film production with virtual and technical characteristics, which breaks through the objective material limitations of traditional film shooting technology and shooting content and has an important impact on the development of film art. Since the birth of online optimization of animation art design user virtual perception, its function has been used for film special effects [23]. With the development of decades, digital virtual scenes, virtual cameras, virtual roles, motion capture, cluster animation, and other advanced digital image technologies have been widely applied in modern film creation and digital technology has gradually risen to the leading position from its the initial function of assisting film and television special effects [24]. Animation art design user virtual online optimization with its own modern digital technology advantages constantly improves the visual expression of film art. It changed the filming and production process of films, gave the audience more intense audio-visual sensory stimulation, and even affected the type composition of modern films, which directly led to the prosperity of spectacle films [25]. Based on material basis, film art adopts the means of continuous recording to shoot performance segments for spatial reproduction. Traditional animation uses frame-by-frame drawing in the form of art for spatial representation. Although both are spatiotemporal integrated arts, the film is constructed on the basis of reality while the animation is constructed on the basis of assumption [26]. Compared with film, animation is closer to the expression of literature and art. It is based on reality and similar to reality, but there is a certain sense of alienation and imagination space. Animation art design user virtual online optimization constructs its own aesthetic norms on the basis of digital technology, breaks through the "hypothetical" form of traditional animation, strengthens the simulation of reality from the perspective of visual perception, realizes the visual realism of pictures and images, and thus reduces the abstractness of traditional animation. It weakens the difference of media caused by the difference of material and technology, shortens the realistic distance of aesthetic sensibility, and makes the boundary of film art and animation art blurred and fused from the image to content and subject matter.

3. Optimization of User Virtual Perception for Animation Art Design Based on Moving Edge Computing

3.1. Online Optimization Architecture. Based on the software-defined network, the solution architecture is generally divided into three layers, including the central cloud, cloud edge, and edge device layer from top to bottom, and the corresponding three layers of perception layer, network layer, and application layer, respectively, are shown in Figure 1. We will take a closer look at these three layers of architecture.

Mobile edge computing networks can provide edge intelligence for aware applications by using their cloud services. Edge intelligence includes a synchronous fusion of multimode sensing information, perceptual information encoding and decoding, prediction, target actuation management, and enhanced security mechanisms. The synchrony fusion of multimode information can combine the perceptual content acquired by different acquisition methods into the content understood and accepted by humans with the frequency and range of synchrony. Perceptual information encoding and decoding of edge intelligence can improve the efficiency, speed, and security of perceptual information transmission and, at the same time, compute and unload the sensors and applications at the perceptual layer. Based on the analysis and judgment of the cached information, such as the operator's behavior and perceived content, the prediction module of edge intelligence predicts the following instructions and controls of the operator through statistical analysis and process analysis. At the same time, the controlled robot is prepared by the predicted operation in advance, which reduces the preheating time of action and improves the reaction efficiency. By setting the security mechanism of the sensing application on edge intelligence, the security of the sensing layer and the application layer can be guaranteed in a unified manner without the need for a security guarantee mechanism with the same modules and functions for each sensing device at the sensing layer and each application system at the application layer. Therefore, the perception layer can be made to focus more purely on sensing content monitoring, reducing its hardware cost and energy consumption, and the

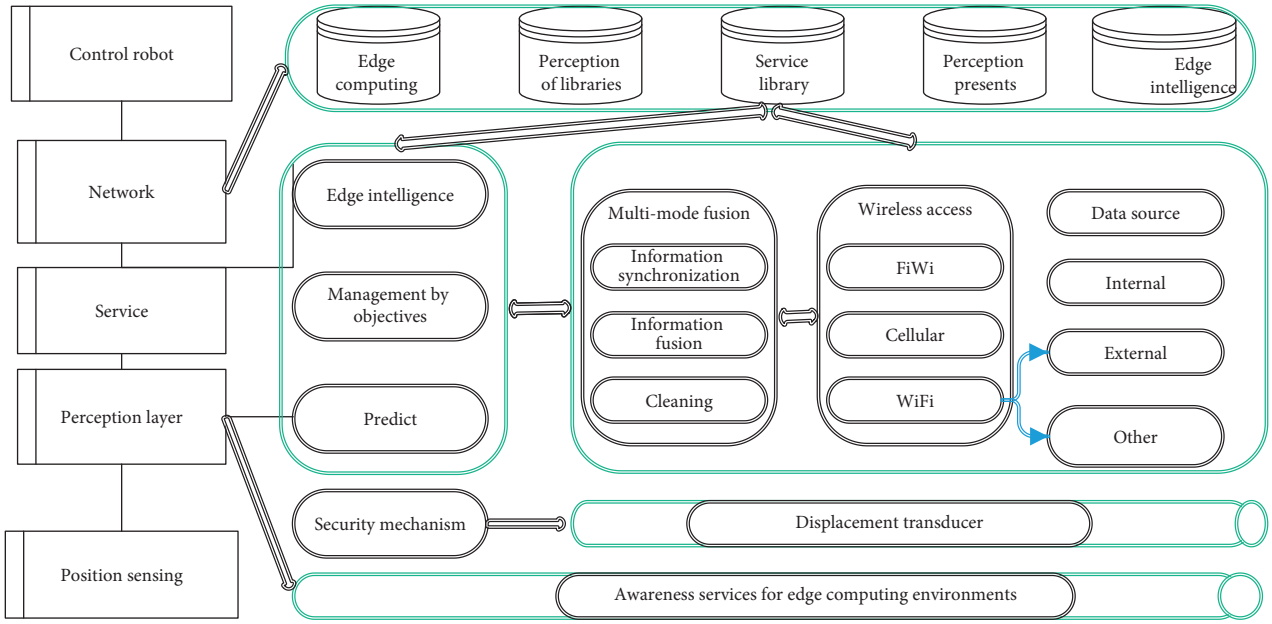

Figure 1: Architecture of aware service scheme in an edge computing environment.

application layer can be made to focus more purely on sensing content presentation and sensing command control, reducing its software cost and computing resource usage.

3.2. User Virtual Environment Animation Art Design Perception Online Optimization. More and more edge devices have computing capability, so as long as they meet the condition of being able to preprocess data, raw data can be preprocessed on the device. We assume that the same sensor information is processed in the same way, including cleaning, transformation, reduction, and compression. The purpose is to eliminate redundant, erroneous, and noisy data, simplify data, and reduce transmission energy consumption. If the device requires preprocessing, the preprocess program is sent along with the task assignment command to the control module on the device. The latency and energy consumption of the transmission preprocessor is negligible compared to the fact that the information gathering takes hours or even days. According to the model, the energy consumption of information preprocessing on the equipment is proportional to the size of data D and the calculation energy of the equipment P, which can be expressed as

$$E_J^K = D_J P_j^d. \tag{1}$$

Once the raw data are preprocessed or processed, it greatly reduces the amount of data to be transferred. Assuming that the reduction ratio of data volume is Y, the data volume L to be transmitted can be expressed as

$$L_{j,g} = \alpha_j \tau_g f_g. \tag{2}$$

Caching in mobile edge networks has proven to be beneficial. The mobile network of the future will be heterogeneous due to the intensive deployment of different types of base stations. As a result, caching can be deployed anywhere in the mobile network. In traditional cellular systems, the content requested by the user must be retrieved from an Internet CDN (Content Delivery Network) node far away from the mobile network. Content is then cached on the mobile core network, but backhaul links are still limited. In addition, with the development of base stations and low-cost storage units, it is possible to deploy caches on both large and small base stations. In a future 5G network, D2D (Direct to Direct) communication could use storage units on users' devices for content sharing based on their social relationships. Figure 2 is a general framework for online optimization of the virtual environment awareness of animation art design users.

In the edge cloud, a large number of edge servers are deployed, usually located at the access point of the network, including but not limited to the router of WIFI and the base station of the cellular network. Edge servers in a region form an edge cloud, providing powerful computing services, storage services, and so on. The edge servers in an edge cloud are managed by a manager, LC mentioned in the previous section, who coordinates the servers in an edge cloud to collaborate with each other to better provide reliable services. It mainly consists of 5 modules.

The network monitoring module is the module to obtain real-time network status and device position movement changes to ensure the continuity of task execution. By analyzing the network information data of devices and servers forwarded by the edge meta-information module, the module records the network status of all devices and maintains the network topology of the whole region. The status is updated as soon as the network status of the monitoring device and the server to which it is connected changes.

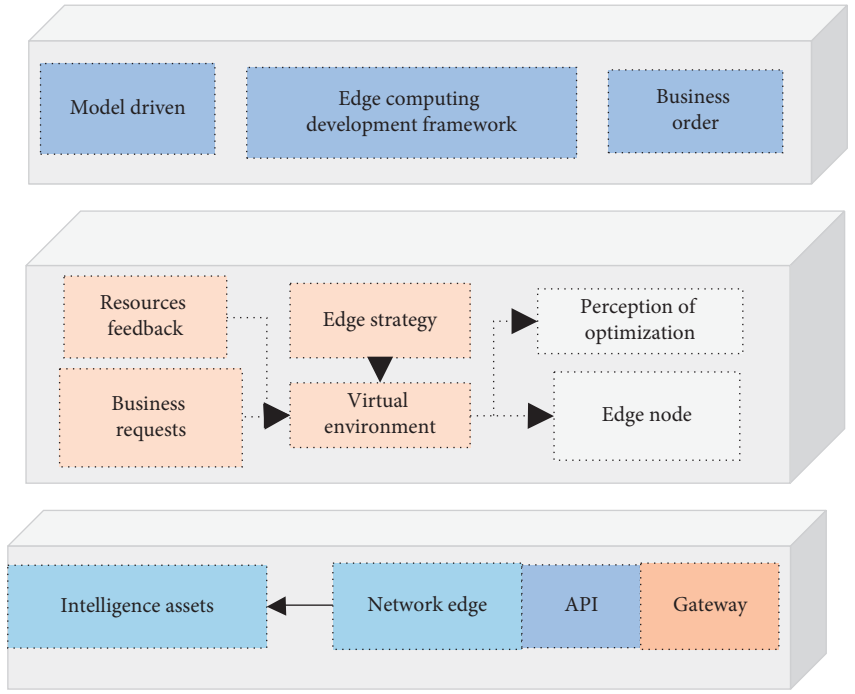

Figure 2: User virtual environment animation art design awareness online optimization architecture.

The edge information management module maintains edge server information of the whole edge cloud and edge device information of each access point as the basis of task scheduling. It will keep a heartbeat connection test with each server and obtain the status of server resources and connected devices at intervals. After updating the information of invalid or newly added devices, it will send the data to the network monitoring module. If a server is found to be facing resource overload or sudden failure, the interface of the migration control module is invoked to implement service migration.

The move control module controls the migration of task images and ensures that only one backup is active in the case of multiple backups. When a new task appears and the initial scheduling is completed, the module calculates the number and location of the secondary backup according to the time sensitivity of the sensor service and sends the image of the processing program of the task to the edge server where the primary backup and secondary backup reside. When a task server fails, it determines whether there is a preallocated backup server. If not, it will select the optimal replacement server in real time and then cooperate with the task scheduling module to migrate services.

The task monitoring module monitors and manages the execution of tasks. It receives the task data sent by the task scheduling module and then collects the data already processed on the edge server in real time, summarizes them, ensures that the data are sent back to the central server, and regularly reports the success rate of the task. During the task execution, the system checks whether the data collected by each server meet the standards, including quality and quantity. Once it is found that the device connected to the server has not transmitted the result many times, it will be regarded as invalid, and the edge information management module will be called to modify the device state and then the scheduling adjustment will be made.

4. Mobile Edge Animation Art Design User Virtual Online Optimization

This problem becomes more difficult when mobile users can carry many types of data without limit. The solution space is much larger than if each mobile user carries up to two types of data. Specifically, when each user has at most two types of data, it will upload data to at most two edge servers. The service cost is unique for the same server combination assigned to the user. However, when each user carries multiple types of data, it is possible to upload data to multiple servers. In this case, route planning should be considered. The same server combination may correspond to different service costs due to the different order in which mobile users access the servers. So the problem in this case is very complicated.

The complexity of computation and large solution space make it difficult for traditional combinatorial optimization techniques to work properly. Therefore, in this section, we propose a multiagent simulated annealing algorithm, CMSA (Carrier Sense Multiple Access), to solve this problem. It first uses a heuristic algorithm to generate the initial solution as a starting point to find a better solution. Then, the algorithm uses multiple agents to generate a new neighbor solution by modifying the current one. Specifically, each agent performs different search methods and compares the current local optimal solution with the current global optimal solution among all agents at certain intervals. When the cost of the

global optimal solution is less than that of the local optimal solution, the agent will update the current solution to the global optimal solution and start to search for neighbor solutions from the updated solution.

We construct the initial solution using a heuristic algorithm, shown in Table 1, that iteratively assigns each type of data to the edge server. Use $C(b, s)$ to represent the change in the current total cost after assigning data type B to the server. In each iteration, the construction algorithm selects a type of data and assigns it to the corresponding edge server. First, the data types and servers that minimize $C(b, S)$ are selected from the unassigned data types and candidate edge servers. The initial solution is then constructed by iteratively performing this process, assigning all data types to the corresponding edge servers.

Table 1: Initial solution construction algorithm.

Input: data type set B, candidate server set S
Output: initial solution h
While $B > 0$ do
For all $b \in B$ do
$Sb = \arg\ \text{minSESC}(b, s)$
$b' = \arg\ \text{minbEBC}(b, sb)$
Assign data type b' to the server to construct the initial solution H
Return h

Motion capture systems commonly used in virtual user online optimization include inertial motion capture systems, mechanical motion capture systems, electromagnetic motion capture systems, and optical motion capture systems. The inertial motion capture system is based on miniature inertial sensors, biomechanical models, and sensor fusion algorithms. Most inertial systems use an inertial measurement unit (IMU) consisting of a gyroscope, magnetometer, and accelerometer to measure the rotation rate, which is converted into a skeleton in the software. An inertial motion capture system can capture the complete motion of the human body in real time. Its advantage is that the capture area is not limited and the motion data can be captured in various environments. The disadvantage is that the positioning accuracy is low and prone to position drift.

Mechanical motion capture systems track the angles of the body's joints directly through sensors connected to the body, often called exoskeleton motion capture systems. The performer attaches the articular mechanical structure to his body, and the mechanical parts move with the performer's movements to measure the relative movement between the parts. Some systems provide limited force feedback or tactile input. Mechanical systems are of low cost, have high accuracy, and can be measured in real time, capturing the movements of multiple roles at the same time. The disadvantage is that the mechanical structure hinders and limits the movements of performers, making it difficult to capture continuous movements in real time. In the space generated by electromagnetic field emission sources, spatial position mapping is accomplished by precisely tracking signals from received sensors placed at key positions in the performer's body. The advantage of electromagnetic motion capture is that it can record six-dimensional information and obtain spatial and directional information synchronously. Performers and animated character models are highly synchronized for easy rehearsal and adjustment. The equipment is simple to set up, the technology is advanced, the stability is good, and the cost is relatively low. Disadvantages are high environmental requirements and the performance venue being near the metal objects; the allowable capture range of the system is smaller than that of optical dynamic capture. Optical motion capture systems use data captured from image sensors to triangulate an object's three-dimensional position between multiple calibrated cameras to provide overlapping projections. Data collection is usually implemented using special tags attached to participants. The new hybrid system combines inertial and optical sensors to reduce occlusion and improve capture accuracy.

The technical advantages of online optimization of virtual users in animation art design are not only suitable for reproducing concrete objects in the real world but also for the simulation of other traditional art types. After the online optimization of animation art design user virtual perception became the mainstream animation creation method and industry standard, the technical exploration aiming at realism began to fall into the state of iteration and repetition and the development route of purely relying on technology to improve the sense of reality would eventually gradually slow down and even stop. The homogeneity of online optimization of animation art design user virtual perception eliminates the differences between different types of traditional animation in terms of materials and media. On the contrary, the openness and diversity of 3D technology are restricted and bound by the inherent artistic style. A few artists and creative institutions are turning their attention to more diverse artistic styles. A series of explorations and experiments were carried out, as shown in Figure 3.

Under the support of computer technology, it presents a vigorous vitality and unique charm. The digital image modeling method made by the computer releases the imagination of creators and elevates film art and television art from the documentary reproduction to the concrete presentation of all levels of human imagination.

5. Example Verification

Three widely used real trajectory data sets are used to evaluate the proposed algorithm. We first compare the total cost of CMSA with the other three comparison algorithms on the three data sets as the number of users changes. As shown in Figure 4, the experimental results show that the performance trend of the total cost of the four algorithms is basically the same in the three data sets, that is, CMSA < DIS (digital information system) < LF (linear filtering) < RAN (rainforest action network), and the total cost of the four algorithms increases with the increase in the number of users (Figure 4).

As shown in Figure 5, we evaluated the variation of the four algorithms with the number of candidate edge servers on three data sets. It can be found that the total cost of CMSA is the lowest and the error bar measures the standard deviation of experimental results, indicating the

Figure 3: Animation art design user virtual perception.

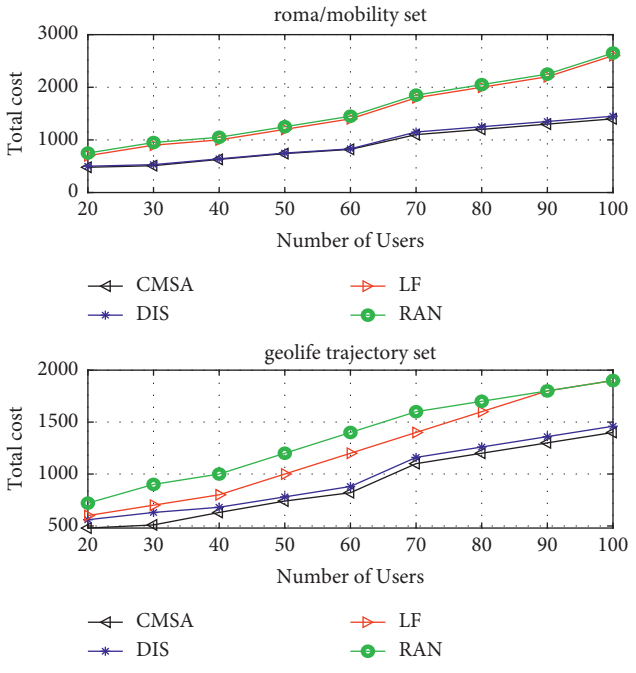

Figure 4: Total cost versus the number of users.

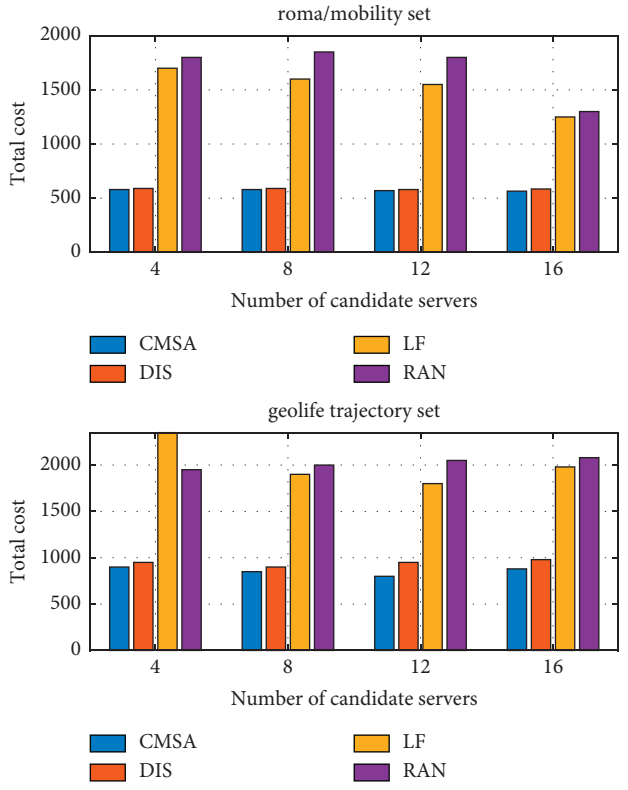

Figure 5: Total cost versus the number of candidate servers.

accuracy of experimental results. The total cost of the four algorithms decreases as the number of candidate edge servers increases because as the number of servers increases, there are more opportunities to activate more suitable servers to reduce the cost.

Finally, we studied the relationship between the number of active servers and the average cost and the number of users, and the experimental results are shown in Figure 6. The average overhead in this chapter refers to the average number of users served by the active edge server. Accordingly, each activated server serves more users and the average overhead increases.

On this basis, we first compare the delay and data under passive recovery and active recovery strategies, as shown in Figure 7. Considering only the mirror transmission time, the mirror transmission time required by the passive recovery strategy is 5.3125 s, accounting for 76% of the total energy consumption, and the total time is 7.673 s, 3.25 times that of the active recovery mode. Active recovery takes up 97% of the time to start the image. Therefore, we can consider this a very time-critical application service. We can consider starting the service container in advance as a cold backup until the primary backup service fails, which can be immediately replaced and provide an almost uninterrupted service.

The development of animation art design user virtual online optimization is closely related to the formation of characteristics and technology. The main development tendency of 3D technology at this stage is to simulate and reproduce the real world. The aesthetic characteristics

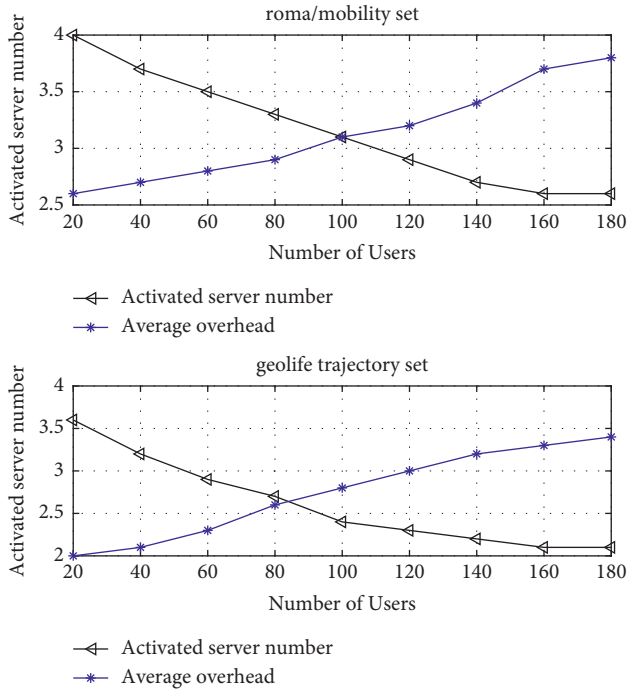

Figure 6: Number of active servers and average overhead versus the number of users.

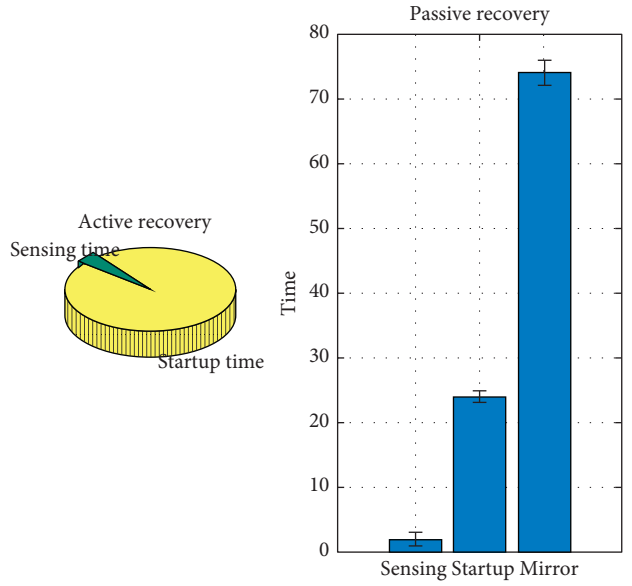

Figure 7: Time comparison of the two strategies.

derived from technology are expressed as the sense of visual reality. Mainstream animation art design user virtual online optimization visual style has been relatively fixed, which is manifested as the combination of traditional animation modeling characteristics and real material texture, that is, the integration of "animation hypothesis" characteristics and "visual reality" characteristics. The reconstruction of traditional animation art type is completed under the background of modern animation art design user virtual online optimization technology. The animation art design user virtual online optimization creation processes are basically solidified on the basis of the traditional animation industry process to enhance the efficiency of multi-line parallel, asset reuse, and other advantages.

6. Conclusion

The development of technology and art alternately promotes the presentation of 3D animation to the world. Mobile edge animation art design user virtual online optimization study of the construction of the theoretical framework, to integrate the fields of computer graphics, traditional animation, painting, and design in the field of art, film, and television art and other relevant research results, made up the concept of dimension as the clue, against the background of economic and cultural dimensions, based on the cognition and experience dimension. The next step is to adapt a two-layer perception management solution to the current development trend of multi-user virtual environments by combining the advantages of the previous spatial interaction perception model and user dynamic interaction analysis perception model.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

References

[1] H. Zhang, Z. Chen, J. Wu et al., "Energy-efficient online resource management and allocation optimization in multi-user multi-task mobile-edge computing systems with hybrid energy harvesting," *Sensors*, vol. 18, no. 9, pp. 3140–3156, 2018.

[2] J. Feng, L. Liu, Q. Pei, F. Hou, T. Yang, and J. Wu, "Service characteristics-oriented joint optimization of radio and computing resource allocation in mobile-edge computing," *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 9407–9421, 2021.

[3] C. Wu, Q. Peng, and Y. Xia, "Online user allocation in mobile edge computing environments: A decentralized reactive approach," *Journal of Systems Architecture*, vol. 113, no. 4, pp. 101904–101923, 2020.

[4] Y. Yin, Z. Cao, Y. Xu, H. Gao, R. Li, and Z. Mai, "QoS prediction for service recommendation with features learning in mobile edge computing environment," *IEEE Transactions on Cognitive Communications and Networking*, vol. 6, no. 4, pp. 1136–1145, 2020.

[5] T. Jing, S. He, and F. Yu, "Joint optimization of computing ratio and access points' density for mixed mobile edge/cloud computing," *EURASIP Journal on Wireless Communications and Networking*, vol. 2021, no. 1, pp. 31–49, 2021.

[6] L. Guangshun, W. Jiping, and W. Junhua, "Data processing delay optimization in mobile edge computing," *Wireless Communications and Mobile Computing*, vol. 2018, pp. 131–139, 2018.

[7] Z. Li and Q. Zhu, "Genetic algorithm-based optimization of offloading and resource allocation in mobile-edge computing," *Information*, vol. 11, no. 2, pp. 83–97, 2020.

[8] K. Fu and J. Ye, "Computation offloading based on improved glowworm swarm optimization algorithm in mobile edge computing," *Journal of Physics: Conference Series*, vol. 1757, no. 1, pp. 12195–12221, 2021.

[9] X. Cui, C. Lu, and J. Wang, "3D semantic map construction using improved ORB-SLAM2 for mobile robot in edge computing environment," *IEEE Access*, vol. 4, no. 9, pp. 134–145, 2020.

[10] A. Abbas, A. Raza, and F. Aadil, "Meta-heuristic-based offloading task optimization in mobile edge computing," *International Journal of Distributed Sensor Networks*, vol. 17, no. 6, pp. 15501–15523, 2021.

[11] S. Wang, M. Zafer, and K. K. Leung, "Online placement of multi-component applications in edge computing environments," *IEEE Access*, vol. 5, pp. 2514–2533, 2017.

[12] X. Cui, N. Shan, and Y. Li, "A multilevel optimization framework for computation offloading in mobile edge computing," *Mathematical Problems in Engineering*, vol. 2020, pp. 1523–1534, 2020.

[13] H. Jin, X. Zhu, and C. Zhao, "Computation offloading optimization based on probabilistic SFC for mobile online gaming in heterogeneous network," *IEEE Access*, vol. 7, pp. 52168–52180, 2019.

[14] J. Liu, "Task offloading and resource allocation algorithm based on mobile edge computing in Internet of Things environment," *Journal of Engineering*, vol. 2021, no. 4, pp. 2134–2145, 2021.

[15] Y. Zhang, M. Zhang, and C. Fan, "Computing resource allocation scheme of IOV using deep reinforcement learning in edge computing environment," *EURASIP Journal on Applied Signal Processing*, vol. 2021, no. 1, pp. 51–69, 2021.

[16] X. Liu, S. Hou, and Q. Tong, "A prediction approach for video hits in mobile edge computing environment," *Security and Communication Networks*, vol. 2020, no. 2, pp. 71–76, 2020.

[17] Q. Liu, R. Mo, and X. Xu, "Multi-objective resource allocation in mobile edge computing using PAES for Internet of Things," *Wireless Networks*, vol. 2020, no. 3, pp. 321–343, 2020.

[18] Dario, Sabella, and Alessandro, "Mobile-edge computing architecture: the role of MEC in the Internet of things," *IEEE Consumer Electronics Magazine*, vol. 5, no. 4, pp. 84–91, 2016.

[19] A. R. Ismaeel, A. Moayad, and K. Yehia, "A collaborative mobile edge computing and user solution for service composition in 5G systems," *Transactions on Emerging Telecommunications Technologies*, vol. 29, pp. 3446–3454, 2018.

[20] K. Yaghmaeian, S. Silva Martinez, and M. Hoseini, "Optimization of As(III) removal in hard water by electrocoagulation using central composite design with response surface methodology," *Desalination and Water Treatment*, vol. 16, pp. 1–7, 2020.

[21] J. Cheng and D. Guan, "Research on task-offloading decision mechanism in mobile edge computing-based Internet of Vehicle," *EURASIP Journal on Wireless Communications and Networking*, vol. 2021, no. 1, pp. 352–365, 2021.

[22] H. Sun, F. Zhu, and Y. Hao, "Unified optimization for multiple active object recognition tasks with feature decision tree," *Journal of Intelligent and Robotic Systems*, vol. 103, no. 2, pp. 61–75, 2021.

[23] B. Yang, X. Cao, and C. Yuen, "Offloading optimization in edge computing for deep learning enabled target tracking by internet-of-UAVs," *IEEE Internet of Things Journal*, vol. 3, pp. 87–98, 2020.

[24] T. Chanyour, Y. Hmimz, and E. L. Mohamed, "Delay-aware and user-adaptive offloading of computation-intensive applications with per-task delay in mobile edge computing networks," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 1, pp. 872–889, 2020.

[25] B. Cao, L. Zhang, Y. Li, D. Feng, and W. Cao, "Intelligent offloading in multi-access edge computing: A state-of-the-art review and framework," *IEEE Communications Magazine*, vol. 57, no. 3, pp. 56–62, 2019.

[26] K. Kononenko, "An approach to error correction in program code using dynamic optimization in a virtual execution environment," *The Journal of Supercomputing*, vol. 72, no. 3, pp. 221–249, 2016.