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Exploration of Personalized User Experience Optimization in Virtual Reality with Deep Learning

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Abstract: With the continuous development of virtual reality technology, optimizing personalized user experience has become crucial, which is the core of enhancing immersion and interactivity. Based on the application of deep learning technology, users' behavior patterns and needs can be efficiently analyzed and optimized, to achieve personalized adjustment of virtual reality experience. This paper describes the main models in deep learning, including convolutional neural networks (CNNS), recurrent neural networks (RNN), short- and long-term memory networks (LSTM), and generative adversarial networks (GANS). Then, it analyzes the status problems of virtual reality personalized user experience, including user adaptability difference, lack of immersion and interaction, comfort and motion sickness. Finally, an optimization strategy based on deep learning is proposed to provide a new technical path for the personalized experience of virtual reality.

Keywords: Deep learning, Virtual reality, User experience optimization.

1. Introduction

In recent years, virtual reality (VR) technology has been widely used in games, education, medical and other fields, and has brought about immersive experiences. Despite this, there are still many problems with current VR systems, especially when it comes to personalized user experience. Thanks to the rapid development of deep learning technology, methods using deep learning are effective in optimizing user experience. Through the independent training and adjustment of the model, this technology can capture complex information such as the user's behavior and emotion, and then create a VR experience that is more suitable for the user's individual needs. By combining deep learning technology, problems such as adaptability, immersion and comfort in virtual reality can be better solved, and the quality of user experience can be further improved.

2. Main Models of Deep Learning

2.1. Convolutional Neural Networks (CNN)

Convolutional networks (CNNS) are widely used in image processing and visual tasks. The core idea is to preserve local information in space and reduce computation by weight sharing through feature extraction of convolutional layer. CNN is usually composed of multiple convolution layers, pooling layers, and fully connected layers. In the convolution layer, the convolution kernel (filter) is convolved with the input data to extract local features. The main function of the pooling layer is to reduce and reduce the computational complexity, while retaining important feature information. The fully connected layer maps extracted high-dimensional features to low-dimensional Spaces to complete tasks such as classification or regression. In the optimization of virtual reality personalized user experience, CNN can process image and video data, such as user pose recognition and scene reconstruction. By training the CNN model, efficient features can be extracted from the user's visual input effectively, to provide each user with a more accurate personalized Experience.

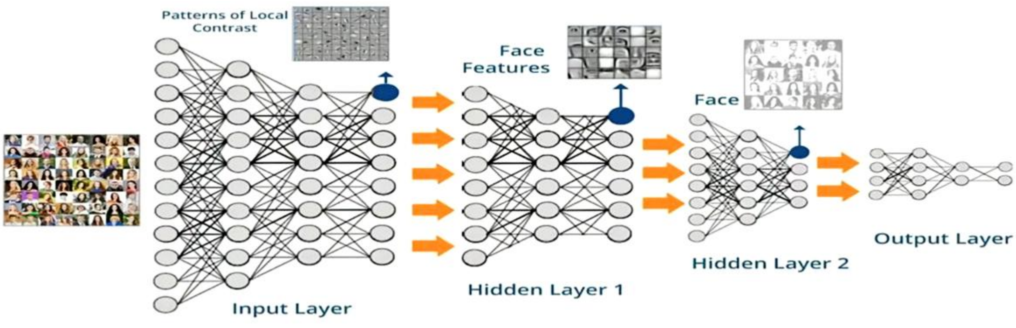

Figure 1. Design principle of convolutional neural network (CNN)

2.2. Recurrent Neural Networks (RNN)

Recurrent neural network (RNN) belongs to a class of neural networks with memory mechanism, and its main feature is that it can process sequential data. It is different from the traditional feedforward neural network, RNN through the loop connection between nodes, so that the network can process the current input while retaining the previous state, to capture the dependency in the time series. Thanks to this unique structure, RNNS show high performance in processing time series-related tasks such as natural language processing, speech recognition, and video analysis. The core idea of RNN is to pass information by hiding the state of the layer, ensuring that at each time node, the output of the network is not only dependent on the current input, but also affected by the previous input (Figure 2).

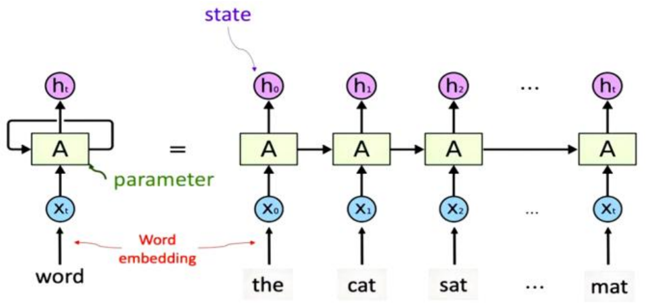

Figure 2. Design principle of recurrent neural network (RNN)

2.3. Long Term Memory Network (LSTM)

Long Short-Term Memory networks (LSTMS) have significant advantages in processing and predicting time series data. Different from traditional RNNS, LSTM solves the problem of gradient disappearance and explosion faced by traditional RNNS in the process of long sequence learning by introducing "Memory Cell" and three gating mechanisms (input gate, forget gate and output gate). The input gate controls the updating degree of the current input information to the memory unit, the forgetting gate is responsible for managing the retention or clearing of information in the memory unit, and the output gate determines the output information content of the memory unit. Through this gating mechanism, LSTM can effectively capture long-term dependencies in a sequence over a longer time step. In the field of virtual reality (VR) applications, LSTM can be used to predict user behavior and model interaction patterns (Figure 3).

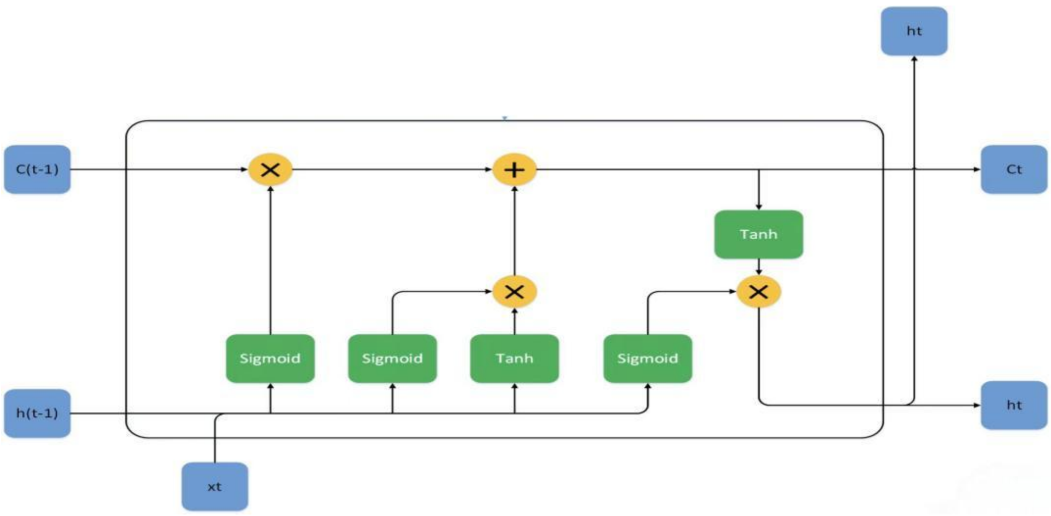

Figure 3. Design principle of Long-Term memory network (LSTM)

2.4. Generating Adversarial Networks (GAN)

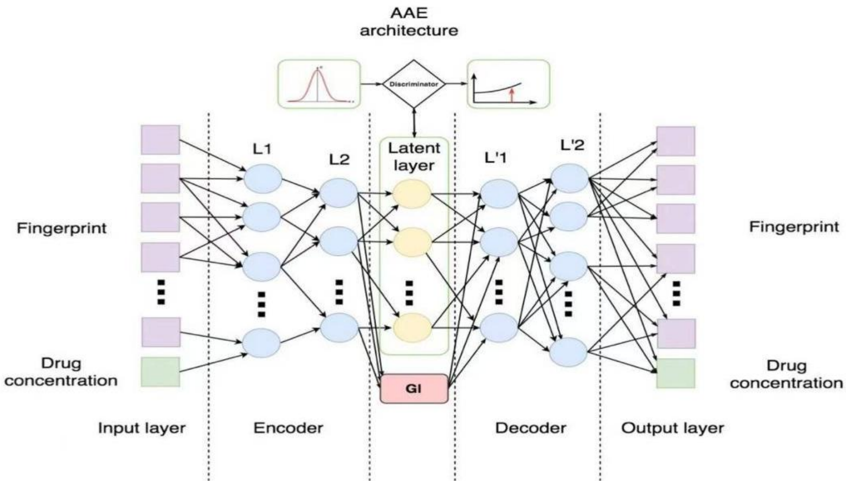

Figure 4. Generative adversarial network (GAN) design principle

The core of generative adversarial networks (GANS) is the adversarial training of two neural networks, the generator and the discriminator, to optimize the model's performance. The generator is responsible for generating fake data from random noise, while the discriminator is responsible for distinguishing the generated data from the real data. The generator continually improves the generated data through backpropagation to fool the discriminator. The discriminator tries to distinguish the authenticity of the data more accurately by enhancing its discriminating ability. In this process, the two play against each other until the generator can produce more realistic data, and the discriminator can more accurately identify the true data. In the field of virtual reality technology, GAN shows its strong application potential, especially in the aspect of personalized user experience optimization. GAN can produce high-quality virtual environment images or personalized virtual characters, and dynamically generate virtual scenes or interactive elements that meet personalized needs according to user feedback and preferences. It greatly improves the user's sense of immersion and interactive experience (Figure 4).

3. The Status Quo of Virtual Reality Personalized User Experience

3.1. User Adaptability Differences

In the application of virtual reality (VR) technology, the adaptability difference of users is one of the key factors affecting the optimization of personalized user experience. Given the personalized characteristics of users in terms of senses, cognition, physical reactions, etc., their immersion and interactive experience in VR environments are often very different. Some users can quickly adapt to the virtual environment and enjoy a smooth interactive experience. Instead, some users may experience discomfort such as dizziness, nausea, and anxiety. These individual differences in adaptability are closely related to the user's age, gender, experience and emotional status. For novice users, the adaptation period may be longer due to the lack of sufficient familiarity and sense of control over the virtual environment, while experienced users can quickly pick up and enjoy the immersive experience. In addition, the speed, depth, and dynamic perception of the virtual world will also vary among users, which will also affect their comfort and engagement in VR.

3.2. Lack of Immersion and Interaction

With the progress of science and technology, virtual reality (VR) technology has gradually entered the public vision, it provides a new immersive interactive experience. However, despite the breakthrough achievements of VR technology in many application areas, the quality of user experience is still constrained by some key factors. Among them, the lack of immersion is mainly related to the hardware performance of the device and image rendering technology. At present, the resolution and frame rate of many VR devices have not reached the standard of providing the ultimate visual experience, thus affecting the authenticity of user immersion. In addition, the interaction mode in the virtual environment also fails to fully meet the individual needs of users, and the traditional input devices such as gamepads and mice are not intuitive enough to operate and give feedback quickly enough. Together, these factors affect the user's experience in the virtual world, making personalized interaction and immersion difficult to achieve.

3.3. User Comfort and Motion Sickness

The rapid development of virtual reality technology has significantly improved the immersion of user experience, but it also brings comfort and motion sickness problems. In the VR environment, users often have uncomfortable reactions such as vertigo and nausea, which are mainly due to the physiological conflict caused by the inconsistency between the visual movement in the virtual world and the movement perception of the body. Especially in the scene of rapid movement or frequent changes in the angle of view, the dissynchronization between the visual and vestibular system is more likely to cause motion sickness response. Different users have different levels of sensitivity to motion sickness, some people may feel uncomfortable in a short period of time, while others can adapt more smoothly. Users' adaptability to VR space is often affected by multiple factors such as personal physiological state, time of use, and movement mode. Long immersive experiences often make motion sickness symptoms more obvious, affecting the quality of user experience and satisfaction. At the same time, the technical parameters of VR devices, such as refresh rate, response delay, and viewing angle switching speed, will also play an important role in user comfort.

4. Strategies for Optimizing Virtual Reality Personalized User Experience Based on Deep Learning

4.1. User Behavior Prediction and Personalized Scenario Adjustment

In the VR environment, the behavior habits and interaction ways of each user are highly individual differences, which forces the system to predict the user's behavior in real time, and adjust the virtual scene accordingly to provide a more immersive experience that meets the needs of individuals. With deep learning techniques, especially neural network models, complex data on user behavior can be efficiently processed to achieve personalized scenario adjustments. Through real-time collection and analysis of the user's behavior, expression, line of sight and other aspects of information, the system can infer the user's interest, preference, mood fluctuations and potential behavior trends, and then dynamically adjust the content and interaction mode of the virtual scene.

Table 1. User behavior prediction and individualized scenario adjustment strategies

tactics	Implementation method	Action and effect
User behavior analysis and modeling	Convolutional neural networks (CNNS) and recurrent neural networks (RNNS) are used to analyze the user's visual, motion, and speech data	Through multi-dimensional data modeling, the potential patterns of user behavior are accurately captured
Interest preference prediction	Based on user history data and real-time behavior data, long short-term memory network (LSTM) is used to predict interest trend	Provide personalized recommendations for users to optimize interactive content and task allocation in virtual environments
Emotion analysis and feedback regulation	A deep emotion analysis model (such as CNN-LSTM) is used to analyze users' facial expressions and physiological responses	Dynamically adjust the emotional atmosphere of a virtual scene, such as changing the sound, lighting, or interaction, to increase immersion and engagement
Scene adaptive adjustment	Based on reinforcement learning algorithm, the elements of virtual scene are adaptive adjusted	Based on the real-time response of users, optimize the scene layout, interactive form and content display to provide personalized experience

For example, Meta's Oculus team has developed an emotion recognition system that analyzes users' emotional responses through facial expression recognition and physiological signal monitoring, and ADAPTS interactive elements in virtual reality based on these emotional data. For example, Oculus has applied emotion recognition technology in its Oculus Venues app. When the system detects that users show dissatisfaction or anxiety at a virtual concert, the system will automatically adjust the volume, brightness, and even the visual content of the scene to help users have a better experience. According to a report from the Oculus team, the technology increased users' emotional satisfaction by more than 18 percent, especially when experiencing long-term immersion with more positive user feedback. Table 1 below shows the specific strategies and implementation methods of user behavior prediction and personalized scene adjustment based on deep learning.

With these strategies, the system is not only able to respond to user behavior in real time, but also to provide a unique immersive experience for each user. This personalized scene adjustment strategy greatly improves the quality of users' experience in virtual reality, making the potential of VR applications in education, entertainment, medical and other fields better played.

4.2. Enhance Dynamic Scene Adjustment and Immersion

By analyzing user behavior and environment interaction, deep learning can achieve more refined and personalized scene optimization, thereby enhancing immersion. This optimization covers not only the transformation of visual elements, but also the simultaneous adjustment of multimodal perceptions such as sound, touch, and temperature. In the application of deep learning, convolutional neural networks (CNNS) and generative adversarial networks (GANS) can effectively deal with dynamic changes in virtual environments. With real-time feedback from user data (such as eye tracking, motion capture), deep learning models can predict user needs and automatically adjust the scene. For example, when a user is interested in a virtual object, the system can change the size, location, lighting and other parameters of the object to attract the user's attention or enhance the interaction with the object, thereby improving the user's sense of immersion. In order to quantify the impact of dynamic scene adjustment on immersion, the following formula can be used for modeling.

$$I(t)=\alpha_1 \cdot \sum_{i=1}^{N} w_i \cdot E_i(t)+\alpha_2 \cdot V(t) \tag{1}$$

Among them, $I(t)$Representative now t immersion, w_i is the weight of the i kind The weight of the perceptual channel, $E_i(t)$is the perceived intensity of the channel now, $V(t)$is the intensity of users' visual feedback to changes in the virtual scene. α_1 and α_2 are the weight coefficients. In addition, generative adversarial networks (GANS) can be used to generate virtual environments with higher realism. By optimizing generators and discriminators in the adversarial network, Gans can create more natural and personalized scenarios. For further optimization of immersion, the following formula can describe the process of personalized adjustment of the scene.

$$S_p(t)=\sum_{i=1}^{N} \theta_i \cdot A_i(t) \cdot f_i(U) \tag{2}$$

Among them, $S_p(t)$ Representation time t down Personalized scene changes, $A_i(t)$for i Scene element at the moment of tAdjusted value of, θ_i Is the personalized weight for the element, $f_i(U)$ base on user preference U a response function to a scene element. In this way, deep learning can dynamically adjust the virtual environment according to the user's behavior and preferences to achieve more precise immersion.

4.3. Improve Personalized Comfort Adjustment and Motion Sickness Prevention

Motion sickness is mainly due to the difference between vision and the perception of the vestibular system, and common discomfort includes nausea, dizziness and sweating. In order to optimize the personalized user experience of virtual reality, deep learning technology can provide effective solutions in regulating comfort and preventing motion sickness. The deep learning technology is used to analyze the user's physiological data (such as heart rate, skin electric response, etc.), which can monitor and judge the user's comfort state in real time. The collection and processing of these data can help the system intelligently adjust the parameters of the virtual environment, such as frame rate, image resolution, and field of view angle, to avoid causing discomfort or motion sickness.

For example, in an experiment conducted by the Massachusetts Institute of Technology (MIT) in the United States, researchers combined the HTC Vive Pro VR device with physiological feedback sensors to monitor the user's heart rate and electrical skin response (GSR) in real time. When the system detects high physiological stress in the user, the speed of movement in the VR environment is automatically reduced, while the color saturation and contrast of the scene are adjusted. Studies have shown that after this personalized adjustment, about 72% of users report a reduction in their motion sickness symptoms and a significant increase in immersion. In the test group, the incidence of motion sickness after adjustment was reduced by about 45 percent, with about 65 percent of users reporting feeling more comfortable and natural during the adjusted experience.

By analyzing multi-dimensional data, including user physiological feedback, behavioral data and user preferences, the system can build a user model, predict and solve potential comfort problems, and apply deep learning algorithms to combine these data for training, the system can identify changes in comfort and behavior patterns of different users, and then dynamically adjust the parameters of the virtual reality environment. According to this model, VR devices will automatically change the interaction mode, such as dynamically adjusting the image display mode or recommending the appropriate comfort configuration for different users. Table 2 below shows several deep learning-based comfort adjustment and motion sickness prevention strategies and their implementation.

Table 2. Deep learning optimization comfort and motion sickness prevention strategies

tactics	Implementation mode	Expected effect
Real-time physiological data monitoring and adjustment	Real-time monitoring of users' physiological state through data such as heart rate and electrodermal response, and adjustment of virtual scene parameters	Reduce the occurrence of motion sickness, improve user comfort
Personalized user modeling and comfort prediction	Based on the historical behavior and preferences of users, the user model is built to predict the fluctuation of comfort level and adjust it in advance	Personalize the experience and reduce discomfort
Field of view angle and frame rate adaptive adjustment	Adjust the angle of view and frame rate of the virtual environment according to the user's response to slow down the rapid movement and visual changes	Enhance user immersion and reduce the risk of motion sickness

Specifically, deep learning technology provides strong technical support for improving comfort adjustment and motion sickness prevention in virtual reality. Through real-time monitoring and personalized adjustment, users can enjoy a more comfortable and natural virtual experience, which greatly improves the application feasibility and popularity of VR technology.

5. Conclusion

With the continuous development of virtual reality technology, deep learning shows great potential in personalized user experience optimization. The use of convolutional neural network, recurrent neural network, long term memory network, generative adversarial network and other models can greatly improve the user's sense of immersion, interaction and comfort. In view of the current problems such as adaptability differences, lack of immersion and motion sickness in virtual reality personalized user experience, innovative strategies can be combined with deep learning technology, such as user behavior prediction, dynamic scene adjustment and personalized comfort adjustment, to create a more accurate and comfortable virtual experience for users.

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