Study on Scene Design for Reducing VR Sickness

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Abstract: Based on the research of virtual reality (VR) motion sickness at home and abroad, this paper proposes the factors affecting VR sickness from the perspective of VR scene design. At the same time, it points out the problems to reduce the sense of sickness in the process of scene design, and puts forward a set of design mode combined with machine learning to optimize VR scene parameters in real time and reduce the sense of VR sickness.
Keywords: VR sickness; scene design; machine learning.

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1. INTRODUCTION

1.1 VR sickness

Virtual reality (VR), also referred to as virtual technology, is also called virtual environment. It is a virtual world that uses computer simulation to generate a three-dimensional space. It provides users with simulations of visual and other senses. It can observe three-dimensional space in a timely and unrestricted manner. Things. The technology integrates the latest developments in computer graphics, computer simulation, artificial intelligence, sensing, display and network parallel processing. It is a high-tech simulation system generated by computer technology. Currently, the promotion of VR is faced with many bottlenecks[1]. No matter how amazing the VR experience can be, most people cannot immerse themselves in the virtual world for a long time because of the existence of "motion sickness". The most common symptoms are general malaise, headache, stomach pain, nausea, vomiting, paleness, sweating, fatigue, lethargy, and disorientation[2]. However, the sickness brought by VR is almost inevitable in the current VR experience.

1.2 Factors that cause or affect VR sickness

At present, many theories have been proposed for the causes of VR motion sickness. From the perspective of physiological factors and individual differences, the causes of VR motion sickness mainly come from the following aspects:

(1) Perceived conflicts - inconsistencies between the vestibular and the visual system

The vestibular system, located in the inner ear, consists of numerous labyrinth and Chambers filled with internal lymphatic fluid. The endolymph fluid produces a flow stimuli with the movement of the head, and the stimulated sensory cells generate electric waves. The vestibular balancer in the inner ear transmits this electric wave to the brain. Under normal circumstances, the brain will issue commands to change the body and visual position to balance this. However, the mismatch between the visual information received by the human eye and the movement signals received by the vestibular balancer affects the vagus nerve, thus causing motion sickness[2-3].

(2) Vergence-accommodation conflict (ACC)

The object is closer, the eyeball is turned inward; the object is farther away, and the eyeball is outward, which creates a visual convergence. There are two reasons for this. One is that the fuzzy loss leads to the convergence of the focus and the parallax (ACC). Since the current head-mounted display device only provides "binocular parallax" and "moving parallax", No "focus blur" is provided, make the focus and the depth of the parallax in the brain to perceive information conflict, thus focusing on loss as a direct result of sickness[4].

Another reason is that if the eyeball is turned inward and toward diplomacy frequently, it will cause visual fatigue, and more serious, it will produce ghosting.

(3) Postural instability theory

Not all scientists agree with the theory of perceived conflict. This theory holds that the occurrence of motion sickness is caused by poor adjustment of the body, mainly reflected in the coupling abnormality between visual stimuli and motor coordination[5]. The characteristics of posture instability occur before sickness, which means that body shaking is the cause of motion sickness, rather than the result of motion sickness. The higher the degree of body shaking, the more obvious the motion sickness symptoms[6-7].

(4) Individual differences

Everyone has different sensitivities to the halo screen[2]. Studies have shown that factors affecting susceptibility to motion sickness, similar diseases, or motion sickness include age, gender, ethnicity, spontaneous posture swing, frequency threshold of scintillation fusion, plasticity or adaptability, and experience with real-world or simulated tasks. Perceptual and cognitive features such as field dependence/independence and mental rotation are thought to have an impact on susceptibility, as are state variables such as fatigue or disease. Past motion sickness history has been found to predict people's susceptibility to various diseases, including immersing themselves in virtual reality.

Studies on motion sickness have found that age and sex affect symptoms. The study found that the susceptibility to motion sickness is almost non-existent in very young people, most noticeable between the ages of 2 and 12, and rapidly after 12 years of age[8]. By the age of 25, this proportion has fallen to about half between 17 and 19 years old. After 25 years, it slowed down more slowly, and after 50 years of age[9], motion sickness is rare. From a gender perspective, women are more likely to develop motion sickness than men. And some studies have shown that ethnic factors can affect susceptibility and Asians are more susceptible to infection. Both subjectively and objectively, they are more susceptible to motion sickness than Europeans or African Americans[10].

2. Factors affecting VR sickness in scene design

VR is a tool for people to interact with virtual environments. At present, the good use of VR in various fields cannot be separated from the optimization of hardware, algorithms and scene design. In view of the above three aspects, we often cannot consider the problem from a single perspective, because any aspect of the problem is limited and involved by the other two factors. This paper discusses the VR sickness problem from the perspective of scene design. At the same time, combining hardware and algorithm problems, taking the scene design as the starting point, the factors affecting sickness are proposed.

(1) Light

From the point of view of sickness caused by focus and parallax conflict, the human eye itself is a complex optical system that changes the power through the contraction of the ciliary muscle, thus ensuring a clear image and focusing on the object. In the face of the loss of the focus of the existing head-mounted display, in order to simulate the focus of the human eye, it is necessary to simulate the true light field effect after capturing the falling point of the human eye focus.

From the perspective of the device itself, the shadow phenomenon is easily recognized by human eyes when it occurs at the edge of moving objects. The human visual system pays great attention to the edge of the object[11], and usually obtains the specific shape of the target object through the edge information and interprets the target object. Among them, the resolution ability of edge blurring, i.e. contrast sensitivity, is positively correlated with the brightness contrast[12]. As a result, if the display device has shadow, the larger the brightness difference, the more severe the sense of sickness.

(2) Field of view

Studies have shown that reducing the field of view (fov)[13] can reduce the sense of dizziness at the expense of the user's presence in the virtual scene. Because the large field of view increases the visual information within the visible range of the human eye, causing visual fatigue, and the excessive angle of view also allows the user to subjectively turn the head. In addition, the resolution of the human eye is about 16k for a single eye. Even though the existing head-mounted device with 8k resolution of both eyes has been introduced, the resolution of most of the head-mounted devices on the market is still concentrated in binocular 4k and 2k. In the case where the display device resolution is not high, the larger the angle of view, the stronger the graininess. But if the field of view is too small, the human eye will see the black side of the VR world, the black edge effect.

(3) Perspective

Studies have shown that by detecting the head-mounted device, when the user is positioned in the virtual scene, the user may experience dizziness when looking down and looking up. According to the experiment, the user may have severe VR sickness when he quickly looks down at the target angle of more than 60 degrees[14].

(4) Scene complexity

(a) In the arrangement of the objects, it is preferable to arrange the arcs in the center of the operation viewpoint, and the arrangement distance is preferably between 3 and 10 meters.

(b) Be careful not to use textures that cause VR sickness memories, such as rotating stairs, dimly lit corridors, etc.

(c) Avoid the use of texture-complex textures and over-prepared models. The high fidelity of the scene increases immersion, but overly complex and realistic scenes, the eye will focus on more detail during the rotation, resulting in vision fatigue. When the lens bound to the user's line of sight moves, the complexity of the texture increases the degree of change of the color of the polygon in the scene, thereby increasing the optical flow .In addition, the optical flow contributes to the user's perception of their own motion, which aggravates the user's perception conflict.

(d) During the design, the size of scene resources should be controlled. When the scene resources are too large for scene rendering, it is easy to lose frames or the refresh rate is low due to network and other reasons, the head display device will produce the phenomenon of image artifacts, thus generating the sense of VR sickness.

(5) Motion parameters

Pay attention to the design of the speed and acceleration of the lens, including the size, frequency and transformation[15] .

The speed of exercise is directly proportional to the onset of VR motion sickness, but not necessarily related to the intensity and deterioration of subsequent symptoms. Studies have shown that acceleration has a significant stimulus to the vestibular perception conflict (either linear acceleration in any direction or angular acceleration). The slower moving speed is generally comfortable, so when the relevant experimental design is done, the speed of the lens is It should be at a constant speed and does not accelerate or decelerate in any acceleration. At the same time, according to the study, the acceleration will touch the threshold of the vestibular perception, and the VR sickness will start. Studies have shown that in order to achieve the same speed of movement, the instantaneous acceleration is more comfortable than the continuous, progressive acceleration.

(6) Operating freedom

The user tries to grasp the control of the lens as much as possible, which can effectively avoid dizziness. If the movement of the lens is not controlled by the user, you can try to make some hints to let the user move his or her own eyes to the expected landing point. You can use the sound effect, the effect of focusing blur, setting the relevant task target indication, etc. as a reminder.

(7) Spatial memory structure

The user's memory structure [16] includes the type of virtual scene, the shape, color, relative position, relative size of the object in the scene, and the frequency of occurrence of the object. Experiments show that VR sickness is positively correlated with the user's presence in the scene, and the memory structure is also positively correlated with the presence, indicating that the memory structure will affect VR sickness.

3. Discussion

There are many factors that cause VR sickness, not only different factors have different degrees of influence, but also single factors have different degrees of influence on VR sickness in different situations. When designing VR scenes, if you blindly consider reducing the sense of VR sickness, the fidelity of the scenes will be reduced, and then the user's sense of immersion will be greatly reduced.

At present, most of the market uses Unity3D and UE4 as the engine for creating and running VR scenes. While considering the factors affecting the VR sickness in the scene, it is also necessary to consider that the virtual scene time (per frame) is changing, and it is necessary to ensure real-time synchronization to reduce the VR sickness. At the same time, try to ensure the user's immersion and interactivity in the virtual scene.

4. Method

In view of the above problems, the design method of VR scene design combined with machine learning is proposed.

4.1 Machine learning

Machine learning, broadly speaking, is a way to give machine learning the ability to do things that direct programming can't. But in a practical sense, machine learning is a way to train a model by using data and then use model prediction [17-18]. The number of nodes in the machine learning input layer needs to match the dimension of the feature. The number of nodes in the output layer needs to match the dimension of the target. The number of nodes in the middle layer can be designed by itself. When designing the learning model, with the increase of the intermediate level, each layer has a deeper abstraction of the previous level, and extracts the abstract features to distinguish the things, so as to obtain better distinguishing and classification ability. Figure 1 is a model diagram of machine learning.

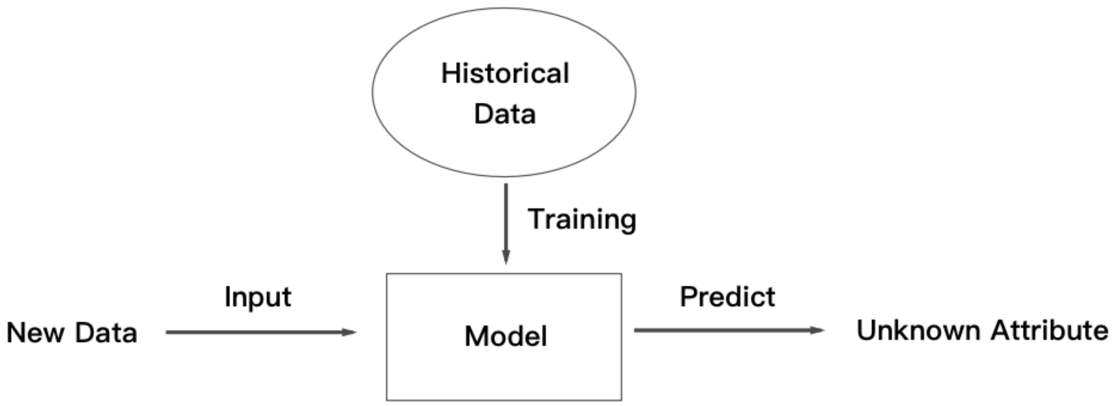

Fig. 1. Machine learning model diagram

The artificial neural network (ANN) is an information system that theoretically abstracts, simplifies and simulates the structure, function and basic characteristics of physiologically human brain neural networks. The neural network structure model is shown in Figure 2. As a parallel distributed processing mode, ANN has the characteristics of nonlinear mapping, adaptive learning and strong fault tolerance. It can deal with the multi-factor variable operating environment of VR scene.

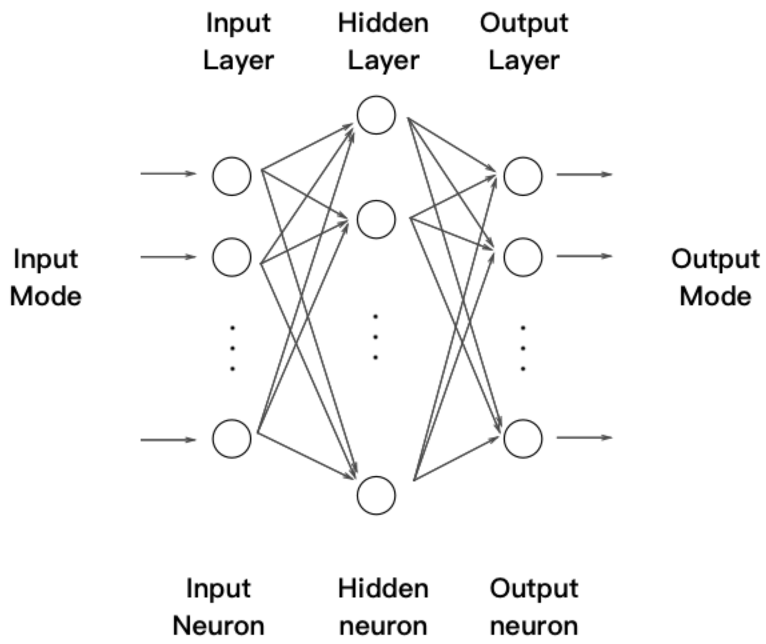

Fig. 2. Neural network structure

The main reasons for combining VR scene design with machine learning are as follows:

(1) The self-factors (light, model, texture, field of view, fixed motion mode and parameters) and user adjustable factors (angle of view, controllable motion mode and parameters) in the virtual scene are intertwined together, forming the interactive environment between users and the virtual reality scene. Therefore, in such a complicated situation, only the combination of machine learning and its characteristics can achieve the purpose of real-time synchronization to distinguish the factors.

(2) According to different VR scene content requirements, the factors that constitute the virtual environment vary greatly between different scenarios. In addition, each frame of the virtual scene changes, so the machine learning and training model is imported into the engine to achieve the purpose of real-time synchronous analysis processing.

(3) If the model trained by machine learning is used in the initial stage of design, the designer can give certain feedback to the setting of the scene factor, and assist the designer to complete the setting of each parameter in the virtual scene in the design stage.

(4) If a model encapsulation derived from machine learning training is directly applied to the scene for an existing scene, adaptive parameter optimization is performed to achieve the purpose of reducing VR sickness.

4.2 Design Pattern

It is proposed that the design model combined with neural network consists of two relatively independent modules: learning (training) and prediction (simulation).

The two modules share the same neural network pattern. In the learning module, through the body sense measurement devices, real-time monitoring and gathering measurements (Electroencephalogram (EEG), Heart rate variability (HRV)) to quantify VR sickness, and the physiological indexes as the basis for training neural networks. Combining the factor variables extracted from the engine to affect the VR sickness, the neural network is used to train the parameters (weight values) of the model. In the prediction module, using the trained model, input a new factor variable for the simulation calculation. See Figure 3, a neural network based VR scene design model.

The network is divided into three layers, the first layer is the data input layer, and each of the neurons corresponds to the factor variable that affects sickness in the VR scene; the second layer is the hidden layer, and the number of neurons is at least 2n/3 (where n The number of neurons in the input layer); The third layer is the output layer, in which the factor variable corresponding to each neuron is the probability of causing VR sickness.

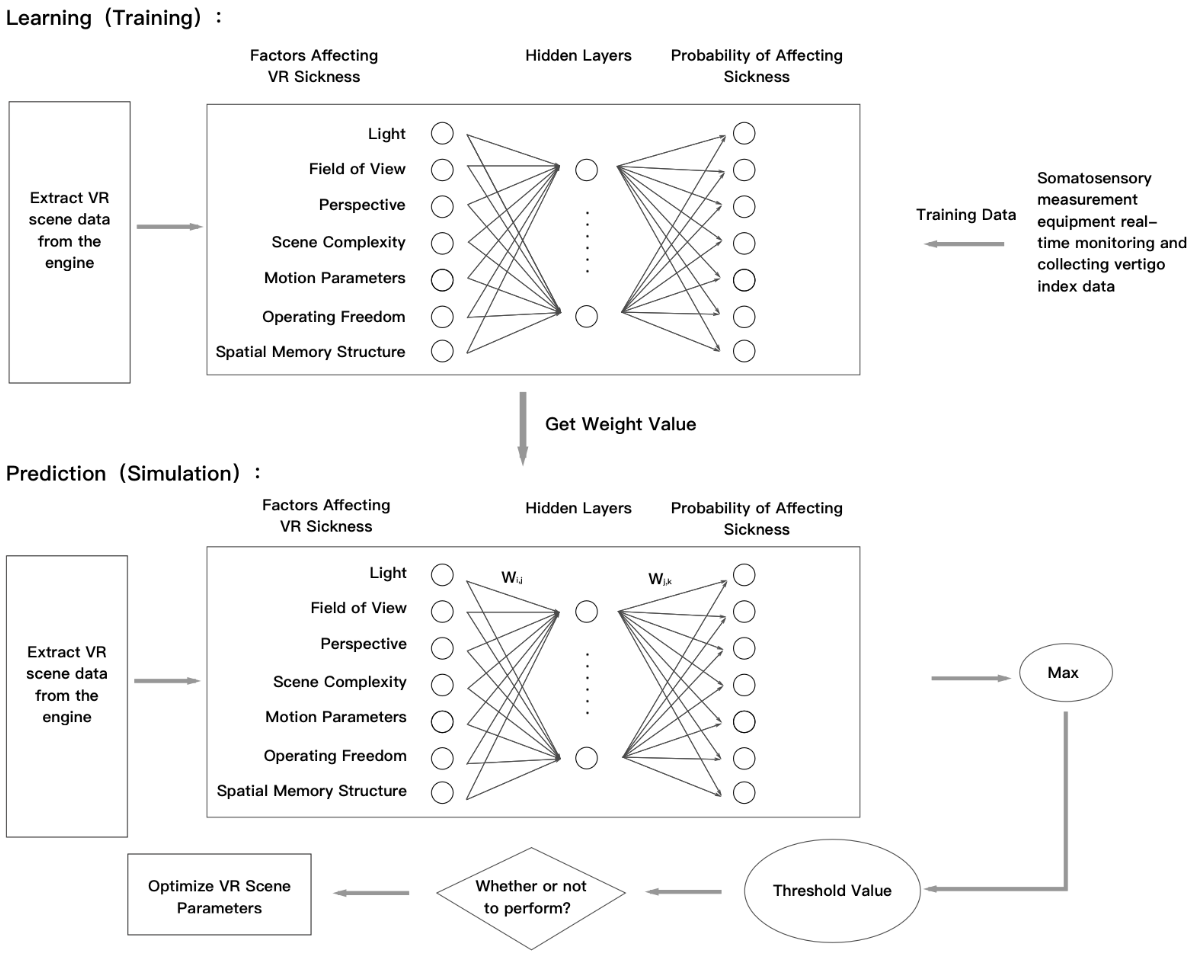

Fig. 3. Neural network based VR scene design model

5. Conclusion

This paper starts from the perspective of VR scene design, and proposes the factors affecting VR stickness. At the same time, it points out the problem of optimizing the VR sickness feeling in scene design. It is hoped that the design of scene content can reduce the sickness in the scope of current hardware limitations. .

Aiming at the factors affecting sickness in VR scene, the method of incorporating machine learning is proposed. The neural network model obtained by training can not only be applied to different VR scenes, but also achieve real-time optimization for the scenes with changing time.

Among them, the physiological index collected by the somatosensory equipment is used as the basis for training the neural network, and its workload is huge, which needs to be gradually solved in the future research.

References

[1] Brooks, J. O.; Goodenough, R. R.; Crisler, M. C.; Klein, N. D.; Alley, R. L.; Koon, B. L.; ...; Wills, R. F. (2010). "Simulator sickness during driving simulation studies". Accident Analysis & Prevention. 42: 788–796. doi:10.1016/j.aap.2009.04.013.

[2] Kolasinski, E. M. "Simulator sickness in virtual environments (ARI 1027)". www.dtic.mil. U.S. Army Research Institute for the Behavioral and Social Sciences. Retrieved 22 July 2014.

[3] Reason, J. T.; Brand, J. J. (1975). Motion sickness. London: Academic Press.

[4] Noah T. Conflict? What Conflict?[J]. New Republic, 1981.

[5] Stoffregen, T. A.; Riccio, G. E. (1988). "An ecological theory of orientation and the vestibular system". Psychological Review. 95: 3–14. doi:10.1037/0033-295x.95.1.3.

[6] Smart, L. J.; Stoffregen, T. A. & Bardy, B. G. (2002). "Visually induced motion sickness predicted by postural instability". Human Factors. 44 (3): 451–465. doi:10.1518 /0018 720024497745.

[7] Riccio, G. E.; Martin, E. J.; Stoffregen, T. A. (1992). "The role of balance dynamics in the active perception of orientation". Journal of Experimental Psychology: Human Perception and Performance. 18: 624–644. doi:10.1037/0096-1523.18.3.624.

[8] Reason, J. T.; Brand, J. J. (1975). Motion sickness. London: Academic Press.

[9] Brooks, J. O.; Goodenough, R. R.; Crisler, M. C.; Klein, N. D.; Alley, R. L.; Koon, B. L.; ...; Wills, R. F. (2010). "Simulator sickness during driving simulation studies". Accident Analysis & Prevention. 42: 788–796. doi:10.1016/j.aap.2009.04.013.

[10] Hromatka, Bethann S.; Tung, Joyce Y.; Kiefer, Amy K.; Do, Chuong B.; Hinds, David A.; Eriksson, Nicholas (26 January 2015). "Genetic variants associated with motion sickness point to roles for inner ear development, neurological processes and glucose homeostasis". Human Molecular Genetics. Oxford Academic. 24 (9): 2700–2708.

[11] W. Osberger and A. J. Maeder, "Automatic identification of perceptually important regions in an image," in Proc. Int'l Conf. Pattern Recognition, 1998, pp. 17–20.

[12] A. Netravali and B. Prasada, "Adaptive quantization of picture signals using spatial masking,"Proc. IEEE, vol. 65, no. 4, pp. 536–548, 1977.

[13] Lin, J. J.; Duh, H. B. L.; Parker, D. E.; Abi-Rached, H.; Furness, T. A. (2002). "Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment". Proceedings of IEEE Virtual Reality. 9: 164–171. doi:10.1109/ VR. 2002. 996519.

[14] Ruddle, R. A. (2004). "The effect of environment characteristics and user interaction on levels of virtual environment sickness". Proceedings of IEEE Virtual Reality. 11: 141–148. doi:10.1109/VR.2004.1310067.
[15] “The Promise and Challenges of Head-Mounted Virtual Reality Displays - Tested.com”. Tested.com. Retrieved 14 July 2014.
[16] Lin J J W, Duh H B L, Parker D E, et al. Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment[J]. Proceedings of the IEEE Virtual Reality, 2002:164.
[17] Martin T. Hagan, Howard B. Demuth. Neural Network Design [M]. Mechanical Industry Press, 2002.
[18] Heji Geng, Changzheng Chen, Sheng Zhang. Intelligent Diagnosis Based on Neural Network[J]. Journal of Vibration Engineering, 2000, 13(2): 202-209.