Check for updates

Design and 3D Visualization Simulation of Smart Home Based on Virtual Reality Technology

Ying Guo

Dalian Vocational & Technical College, Dalian, Liaoning, 116000

53225338@qq.com

Abstract. With the rapid development of high technology, smart home can be welcomed with its convenient, comfortable and safe application experience, but it also limits consumers' design needs and product experience because of its variety, complex structure and high cost. In this regard, based on the shortcomings faced by the current smart home design and experience process, this paper will propose a set of smart home design and three-dimensional simulation display system construction scheme, relying on the actual advantages of digital and virtual design technology to realize the innovation of design language, creative techniques and display forms. The system takes virtual reality technology as the core, builds a design and visual rendering engine by relying on 3ds Max, Unity3D and other software, and forms a server-side framework by combining ASP.NET framework and Libuv class library to meet the front-end demand for resources and data calling. Practice has proved that the system can combine data information with functional applications, support users to complete the design and display of smart homes in virtual scenes, achieve the goal of what you see is what you get, meet users' personalized needs and enhance users' interactive experience.

Keywords: virtual reality technology; smart home design; 3D modeling; visual interaction; computer software application

1 Introduction

In the era of digital intelligence, smart home, as an integration of home living facilities with many technical applications, can effectively improve the comfort, convenience and safety of people's lives, and thus is favored by consumers. Especially among young consumers, smart homes have more fashionable design styles, more humanized functional settings and richer category choices, which are more in line with their advanced consumption concepts and diversified and personalized practical needs. [1] However, the smart home is highly customized, and there is a lot of communication and modification in the stage of scheme design and product selection, which leads to the problems of long design cycle and low design efficiency. In addition, because of its variety, complex structure, high cost and other characteristics, smart home is difficult to give consumers a more realistic sensory experience, which limits consumers' choice and easily leads to the mismatch between the design scheme and the actual effect. [2] In view of

R. Appleby et al. (eds.), *Proceedings of the 2nd International Conference on Intelligent Design and Innovative Technology (ICIDIT 2023)*, Atlantis Highlights in Intelligent Systems 10,
https://doi.org/10.2991/978-94-6463-266-8_23

this, this paper believes that under the consumption mode of smart home products oriented by actual experience, introducing virtual reality technology and visual interaction technology into the design and exhibition process of smart home to form a brand-new digital design mode provides a set of practical solutions to solve many shortcomings faced in the traditional two-dimensional graphic design process. [3] The introduction of smart home design and three-dimensional simulation display system promotes the combination of smart home design and experience. Compared with the traditional renderings, consumers can participate more in the design process and get real-time three-dimensional feelings in the virtual reality scene, so as to modify and adjust the design scheme more intuitively, and then improve the design effect.

2 System construction

The design of smart home and the development of 3D simulation display system are divided into two parts. One is to complete the front-end virtual design and visual rendering engine based on 3ds Max, Unity 3D and other software. The other is to complete the back-end management and service framework in ASP.NET environment, and rely on Libuv class library to complete the data communication between the front-end and the back-end, so as to improve the overall business logic control accuracy of the system.

First of all, the overall architecture of the front-end virtual design and visual rendering engine is shown in Figure 1. All kinds of smart home products involved in the system will be transformed into 3D digital models by 3ds Max software, and the materials, colors and luster will be baked to make the models more realistic and vivid. [4] After the design and construction of various models are completed, 3ds Max software will export all 3D digital models as. FBX files, and continue to complete the integration and assembly of models and scenes, the addition and optimization of dynamic effects, the setting and processing of objects in the environment and the development of key interactive functions in Unity 3D software. [5]

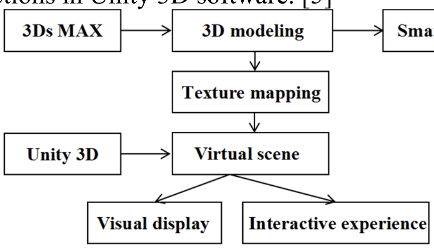

Fig. 1. Virtual design and visual rendering engine process

Secondly, the management and service framework of the back end of the system will be built based on a lot of script editing work. The overall development environment includes Windows10.0 operating system, ASP.NET supporting .net framework 4.7.1 framework, Visual Studio Code integrated development tool, Windows IIS 10.0Web server and SQL Server 2019 database. For the front-end and back-end data communication, it depends on the methods of SendMessage and Application. ExternalCall under

Libuv class library, and the real-time data transmission is completed through ProtoBuf function. [6]

3 Functional implementation

3.1 Online design

The whole process of online design of smart home consists of several steps, such as apartment building, 3D smart home design, interactive control, virtual experience and so on. [7] After logging into the system, users can build a basic apartment space by themselves, or choose a preset apartment space model in the system to enhance the authenticity of the virtual experience. The 3D smart home design is completely realized by relying on the massive home product model material library, and users can directly add, delete, modify and other operations under the editor page. Some operation codes are shown below. [8]

```
void Start () {
  canDrag = 1 << LayerMask.NameToLayer("Cube");   }
void Update () {
  if (Input.GetMouseButtonDown(0))
  { if (CheckGameObject())
    { offset = dragGameObject.transform.position - Camera.main.Screen-
ToWorldPoint(new Vector3(Input.mousePosition.x, Input.mousePosition.y, tar-
getScreenPoint.z)); }
```

Taking security monitoring as an example, when the user drags the camera to be installed into the apartment space, the system will determine the specific location of the camera according to the dragging distance. In the process, the system will build a two-dimensional plane coordinate system XOY in the apartment space, and determine the displacement of the camera in the virtual space with the center origin of the reference object. When the horizontal displacement of the camera model in XOY coordinate system is m and the vertical displacement is n, the formula for calculating the position of the reference object in XOY coordinate system is shown in Formula 1. Where w is the overall X-axis displacement, l is the overall Y-axis displacement, and (x_0, y_0) is the center position of the reference object.

$$x_0 = \frac{w}{2} + m, \quad y_0 = \frac{l}{2} + n \tag{1}$$

Then, the three-dimensional coordinates of the reference point are obtained by using the GetPosition function. As shown in Formula 2, p represents the actual three-dimensional spatial position of the household item model, p_0 is the coordinate of the reference object, and p_z and p_l are the relative positions in the plane coordinate system. [9]

$$p(x,y,z) = \frac{p_0(x_0,y_0,z_0) - p_z(x,y,z)}{p_l(x,y,z) - p_z(x,y,z)} \tag{2}$$

3.2 Virtual interaction control

When the user determines the position of the camera, he can control the camera in detail in the back-end interface of the system. The front end and the back end of the system keep the same data. After adding a camera in the front end, the corresponding control module will also be generated in the back end interface. The back-end control module can support users to carry out detailed interactive control on the camera, such as timing switch, angle adjustment, multi-screen display and so on. Figure 2 shows the virtual interactive control interface in the system.

Fig. 2. Camera virtual interaction control interface

3.3 Panoramic roaming

When the smart home design is completed, the effect rendering can be completed online and the panoramic roaming function can be realized. In the process of rendering, in order to improve the visual effect of the virtual scene of smart home, the system will use BRDF model to illuminate and generate the surface color of the complex materials of each model in the scene, so as to make it as accurate as possible to approximate the materials in the real world. [10] The essence of BRDF model is bidirectional reflection distribution function, which contains many formulas and algorithms. Common BRDF models include empirical model and physical model. The Unity3D software on which this system is based, its Standard Shader component will adopt the physical model by default. Formula 3 is the Cook-Torrance BRDF formula, where v represents the line of sight direction, h represents the micro-surface normal, l represents the light direction, n represents the vertex normal, D represents the normal distribution function, F represents the Fresnel equation, and G represents the geometric function. Figure 3 shows the illumination under the Cook-Torrance BRDF formula.

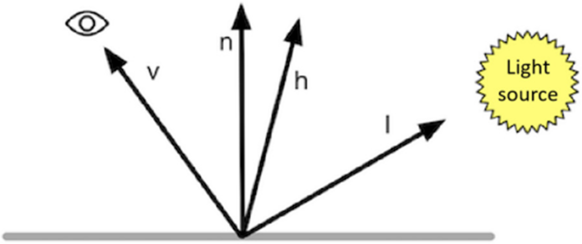

Fig. 3. Illumination under the micro-plane theory

$$f(l,v)=\frac{D(h)F(v,h)G(l,v,h)}{4(n\cdot l)(n\cdot v)} \quad (3)$$

Compared with the simple illumination simulation of the empirical model, the physical model based on Cook-Torrance BRDF formula introduces the theories of material surface roughness, micro-plane and Fresnel reflection to change the calculation coefficients of diffuse reflection and highlight, and then approximately obtains the reflection and refraction properties of the material to enhance the physical credibility of the virtual scene. Taking item D as an example, the model surface roughness α is introduced, and the calculation formula of item D is shown in Formula 4. Figure 4 shows the contrast effect of model materials under different roughness under illumination. The results show that the higher the roughness, the lower the consistency between the micro-surface orientation and H, so that the illumination can not be concentrated and the overall effect of the model is gloomy.

$$D(h)=\frac{\alpha^2}{\pi\left((n\cdot h)^2(\alpha^2-1)+1\right)^2} \quad (4)$$

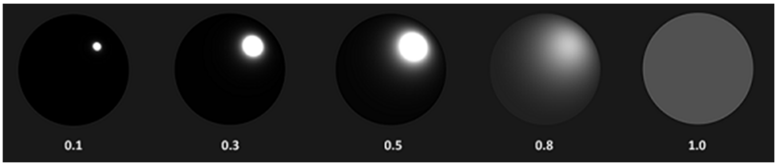

Fig. 4. Contrast effect of model materials with different roughness under illumination

In addition, panoramic roaming will optimize the texture and materials of many models in a unified way, so as to further reduce the load of server rendering during panoramic display. Generally, it is realized by deleting redundant or invisible scenes, changing high mode to low mode, and calculating material bitmap nodes. Table 1 shows the system operation before and after the optimization.

Table 1. The system operation during the panoramic display

Project	Texture, material	Memory consumption	Runtime
Sitting room	Before optimization	54%	2.69s
	After optimization	40%	1.76s
Bedroom	Before optimization	43%	1.97
	After optimization	36%	1.08s
Toilet	Before optimization	65%	3.99s
	After optimization	46%	2.64s

4 Conclusions

In order to improve the effectiveness of smart home design and experience, this paper constructs a smart home design and three-dimensional simulation display system based on many shortcomings in the traditional two-dimensional graphic design mode. The system takes virtual reality technology as the core, focusing on online design, virtual interactive control, panoramic roaming and other aspects to realize the change of smart home design mode and increase the design flexibility and the authenticity of experience. In the follow-up research, the system will further improve the overall quality and classification accuracy of smart home product model, strengthen the fluency and immersion of virtual interactive operation, and make a positive attempt for the transformation and upgrading of smart home industry.

Acknowledgments

2023 Research topic of Modern Distance Education Society of Liaoning Province: Exploration and practice of virtual imitation training base construction under digital background 2023XH-11

References

1. Fu Xinyi et al. Future-oriented Frontier Progress of Smart Home[J]. Science & Technology Review.2023.04.
2. Wang Yinchuan, Pang Zhihui. Research on Whole House Smart Home Design in the 5G Era[J]. West Leather.2021.01.
3. Zhaocheng Wenlong. Design and Research of Smart Home Products Based on Immersive Interaction[D]. Shandong University of Art&Design.2021.04.
4. Ning Xin et al. Research and Application of 3D Modeling Technology in Virtual Reality[J]. SP.2018.08:75.
5. Song Chuanlei, Hou Shizhong. Unity3D Virtual Reality Scene Analysis and Design[J]. China Market.2017.06.
6. Wang Haoyu. Design and Simulation of Interaction Based on Rigid Body in Unity3D[J]. Information & Computer.2021.11.
7. Zheng Qifan et al. Research on Innovative Design of Whole House Smart Home in the 5G Era[J]. Jushe.2023.02.
8. Xu Jia. Smart Home Virtual Simulation System Based on Unity3D[J]. Sensor World.2019.11.
9. Han Ning. Research on the Application of Virtual Reality Technology in Smart Home Design[J]. Public Communication of Science & Technology.2020.11.
10. Che Sen et al. Research on the Production Method and Key Technologies of Panoramic Roaming[J]. Engineering of Surveying and Mapping.2021.09.