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CAD Design and Implementation of Virtual Reality Booth Based on Unity Technology

Guangpeng Yue[1], Fengze Li[2], Ravi Tomar[3] and Thipendra Pal Singh[4]

[1]College of Industrial Design, LuXun Academy of Fine Arts, Shenyang, 110000, China, guangpengyue@163.com
[2]College of Industrial Design, LuXun Academy of Fine Arts, Shenyang, 110000, China, fengzeli8@126.com
[3]School of Computer Science, University of Petroleum and Energy Studies, Dehradun, India, 248171, ravitomar7@gmail.com
[4]School of Computer Science, University of Petroleum and Energy Studies, Dehradun, India, 248171, thipendra@gmail.com

Corresponding author: Ravi Tomar, ravitomar7@gmail.com

Abstract. It is vital to analyze several elements before adopting Internet of Things solutions, proper and successful implementation of the plan, in order to prevent Internet hardware platforms, software service design flaws, and software service validation challenges. This paper proposes the development of a CAD simulation platform to simulate real physical environments and non-homogeneous equipment using virtual reality technology, to simulate real phenomena, and to address design segmentation and resource consumption of software systems and hardware platforms when implementing an Internet objects solution, which is a way to implement parallel software and hardware development. The following are the outcomes: For various physical factors, the CAD simulation platform described in this document can reach an average simulation speed of 94%; the simulation platform applied to the smart home simulation scene can preserve the smoothing effect. The average frame rate is around 30 frames per second, and the produced scene is quite smooth; the system takes up roughly 75% of real-time rendering, 80% of scene conversion, and 80% of data serialization. It is demonstrated in this research that the virtual reality booth based on unity technology can successfully simulate the features of the genuine world while ensuring scene smoothness with reduced system use.

Keywords: Internet of things; Virtual reality; Unity; CAD design.
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1 INTRODUCTION

The Internet of Things (IoT) brings together many technical disciplines, such as computers, communications, artificial intelligence, and cognitive science will be able to implement coordination information exchange, remote control, intelligent application system [1-2]. IoT devices collect data and send it to a central data server, where information is analyzed, collated, distilled, and used to simplify a range of tasks. The Internet of Things benefits the commercial sector, government, organizations, and individual consumers [3, 4]. The Internet of Things may be used in a number of ways in both the private and public sectors. The Internet of Things allows people to track things like missing pets, home security systems, and appliance maintenance schedules [5, 6]. Customers may use the Internet of Things to make restaurant reservations, check their fitness progress and overall health, and even get coupons for a business just by walking past it. As the core business of the next Internet development, the Internet of things has attracted extensive attention and research from all countries [7]. However, the development of Internet of things at home and abroad is still in its infancy. The assemblage of gadgets, computers, communication, and data analysis is still on the horizon over thirty years later, but it is growing closer every day. The Internet of Things (IoT) refers to a network of networks (mainly for allowing machine-to-machine communication) as well as a bigger ecosystem that includes sensors, connection, and analysis. At present, many Internet of Things solutions only stay in the "design concept" stage and have not been implemented yet [8, 9]. We've allowed the devices to collect and exchange data, as well as make correct and intelligent decisions, by linking them to each other and the internet (complex mechanisms). This step produced outstanding results [10, 11]. These massive data sets include crucial information that might aid with home security, entertainment, water conservation, and even fuel emission management. Smartphones, direct-to-home television services, smart televisions, and other Internet of Things gadgets have all become commonplace in our lives [12, 13].

At present, the industrial characteristics of the Internet of things are the main reasons restricting its development. It makes the Internet of things mainly face the following problems:

1.1 Lack of Unified Industry Standards

The current field of Internet of things is occupied by different companies, enterprises and standards organizations. They focus on different service sectors and develop standards for their respective industries, which has led to the development of the Internet of Things, which is becoming more and more fragmented and makes it impossible to integrate multiple solutions [14]. Internet of Things (IoT) technology has helped almost every industry, making it simpler to launch new firms and boost efficiency [15, 16]. Connecting devices, managing chores, evaluating prospects, and securely sending data have all become easier thanks to IoT solutions. They help businesses grow by providing a safe operational environment [17, 18]. The efforts have been made to provide End-to-end IoT solution development necessitates the creation of embedded systems, cloud architecture, application enablement, data analytics, security design, and back-end system integration [19, 20].

1.2 Design Fault between Hardware Platform and Software Service

The solution of Internet of things mainly involves two parts: hardware platform and software service. For the hardware platform, it mainly constructs the device management scheme, and accesses, deploys and manages large-scale and most heterogeneous terminal devices at the perception layer; For software services, the default underlying environment is fully deployed, which can provide software services to interact with the hardware platform. Therefore, software services mainly focus on the business processing logic of the upper layer [21]. However, in actual engineering practice, the underlying environment, that is, the hardware platform, is not given, and there is usually only an abstract environment for testing. Moreover, due to the great differences in the focusing objectives and technical requirements of hardware platform and software service, they are usually developed separately. The primary problem caused by the design fault of hardware platform and software service is how to give a verification environment to help the upper software service to verify [22].

1.3 Verification Difficulty

Although the existing Internet of things service platform (such as onem2m) ensures the access of heterogeneous devices, the deployment of the hardware platform will involve a lot of equipment capital, human capital and resource consumption. The upper application services can only be tested and updated iteratively after the matching of the hardware platform is complete, which makes the design and implementation of the hardware platform and software services cannot be carried out synchronously [23].

The design fault of hardware equipment and software services and the difficulty of verification of software services restrict the use of Internet of things solutions, which makes the current Internet of things urgently, need to find a solution. In this way, it can ensure that the upper application services can be tested and simulated without relying on the complete physical environment and real equipment, realize the parallel development of hardware platform and software services, and finally put into use in the real physical space [24]. The testing and commissioning of the existing Internet of things application services are mostly based on simulation data. Software services are developed and demonstrated through test cases and simulation data written for specific Internet of things solutions [25]. This method considers limited test scenarios, heavy workload and poor display effect. At present, using virtual reality technology to simulate real field has become an important research direction to solve the fault problem of hardware platform and software service [26]. Figure 1 shows Unity 3D virtual reality. Virtual reality technology is quite useful. When three-dimensional virtual technology is used to model buildings, the BIM model is used to completely express the practical benefits of virtual technology in three-dimensional building model modeling, and it is extensively utilized in building virtual reality modeling.

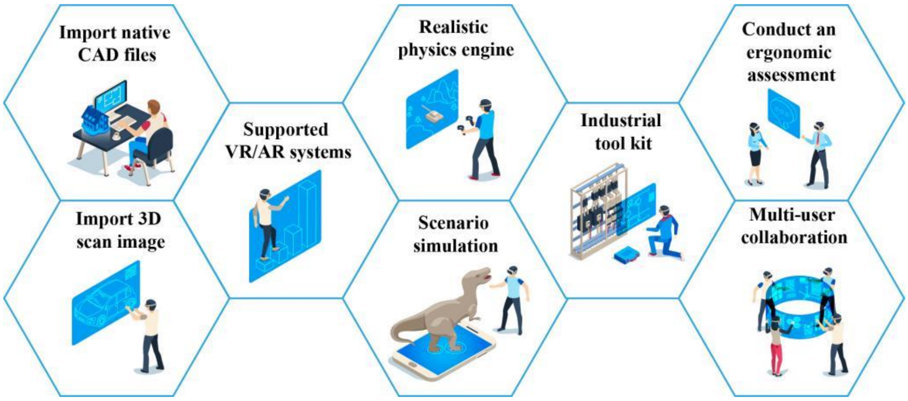

Figure 1: Unity 3D virtual reality.

Many technological areas, such as computers, communications, artificial intelligence, and cognitive science, are brought together by the Internet of Things. Various corporations, enterprises, and standards bodies are now active in the Internet of Things sector. The Internet of Things' industrial qualities are now the key factors limiting its development. Although existing Internet of Things service platforms (such as onem2m) allow heterogeneous devices to connect, however, deploying the hardware platform will need a significant amount of equipment, human capital, and resource consumption. The majority of simulation data is used in the testing and commissioning of current Internet of Things application services.

2 LITERATURE REVIEW

Using virtual reality technology to evaluate and verify the platform scheme of the Internet of things, and deploying the simulator in the virtual reality environment can more accurately capture and simulate the possible behavior of users in intelligent buildings and reproduce the interaction between users and devices in the physical environment. As virtual reality technology develops, many relevant countries and companies have conducted research on the combined use of virtual reality and the Internet of Things, and the current research is as follows.

The United States has made the most in-depth use of virtual reality technology, from the initial simulated training of astronauts by the U.S. military to the current medicine, military aerospace, interior design, industrial simulation, emergency calculation, game entertainment and urban simulation [27]. In 1990, NASA established the space station to conduct virtual simulation of the real-world training system in order to strengthen the astronauts' aviation adaptation and satellite maintenance skills. There is also the "virtual planet exploration" (VPE) program being implemented. At present, its research field includes all the software and hardware equipment of virtual reality system. Currently, his research area includes all hardware and software of virtual reality systems. Currently, the first and most popular organization to study virtual reality technology is the Department of Computer Science at the University of North Carolina (UNC), which specializes in molecular modeling, aerospace, medical technology simulation, and building modeling, but they focus on molecular research, and have no obvious outstanding achievements in building simulation and other research fields related to the Internet of things [28]. In addition, the roaming studio at the University of California, Berkeley has conducted a lot of research on architectural roaming. They conduct three-dimensional simulation of real buildings through virtual reality technology, so that users can get an immersive and realistic experience [29]. In 1996, they used this technology to construct the virtual reality of the design scheme of the computer specialty teaching building of Berkeley University, realized the advance roaming, and timely found and repaired the defects in the architectural design [30]. Virtual reality has a wide range of applications, ranging from academic study to engineering, design, business, the arts, and entertainment. Virtual reality, regardless of its use, generates a collection of data that is then utilized to build new models, training techniques, communication, and interaction. In many respects, the options are limitless.

Behandish et al. created a general and effective virtual force model assembly [31]. Their method involved creating artificial energy fields surrounding the virtual world. Objects for detecting collisions between components are also guiding the parts. During virtual assembly, they can create their chosen spatial arrangements. One issue that makes non-immersive VR training less effective is that previous study has shown that when utilizing a stereoscopic display, users are more successful at arranging items in a 3D environment [32]. Physics-based modeling (PBM) and constraint-based modeling (CBM) are the two most often utilized VA approaches [33, 34]. VR is one of the most recognized usage cases such as games, vehicle simulators including flight simulators, data visualization applications, and medical applications like stroke rehabilitation [35].

Due to the late start of the research on Internet of things and virtual reality technology in China, and due to the constraints of relevant software, hardware and deployment environment, there is still a certain gap in both virtual reality technology and Internet of things research compared with some of the above developed countries, but relevant national departments and scientific research institutions have begun to pay attention to and invest in research [36]. Many schools have also studied the combination of virtual reality and the Internet of things.

Led by Beijing University of Aeronautics and Astronautics, its computer department is one of the earliest departments engaged in virtual reality research, the hardware design and development of virtual reality visual interface and the description and processing of object physical characteristics. The realized virtual reality demonstration system can be used for pilot training, and an online virtual reality research forum has been established [37]. In terms of real-time scene rendering technology, they have studied the core technologies in the virtual environment such as real-time graphics generation, collision detection and complex model simplification, and achieved a lot of research results [38]. Major organizations and universities have carried out research work on the combination of virtual reality and Internet of things. However, they mostly integrate virtual reality and Internet of things technology from scene roaming and human-computer interaction, and build a virtual demonstration scene with Internet of things solutions through graphic rendering and physical engine. However, they rarely involve the use of virtual reality technology to build a simulation environment to help the development and testing of Internet of things application services [38]. There is indeed a gap for both virtual reality technology and Internet of things research in China compared to some developed nations, due to the late beginning of investigation on Internet of things and virtual reality technology in China, as well as the constraints of relevant software, hardware, and deployment environment, but appropriate national agencies and scientific research centers have started to give heed to and make investments.

3 RESEARCH METHODS

3.1 TOF and Zigbee Networks

In this paper, a virtual simulation booth is established based on Unity3D Internet of things, in which TOF and Zigbee technologies are used. Zigbee is a standards-based wireless technology that enables low-cost, low-power wireless M2M and internet of things (IoT) networks. Zigbee is an open standard for low-data-rate, low-power applications. For IoT device makers, Zigbee is a common choice. It has most of the essential capabilities customers want (connectivity, range, and security), plus it's an open-industry standard, so it'll work with any Zigbee-certified device. In recent years, indoor positioning has gradually become a basic function in many terminal applications, and has been applied in civil, disaster protection and peacekeeping missions. Compared with relying solely on satellite positioning outdoors, there are many signal sources that can be used for positioning in indoor scenes. Different indoor positioning signal sources also produce a variety of indoor positioning algorithms, including ranging-based positioning algorithm. The hardware on which the algorithm depends has direct ranging ability, that is, TOF based positioning algorithm [40].

In this paper, the equipment provides the functions of signal transmission and reception, timestamp recording and delayed transmission. Under the premise of asynchronous clock between hardware, single side two-way ranging (SS-TWR) can be adopted. The calculation formula of signal flight time is equation (3.1):

$$TOF = \frac{1}{2} \times \left((T_3 - T_0) - (T_2 - T_1) \right) \tag{3.1}$$

This method is not commonly used because there is a deviation between the clock of the base station and the tag and the standard clock. It is expressed by the clock drift rate, taking $\mathrm{k} = 10\ \mathrm{ppm}$. Assuming that the tag delay time $\mathrm{T_d}$ is 3ms and the signal flight time TOF is negligible compared with the delay time, the ranging error caused by the delay time is equation (3.2):

$$|r| = \frac{1}{2} \times |k_b - k_t| \times T_d \times c \tag{3.2}$$

When b=0$|\mathrm{k_b} - \mathrm{k_t}| = 5\ \mathrm{ppm}$, $|\mathrm{r}| \approx 2.25\mathrm{m}$, in practice, $|\mathrm{k_b} - \mathrm{k_t}|$ may be higher than 5 ppm, which will bring great ranging error. In order to reduce the influence of clock drift on ranging, double-sided two-way ranging (DS-TWR) method is adopted. This method adds another delay and signal transmission and reception on the basis of SS-TWR. The TOF calculation method of DS-TWR method is equation (3.3):

$$\begin{cases} T_{r1} = T_3 - T_0, T_{p1} = T_2 - T_1 \\ T_{r2} = T_5 - T_2, T_{p2} = T_4 - T_3 \\ TOF = \dfrac{T_{r1} \times T_{r2} - T_{p1} \times T_{p2}}{T_{r1} + T_{r2} + T_{p1} + T_{p2}} \end{cases} \tag{3.3}$$

The approximate calculation formula of ranging error caused by clock drift in this method is equation (3.4):

$$|r| \approx TOF \times \frac{1}{2} \times |k_b + k_t| \times c \tag{3.4}$$

Take $\mathrm{k_b}$ and $\mathrm{k_t}$ as 20ppm. If the distance between the base station and the tag is 200m, the TOF is about 666 ns, and the ranging error is equation (3.5):

$$|r| = 666 \times 10^{-9} \times 20 \times 10^{-6} \times 3 \times 10^{8} \approx 0.004m \tag{3.5}$$

That is, the ranging error of DS-TWR method due to clock drift is mm, so the actual TOF working mode should adopt DS-TWR method.

This paper introduces ZigBee wireless communication technology to standardize the information communication of PLC control system. The filtering algorithm is adopted to filter the redundant noise of the data collected by the gateway. Considering that the state data of the system working environment is discrete distribution, in view of this situation, the value of the system control variable is set to be stable, and the production equipment state data in discrete time domain is expressed through Kalman filter. The expression is as follows (3.6):

$$S(x) = \frac{AS(X-1)+B+W(x)}{S(x)+V(x)} \tag{3.6}$$

Where, $S(x)$ and $S(x-1)$ are the estimated values of production equipment state data at time x and time x-1 respectively; A and B are the system definition parameters; $W(x)$and $V(x)$ are the noise of the system and working environment respectively.

Calculate the covariance $P(x/x-1)$ of the estimated value of x-time and x-1 state data, and the formula is formula (3.7):

$$P\left(\frac{x}{x-1}\right) = \frac{AH(x-1)H(x)+Q}{R} \tag{3.7}$$

Where, $H(x-1)$ and $H(x)$ are the system observation matrix at time x and time x-1 respectively; R is the system covariance; Q is the gain coefficient.

Further optimize $P(x/x-1)$ to obtain the optimal estimation value $K(x)$ of the system time. The expression is equation (3.8):

$$K(x) = \frac{LK(x-1)}{P\left(\frac{x}{x-1}\right)+f} \tag{3.8}$$

Where, $K(x-1)$ is the optimal estimated value of state data at time x-1; L is the $K(x-1)$ value covariance; f is Gaussian white noise.

After the original data is filtered, the PID controller optimization algorithm is adopted to make the state variables of the production equipment collected by the system closer to the real value of the environment. Each state data is abstracted as a particle, and the particle space position is determined according to the particle moving speed and inertia, so as to find the optimal path to reduce the system error. The weighted parameters E_1 and E_2 of the PID controller are defined, and the expression is formula (3.9):

$$\begin{cases} E_1 = \dfrac{a_1 e_1[I(x)-D(x)] + a_2 e_2[O(x)-D(x)]}{gv(x)} \\ E_2 = D(x) + v(x+1) \end{cases} \tag{3.9}$$

Where, a_1 and a_2 are particle accelerations; $e_1$and e_2 are random parameters; $I(x)$and$O(x)$ are the position of particles and particle swarm at time; $D(x)$ is the optimal position; g is inertia parameter; $v(x)$ and $v(x+1)$ are the speed.

The state equation of system variance is equation (3.10):

$$H(x) = E_1 \int_0^x P'\left(\frac{x}{x-1}\right)dx + E_2 \frac{dP'\left(\frac{x}{x-1}\right)}{dx} \tag{3.10}$$

Where, $P'\left(\frac{x}{x-1}\right)$ is the optimized system variance.

3.2 System Deployment

The system developed in this article is based on the cloud platform, and IoT versions and simulation environments have been added to the simulation platform to create virtual reality demonstration versions that replace the real physical world to access the existing oneM2M authentication cloud platform and smart home services. Communicate with them see Figure 2.

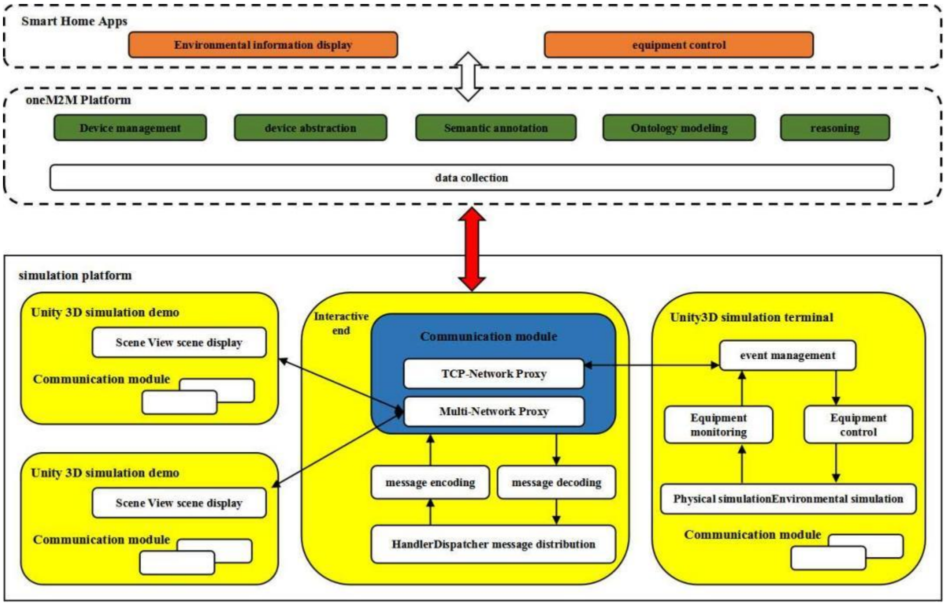

Figure 2: Architecture diagram of demonstration system based on Simulation Platform.

3.3 System Interaction

Scene interaction: as the interface between users and virtual scenes, it mainly carries out system display and event interaction through simulation demonstration end. Therefore, the simulation demonstration end needs to listen to the user's relevant instructions for the control role, and correspondingly change the position and animation display of the role. At the same time, the scene also needs to refresh the current environmental information and prompt module in real time in order to display the information to the user.

Information interaction: the demonstration system in this paper requires the upper cloud platform and unity simulation platform to provide a unified interactive object format. Through the existing JSON plug-in, the object can be transformed into serialized data and then transmitted. After that, it can be desterilized and re transformed into objects in different languages. For the environment interaction object of smart home, this paper proposes to use communication request and communication response for object transmission.

General interaction protocol: the communication between the simulation end, the simulation and demonstration end, and the upper general service layer needs to be realized through the middle interaction end. The server interaction end of this paper is realized by the NiO network framework based on Netty. In order to realize the data communication of demonstration end, simulation end, upper general service platform and interactive processing end, the communication protocol and data protocol of transmission need to be preset. At present, the communication protocols mainly include TCP, UDP, HTTP and FTP. As a data exchange format, the data protocol is mainly used to ensure the mutual understanding of structured data between the communication parties. The network communication module needs to encapsulate the data through the encapsulation process in Figure 3.

3.4 Furniture Demonstration System based on Internet of Things Simulation Platform

The hardware environment deployment of the virtual reality simulation platform based on smart home is shown in Table 1. The simulation demonstration end needs graphics rendering, consumes a lot of computing resources, and needs to be given the highest configuration.

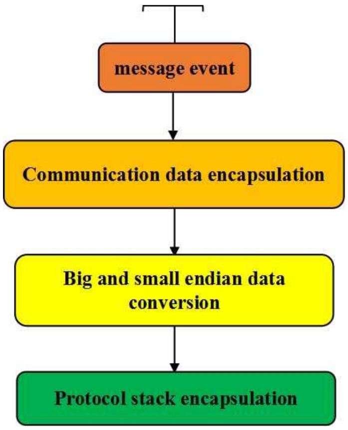

Figure 3: Network communication data encapsulation flow chart.

Name	*Detailed configuration*	*Quantity*
Simulation demonstration end	4-core 8-thread i7 CPU, 16G RAM, GTX745 GPU, 1T hard disk	1
Interactive end	4-core 4-thread i5 CPU, 8G RAM, 1T hard disk	1
Simulation end	4-core 4-thread i5 CPU, 8G RAM, 1T hard disk	1

Table 1: Hardware environment of virtual reality simulation platform.

The software environment deployment of virtual reality simulation platform based on smart home is shown in Table 2. The simulation demonstration end needs to use UI for information interaction, and UGUI is called for two-dimensional plane rendering.

Name	*Development environment*	*Language*	*Related tools*
Simulation Demonstration End	Unity3D 5.1.0f	C#	UGUI, protobuf, JsonDotNet1.4.0
Interactive End	Intellij IDEA14	Java	Netty, protobuf, fastjson
Simulation End	Unity3D 5.1.0f	C#	Protobuf, JsonDotNet1.4.0

Table 2: Software environment of virtual reality simulation platform.

4 RESULT ANALYSIS

4.1 Physical Environment Simulation

Physical environment simulation requires that the simulation environment information can truly simulate the change of environment state, which requires that the environment state is closely related to the equipment state and simulation time, and can change accordingly. Here, test cases are constructed with some interaction scenarios and tested item by item to verify whether the physical environment simulation of the simulation platform works as expected. The results are shown in Figure 4.

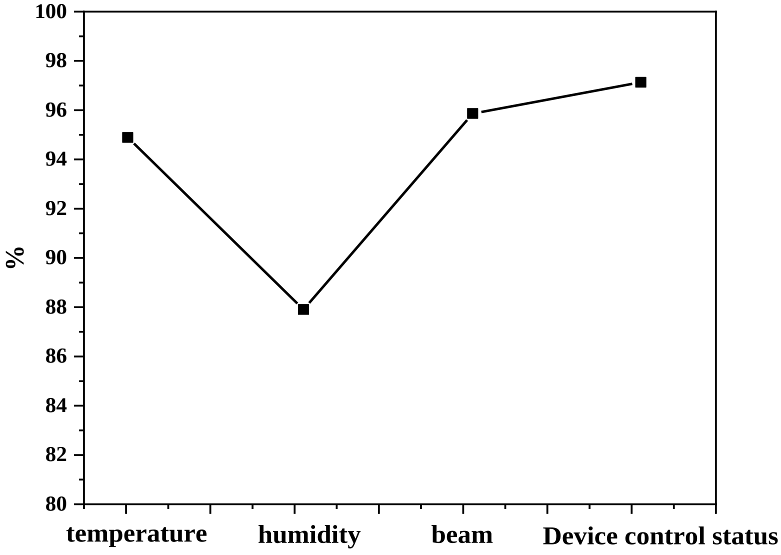

Figure 4: Platform simulation rate.

As shown in Figure 4, the simulation platform designed in this paper can achieve an average simulation rate of 94% for various indicators, of which the highest simulation rate of equipment control state can reach 97%.

4.2 Performance Test

Because the visual properties of the human eye are preserved, the human eye can retain its image for 0.1-0.4 seconds, and the limited human eye makes it impossible to distinguish images from more than 30 frames. To keep the visual effects even, the screen update of this simulation platform needs to reach at least 15 FPS, and up to 30 FPS during animation playback. To test the visual effects, the current system's FPS size is monitored through the Statistics control panel in Unity3D's Game Mode. The test results show that once the interface is started, the on-screen update stabilizes first at 14FPS and then at 20-25FPS. For animations (quick camera rotation, car mode operation, etc.), screen updates are usually stored at 35-45FPS, as shown in Figure 5. Smart home simulation images can maintain the effect of smoothing the image. The average frame rate remains around 30 FPS, and the picture shown is very smooth.

4.3 Occupation of System Resources

The system consumption of the simulation platform mainly lies in the virtual reality simulation of the simulation demonstration end. It consumes a lot of computer resources because it converts virtual reality into real-time images, scenes, and data in series, while the interaction end and simulation end focus on the background logic forwarding and data simulation, and do not involve large concurrent communication and resource consuming graphics rendering, the system resource requirements are not high. Using Unity3D's Profiler dashboard, determine whether the simulation platform resource load is reasonable by observing the computer resource consumption of the simulation terminal in real time. As shown in Figure 6, the real-time rendering system occupies about 75%, the scene conversion system occupies about 81%, and the data serialization system occupies about 82%.

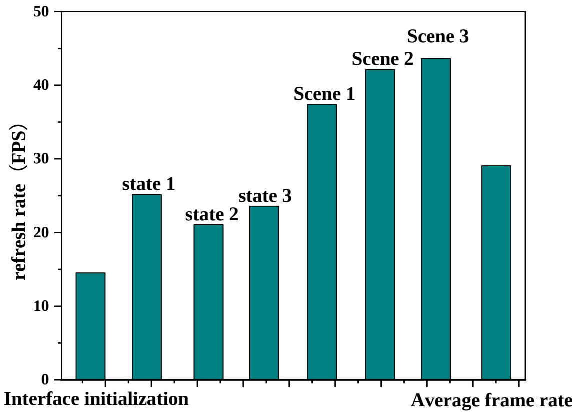

Figure 5: Frame rate of different scenes.

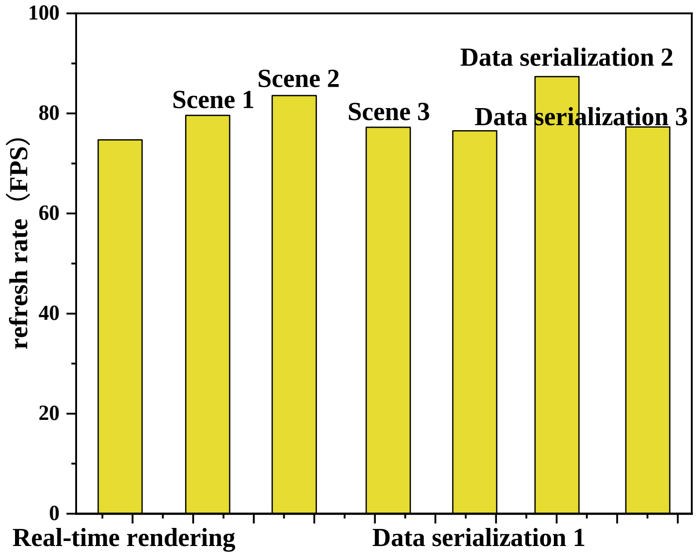

Figure 6: Resource occupancy analysis.

5 CONCLUSION

Internet of Things is slowly enriching our lives. However, due to design errors in the Internet of Things hardware and software services, and the difficulty of verifying software services, the Internet requires multiple certifications before implementation. Internet item verification schemes vary mainly based on the users' actual use cases. There is no unified verification scheme to follow, no system architecture, and no interaction with users. In response to the above questions, this article will focus on perform the following tasks.

1) Analyze the current state of the Internet of Things industry and suggest that the development of Internet of Things solutions requires the protection of non-homogeneous architectures, the isolation of services and equipment, and the display of Internet of Things. Provide all-round customer service.

2) Considering the wide range of application options available on the Internet of Things, the presentation system needs to be highly scalable and reusable. The simulation platform divides the system into three parts: end of simulation presentation, end of interactive processing, and end of simulation, and develops a rotation event standard to implement a simulation platform based on physical simulation, event creation, and network data transmission for the scene. The simulation platform provides a physical simulation and imaging call interface for the top-level presentation system, which is suitable for modifying the simulation environment to achieve fast simulation results in the top-level presentation system.
3) Analyzing the current state of development of virtual reality technology, this work selects Unity3D to implement the simulation display side and the visual and physical simulation part of the simulation side, and connects the two interaction centers using NIO-based software. The Netty framework builds the server communication side and the TOF And Zigbee network, and finally builds and implements the simulation platform.
4) In line with the current development of the Internet of Things, we propose to create a modeling system for the smart home, create a smart home demonstration system based on the above simulation platform, and implement real-time 3D imaging, scene imaging and virtual environment simulation.

Guangpeng Yue, http://orcid.org/0000-0001-7763-4237
Fengze Li, http://orcid.org/0000-0001-8991-5984
Ravi Tomar, https://orcid.org/0000-0002-8957-6756
Thipendra Pal Singh, https://orcid.org/0000-0002-9991-6494

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