Design and Implementation of Drilling Engineering Simulation System Based on Unity3D

Aiqing Huo\textsuperscript{1, a}, Jingrong Xu\textsuperscript{2, b}, Haoping Li\textsuperscript{3, c}, Zewen Wang\textsuperscript{4, d}

\textsuperscript{1}School of Electronic Engineering Xi’an Shiyou University Xi’an, China
\textsuperscript{2}School of Electronic Engineering Xi’an Shiyou University Xi’an, China
\textsuperscript{3}R&D Management Department Xi’an Changyuan Electronic Engineering Co., Ltd. Xi’an, China
\textsuperscript{4}School of Electronic Engineering Xi’an Shiyou University Xi’an, China
\textsuperscript{a}E-mail: aqhuo@xsyu.edu.cn, \textsuperscript{b}E-mail: 2867255600@qq.com, \textsuperscript{c}E-mail: 895720801@qq.com, \textsuperscript{d}E-mail: 1030135717@qq.com

Abstract. In this paper, a drilling engineering simulation system is designed and developed aiming at some problems existing in traditional well control safety operation training. The overall design and process of the virtual simulation system were given, optimized and rendered the models of the drilling engineering equipment and the wellsite scene were created using the software 3Ds Max. With the aid of the Unity3D development platform, the oil drilling virtual simulation system was constructed, which realized the interaction between the wellsite roaming system and drilling operations. The system has the characteristics of low development cost, strong real-time interaction, realistic immersion and meets the needs of oilfield drilling engineering training.

1. Introduction
The training of well control operators before taking their jobs is particularly important for well control safety. In view of the low efficiency of traditional well control operation training methods and the current VR(Virtual Reality)-based oilfield drilling simulation training system, there are some problems such as single function, poor screen immersion, and lack of interactivity. Using the secondary development of virtual simulation algorithms, 3Ds Max three-dimensional modeling technology and the cross-platform characteristics of the software, combined with the HTC Vive virtual equipment, a drilling engineering virtual simulation training system based on the Unity3D platform was designed to realize the immersive interaction between the well controller and the simulation system, which greatly improves training efficiency.

2. Overall design of virtual simulation system
The process of developing virtual oilfield drilling engineering based on Unity3D software is essentially the process of developing a virtual reality system. The overall design flow chart of the drilling engineering simulation system is shown in Figure 1.
In order to realize the drilling engineering simulation system, the following key technical operations will be carried out in accordance with the basic layout of a certain well site and the planning diagram of the composition system:

1. Firstly, collecting and processing the original data of the well site as the basic work, and establishing a virtual three-dimensional visualization model by using 3Ds Max software and the real-time data of the well site;
2. Secondly, Photo Shop and Substance Painter software are used to optimize the model, texture mapping and rendering of the constructed 3D model, and the FBX format file is packaged and exported;
3. Then import the exported FBX files into Unity3D software to improve the virtual environment of drilling engineering and make use of the script programming with Unity3D software itself (engine script editing supports three scripting languages including Java, C# and Boo, which can create powerful interactive content\cite{1}. In this paper, C# scripting is used) to add virtual interaction design such as scene tour, system interface, collision detection, fluid effect, and preset system to realize motion control of the device model in the virtual scene\cite{2};
4. In addition, with the help of interactive devices such as HTC Vive head-mounted displays, data handles and position trackers, as well as the human body’s own perception, the operator can close experience and be familiar with the well site environment and various tools of the position and function, which can better accept training on skills and job requirements\cite{3} to achieve immersive interaction between well control personnel and the simulation system.

3. Construction and optimization of 3D models and wells scene

Three-dimensional models and scenes are the foundation of the whole virtual reality system, which directly affects the reality of the virtual environment. In this paper, Autodesk 3Ds Max was used to create a 3D model and Unity3D was used to optimize the virtual wells scene.

3.1. Establishment of 3D model

The principle that should be followed to establish a 3D model in 3Ds Max software is to use the simplest model as far as possible under the premise of ensuring high authenticity of the model\cite{4}\cite{5}. Therefore, to meet the needs of drilling engineering, the models of equipment scenes such as derrick, substructure, blowout preventer (BOP), driller's room, hoisting system (such as winch, wire rope, crown, traveling block, etc.), rotating system (Turntable, top drive system, etc.), circulating system (drilling pump,
surface manifold, drilling fluid purification equipment, etc.), VFD(Variable Frequency Drive) room, diesel generator set and other equipment scene models were created respectively, and then each model created by the merged into an object. Finally, the establishment of the virtual model of the drilling well site is completed.

3.2. Optimization of model and scene

Based on the preliminary construction of the simulation model, the model optimization and rendering processing in the later stage are the important links of the virtual scene of well engineering.

Model optimization mainly refers to reducing the number of vertices, edges, triangles and polygons that constitute a 3D model as much as possible while ensuring that the model structure is correct and does not destroy the reality of the model. And this rendering mainly uses PS (Photo Shop) and SP (Substance Painter) two software, as well as VRay renderer. After the constructed wellsit equipment model was optimized by UVW in 3Ds Max, the FBX file was exported\[6\], and then PS and SP software was used to add materials, textures, and adjust lighting and other parameters.

3.3. Construction of Wellsite Virtual Scene

VR technology is used to construct the virtual scene of oilfield drilling engineering, which requires the simulation model to have a high degree of authenticity and real-time performance in the display equipment, so as to create a kind of realistic sense of on-site experience for users.

Create a new Scene and drag the exported FBX model to the Scene view. It should be noted that the model must be embedded in the media (Embed Media) check box when exporting. Unity 3D will automatically generate a folder for storing the matching textures of the FBX model to avoid the loss of textures. Texture editing and texture processing of the model are carried out in Unity based on the maps made in SP, PS and VRay renderer. Then the 3D model of the newly created drilling project can be displayed in the Scene view.

In addition, by virtue of the inherent resource package of Unity3D software, other essential elements of the virtual environment, such as mountains, trees, vegetation, water, sky, light source and sound effects, are added to make the drilling virtual wellsite scene more real and natural\[7\]. It is worth noting that in the terrain rendering process, the trees and vegetation on the mountains are distributed as sparsely as possible, which can reduce the requirement of computer hardware for scene rendering and avoid unnecessary computer lag phenomenon. The final rendering of drilling engineering equipment and wellsite is shown in Figure 2.

![Figure 2](image.png)

Figure 2: The effect diagram of well site construction of virtual drilling engineering

4. Realization of Virtual Drilling Engineering Simulation System

The realization of interactive functions of the virtual reality simulation system is a key part of the virtual drilling engineering simulation system. In this paper, the operating interface of drilling engineering simulation system was developed by virtue of Unity3D platform. By adding C# script program and key association, the wellsit roaming system and the drilling operation system are designed to realize the interactive functions of wellsit roaming and operation system operation.
4.1. Realization of Wellsite Roaming System

The roaming system mainly realizes the wellsite roaming of well control operators. This roaming system consists of two ways: one is roaming from the perspective of the first person, which realizes the independent observation of local wellsite equipment and resources; the other is the third-person view roaming, which can patrol of the entire wellsite by controlling the zoom of the field of vision and the all-round free movement of the position.

The realization of third-person roaming is used to enter the wellsite from a third perspective, and click the left mouse button to control the movement of the character. When clicking "Terrain" with the left mouse button, the character moves to the position clicked on the ground. It can also control the zoom of the camera's field of view to inspect the whole wellsite from the third-person perspective. It is worth noting that when setting up the roaming system, it is necessary to make collision objects to block the role controller, so as to prevent the character from passing through the wall and equipment during roaming and losing its authenticity[8]. The rendering of third-person roaming is shown in Figure 3.

![Figure 3: Renderings of third-person roaming](image)

4.2. Simulation realization of drilling engineering operation process

The oil drilling operation process is quite complex, and the entire oil drilling project has eight major systems, including lifting system, rotary drilling system and circulation system[9]. In order to realize the authenticity of simulation of the drilling engineering operation process in the virtual system, it is necessary that the scene model motion control of the eight petroleum drilling systems is consistent with the operation process of actual well site. Taking rotary drilling system as an example, this article describes the simulation of operation process.

4.2.1. Realization of Rotary Drilling System

Rotating system mainly controls the rotating operation of drilling tools in drilling field, and plays the role of driving drilling tools and drill bits to break rock strata. Through the control interface, the operator can realize the rotation of the drilling tool. At the same time of rotation, it can raise and lower the drilling tool, and control the function of speed increase, speed reduction and brake.

By clicking the "Rotate Drilling system" button, the system interface will pop up a navigation interface to introduce the operating buttons and functions; after entering the rotary drilling system interface, the rotary drilling system function operation button will appear on the interface, and the button function corresponds to the operation control described in the text. Among them, sliding the middle mouse button can enlarge and reduce the camera screen, and using the right mouse button to move left, right, up and down to control the camera to view in all directions. In this system, by controlling the interface buttons, the shape of the drilling tool can be changed to realize the human-computer interaction function. The operation interface of the rotary drilling system is shown in Figure 4.
4.2.2. The realization of the function of the simulation operation of the rotary drilling system

In the design of the operation animation demonstration of the system, the C# script language program
is associated with the buttons to control the drilling tool operation and realize the interaction between
the operator and the system. By associating the "lifting tool" and "drilling tool" buttons to realize the
operation of lifting and lowering the drill tool while the drill tool is rotating; the running speed of drilling
tools is controlled by the associated "speed increase" and "speed decrease" buttons. The specific control
method is as follows: click the speed decrease (increase) button once, and its speed will double and
decrease (increase); through the associated "brake" button, the rotary drilling pause operation is realized.
Part of the code is implemented as follows:

4.2.2.1 Lifting rotation, lowering rotation and braking operation of drilling tools

```csharp
public void Down_Click() //Click to start moving, the value is -1
{  MoveDirection = -1.0f;
   isStop = false;  }
public void Up_Click() //Click to start moving, the value is 1
{  MoveDirection = 1.0f;
   isStop = false;  }
public void Stop_Click() //After clicking, it will stop moving
{  isStop = true;  }
```

4.2.2.2 Acceleration and deceleration effects

```csharp
public float DownSpeed = 4.0f; //Moving speed
public float TurnSpeed = 120.0f; //Spinning speed
public void Accelerate_Click() //Click and the speed will be multiplied by 2
{  TurnSpeed *=2;  }
public void Decelerate_Click() //Click and the speed will be divided by 2
{  TurnSpeed /=2;  }
```

* Implementation of other oil Drilling Engineering Operation Systems

Other petroleum drilling engineering operation systems are basically similar to the simulation
implementation of the rotary drilling system. By adding script programs and buttons to associate, which
can control the motion status of related equipment, the relevant operation of virtual petroleum drilling
engineering operating system can be realized and good virtual interaction effect can be achieved.
Among other things, the lifting system, associated with the keys through C# scripting language,
allows the well controller to use the control interface to lift, lower, decelerate, accelerate, and brake the
drill string and reflect the position of the drill string at different times.
The animation effect of the drilling fluid in the circulation system along the pipeline is simulated by combining the Obi Fluid plug-in and the Unity3D particle system, achieving a real and natural effect.

5. Conclusion
In this paper, a drilling engineering virtual simulation system based on Unity3D is designed. According to the actual oil drilling process, the optimized well site equipment model and well site scene are constructed by using 3D modeling software 3Ds Max, and the model and scene are optimized and rendered to approximate the real scene. The operation interface of drilling engineering simulation system is designed and developed. Through programming, the wellsite roaming system and drilling operation system are designed to realize the interaction between wellsite roaming and operation system. The virtual simulation system has immersive interaction and control functions, which improves the efficiency of drilling engineering safety operation training to a certain extent, and provides technical support and guarantee for the development of oil drilling engineering training business.

Acknowledgment
The completion of this paper is inseparable from the support and help of all members of the Automation 104 Laboratory of Xi’an Shiyou University. Thanks to Wenle Zhang, Hao Liu, Yi Li, and Yuyan Yang for their guidance on scientific research and technology, and Shuhan zhang for helping to collect information. Here, I would like to express my sincere thanks to those who have given me support and help.

This research was supported by the scientific research project of the Key Laboratory of Education Department of Shaanxi Province (17JS108).

This research was partially supported by General Project of Shaanxi Provincial Science and Technology Department-Industrial Field (No. 2020GY-152).

This research was supported by the scientific research project of the Key Laboratory of Education Department of Shaanxi Province (17JS108).

Funded by Xi’an Shiyou University Graduate Student Innovation and Practice Ability Training Program.

References
[1] Jun Han, Heng Zhang, Xinyu Jiang, and Dongxu Jia. Development of a virtual reality system for microseismic monitoring and analysis based on Unity3D [J]. Coal Science and Technology, 2019,47(05):151-155.
[2] Mingsheng Yang and Yuanbiao Hu. Design and implementation of core drilling rig simulation operating system based on Unity3D [J]. Non-ferrous metal engineering, 2020,10(09):117-121.
[3] Xiangdong Liu, Liwei Cui, Haiyan Guo,Zengxiang Wang and Kang Chen. Songke Erjing Core Cognitive Immersive Virtual Reality System Design and Development [J]. China Mining Industry, 2018,27(S2):268-271.
[4] Shuyuan Fan, Dunming Liao, Dongxin Ling, Bingyang Xue, Fei Sun and Zitian Fan. Development of a virtual reality system for lost foam casting based on Unity3D [J]. Laboratory Research and Exploration, 2018,37(05):108-113.
[5] Naidong Tian and Haike Zhou. Overview of Jack-up Drilling Platform Drilling Package System [J]. Ship Engineering, 2011,33(S1):89-92.
[6] Chunxiao Li, Ruizhi Sun, Yizhou Dai, Saizhou Cai,Qian Li and Jiayao Li. Intelligent display platform of ancient Chinese farming virtual scene based on Unity3D [J]. Transactions of the Chinese Society of Agricultural Engineering, 2017,33(S1):308-314.
[7] Anqing Zhu and Anchao Hu. Construction of Shipbuilding Virtual Simulation Teaching System Based on Unity 3D [J]. Laboratory Research and Exploration, 2018,37(06):117-120.
[8] Yinan Miao and Yanchun Shen. Research on Virtual Reappearance System of Traffic Accident Based on Unity3D [J]. Computer Simulation, 2018,35(12):122-126.
[9] Shujie Liu, Xiangqian Yang, Hua Guo and Chao Zhou. Research on Safety Interlocking Technology of Drilling Rig Well Control System [J]. Coal Technology, 2017,36(04):316-318.
[10] Weili Ding, Tao Yang and Wenfeng Wang. Research and implementation of a coal terminal visual
simulation monitoring system based on Unity3D [J]. High Technology Communication, 2019, 29(08): 791-798.

[11] B. Weibing, Z. Weixin and H. Guang, "Rapid Construction of Virtual Maintenance Training System Based on Unity3D," 2018 IEEE International Conference of Safety Produce Informatization (IICSPI), Chongqing, China, 2018, pp. 158-160, doi: 10.1109/IICSPI.2018.8690454.

[12] Y. Kuang and X. Bai, "The Research of Virtual Reality Scene Modeling Based on Unity 3D," 2018 13th International Conference on Computer Science & Education (ICCSE), Colombo, 2018, pp. 1-3, doi: 10.1109/ICCSE.2018.8468687.

[13] B. A. Koca, B. Čubukçu and U. Yüzgeç, "Augmented Reality Application for Preschool Children with Unity 3D Platform," 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Ankara, Turkey, 2019, pp. 1-4, doi: 10.1109/ISMSIT.2019.8932729.