Designing and Realization of VR Simulation System on Oilfield Flooding

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Abstract. Water injection system is a large production system of oil field, this system works not only in vast area, but also in complex working conditions with great energy consumption. Since the Ninth Five-year Plan period, under the concept of national advocate with energy conservation, emissions reduction and low carbon environmental protection. The process of simulation, optimization and energy conservation of water injection system has been the focused problem of oil sector. This article based on the existing oil field water injecting simulation system, combining the virtual reality technology with water injecting system simulation technology, analyzing and researching with 3D display and virtual interaction of water flooding simulation system as a starting point, designed and excavated a complete set of oil field water injection virtual-reality simulation system in order to assist production management of on-site technical personnel.

1. System requirements and feasibility analysis

1.1. System requirements analysis.
In the process of system development, the analysis of system requirement and feasibility is one of the most important links in the process of development. System demand analysis, although tedious and complex, plays an important role in guiding and paving the way for the smooth progress of the following work. First of all, users may not have the knowledge of system development and cannot clearly elaborate their needs, so we should communicate with users repeatedly during the analysis of system needs in order to fully understand their needs, so as to help users solve problems better. Secondly, because a good demand analysis has an important guiding significance for the setting of the system, if the demand analysis of the system is not perfect or does not meet the requirements of the user, it will encounter great troubles in the design and operation of the system, but also may cause long-term repeated modifications.

Oil field water injection virtual reality simulation system is mainly aimed at the technical personnel of oil field water injection department. The objective and overall task of the system development is aimed at the inconvenient operation of the existing oil field water injecting system and the boring display of interface and data. Combining 2D data with 3D scene, achieve virtual manipulation with strong sense of immersion in virtual scene. Through extracting the production data of a very date of the injection well and the injection station, the property parameters and the simulation parameters of injection stations, injection wells and nodes can be viewed respectively in 3D virtual environment. Finally, by adjusting the valve and related equipment in the virtual scene to change the opening of the valve or the working state of the equipment, the corresponding parameters in the database will be changed along, and the
existing oilfield water injection simulation and optimization system is used to re-calculate, highlighting the characteristics of simple operation, strong immersion and interaction[1]. Thus improve the work enthusiasm of technical personnel, and finally achieve the purpose of improving work efficiency.

1.2. System requirements analysis.

1.2.1. Economic feasibility analysis. For the development of the oil field water injection virtual reality simulation system, the software and language used are relatively mature. Thus, the time needed for development will be rather short and the cost won’t be expensive, the development equipment is mainly computer, no other equipment input is needed, so from the economic point of view, the development of the system is feasible [2].

1.2.2. Technical feasibility analysis. At the technical level, the development tool used in the development of oil field water injection virtual reality simulation system is the widely used Unity3D software for virtual simulation at home and abroad. The software supports three development languages: Boo, JavaScript, and C# [3]. Combined with the analysis of the popularity of the application of the above languages, C# language is finally adopted for system programming. NETFramework is selected as the platform for development, and Excel is used as the data processing software.

1.2.3. Operational feasibility analysis. The virtual reality simulation system of oil field water injection consistent with the existing oil field injecting simulation software in the operation process, and designed while fully considering the convenience of operation of the users as well as the impact of the visual and immersive, the impact of the visual and immersive, make the system be as convenient and easy to use to the users as possible, in that case, the technicians will save a certain amount of time while learning to use the software [4]. To sum up, this system is feasible in operation.

2. Research and Development of Oil Field Water Injection Virtual Reality Simulation System and Key Technology Realization

2.1. Production data extraction and key technology research and realization

2.1.1. Read PC local database files through Unity3D. In Unity3D, there is no control similar to the control that directly opens the desktop dialog box in C++Builder or VS. It needs to realize its function through script programming. The specific implementation process will be described in detail in the next part. Compared with Visual Studio or C++Builder Unity3D, it is more open and does not have absoluteness, but at the same time, it also increases the difficulty of Unity3D when reading data files in the call window [5]. In order to solve this problem, this paper introduces a new way to read data files, that is, combining the script development function of Microsoft basic class library with the two modules of NGUI button and NGuabel in Unity3D plug-in NGUI, so as to realize the reading and display of data [6].

Before the concrete implementation, the first thing to do is to set the operating platform of the system, to ensure that the system in the following operation work to avoid unnecessary mistakes. First open the PlayerSettings panel, which appears under the Inspector window. After creating the project, Unity3D can only call the class library files contained in Unity3D software through the script. In order to retrieve the window dialog box and read Excel data files with C# language in Unity3D, the class library files encapsulated in the Microsoft system need to be imported into the Assets folder of Unity3D.

After the operation of the system, if the extracted data does not conform to the matching fields of the production data, such as injection well number, production date, pipeline pressure, tubing pressure, etc., that is, the extracted data file conflicts with the system requirements, the system will automatically display error information.
2.1.2. Extraction of production data. The extraction of oil field water injection production data mainly includes the extraction of water injection station data and water injection well data. Click the button "Data of Water Injection Wells" in the upper left corner of the control panel to open the data extraction panel, and then click the desktop dialog box of "Data Extraction" to read the data, and select the corresponding Excel file to display the internal data in the file. The data extraction method of water injection station is exactly the same as that of water injection well, which will not be elaborated here.

2.2. Data visualization and non-quantitative display and its key technology realization

2.2.1. Inquiry of water injection station, water distribution room and water injection well. In the process of production and operation of oil field water injection system, users need to inquire some water injection station, water distribution room or water injection well, so that they can grasp the changes of production data and simulation data in real time.

This paper proposes two solutions to this problem: one is to use attribute data (the number of each record) to query the graph function, that is, to search the production unit to be queried quickly through the lower control panel. For example, taking the query of water injection station as an example (see Figure 1), the production unit selected for query will be quickly locked in the center of the three-dimensional virtual space, so as to provide users with the advantages of speed, convenience and high work efficiency for subsequent operations.

![Figure 1. Visualized query of water injection station](image)

The key technology used in this method is coordinate transformation. In Unity3D, the virtual environment of three-dimensional space is rendered by Camera. There must be at least one Camera in a system, otherwise the scene will not be displayed. Each 3D entity unit in the scene is called a GameObject. These 3D entity units are independent of each other, or can be thought of as independent "bodies". In order to make these "bodies" conduct behavior and information feedback in the way required by users, a series of components should be added to the three-dimensional entity unit to make it have certain "thinking characteristics".

2.2.2. Simplified display of pipe network. Oil field water injection pipe network system is a large and complex fluid network system, take oil field water injection system in Daqing as an example, the number of nodes in the water injection system reach thousands. So when the simulation calculation was carried out on the system, the dimension of the control equation will also increase, and that put forward higher requirements of the computer capacity for the operation. Therefore, it is necessary to simplify the oil field water injection pipeline network. The oil field water injection virtual reality simulation system
simplified the water injection system of an oilfield in Daqing twice. The first simplified and optimized branch lines of pipe network, water injection well and water distribution room, etc. The second simplification eliminates the redundant nodes in the remaining trunk pipeline path.

2.2.3. **Cell name display.** System unit name display function mainly includes four parts: water injection station name display, water distribution room name display, water injection well name display and valve name display. In the indexing, we should focus on the graph data, regard the name attribute data as a part of the graph, and combine the two organically. Then, the Excel data processing tool is used to index and display the attribute database corresponding to the graph data. The name is displayed directly above each corresponding 3D model to facilitate user observation. This function is combined with the query function in 2.2.1 to facilitate users to understand what production unit is represented by each 3D model, so as to query the specified production unit.

In this paper, LOD technology is used to display the hierarchical relationship of virtual 3D scene model, which is called LOD (level of detail) technology. The technology is based on the distance of the models in the virtual 3D environment from the camera and the importance of their roles in the corresponding scene to determine the different allocation of rendering resources.

In the three-dimensional oil field water injection virtual reality simulation system, the LOD technology can also be used to divide the model levels, which can not only reduce the computing pressure of the computer, but also make the display effect more real. In addition, LOD technology requires less memory configuration of the computer, and can be quickly simulated in the virtual reality simulation of oil field water injection.

2.2.4. **Display of pipeline parameters and its key technology research and implementation.** The parameter display of the pipeline is divided into two parts. One part is the basic parameter display of the pipeline, including the outer diameter of the pipe, the wall thickness of the pipe and the length of the pipeline. This part of data is displayed in the same way as the unit name in Section 2.2.3, which is mainly divided into main line parameters and branch line parameters. In other words, the basic parameters of the pipeline are displayed directly above each corresponding pipeline in the format of "pipe outer diameter -- pipe wall thickness -- pipe length".

The other part is to select the pipeline to be queried and display all attributes of the pipeline and data information after adjustment of calculation, such as pipe flow rate, pipe head loss, pipe material, pipe number, coordinates of upstream and downstream nodes of the pipe element, etc., through display panel. Compared with the first display method, this display method is more convenient for users to visually view various data.

3. **Interactive control and numerical simulation of oilfield water injection virtual reality system**

3.1. **Valve interactive regulation and numerical simulation algorithm realization**

The external components of gate valve involved in this paper mainly include handwheel, oil ring, coupling nut, coupling bolt, valve body and valve mother. The 3D modeling process of gate valve is realized by 3dsMax software. In the virtual three-dimensional environment of the oilfield water injection virtual reality simulation system, the handwheel of the gate valve is mainly rotated clockwise and counterclockwise along the central axis. Therefore, special attention should be paid to the Z-axis of the three-dimensional coordinate axis of the handwheel in the 3dsMax software to make the Z-axis of the geometric central coordinate of the handwheel in a straight line. Finally complete the production of UVW expansion map and save the model as .FBX file format and import it into Unity3D.

The basic thinking on research of virtual gate algorithm is in the midst of Unity3D software through monitoring the handwheel along the Z axis(vertical axis) of rotation Angle $\theta$ to change the gate of the opening of the relative value of $k$. When the relative opening value $k$ is greater than or equal to 0.2, the basic data such as the length, outer diameter, wall thickness and roughness coefficient of the tube element where the gate valve is located are read and given to the corresponding declared variables, by
comparing the nominal diameter of the tube diameter to determine $\zeta$ gate resistance coefficient is calculated using the mathematical model of the resulting additional pipeline length value of the $L_S$ and return its value to the value of calculating pipeline length $L_Z=L+L_S$, stored in the database for the next call to read.

The code is attached to the corresponding gate valve handwheel. When the gate valve is dragged, the handwheel will rotate along the vertical axis of its own coordinate system and stop rotating when the mouse is released. At the same time, the length of the pipeline is changed and the value of valve opening is displayed on the operation interface, finally realizing the desired effect.

3.2. Virtual adjustment of water injection station

Operator in water injection station within the virtual 3 d space when roaming need to control components, including injection pump switches interact components mainly includes the six types: injection pump, injection pump and frequency conversion equipment knob switch control button switch lamp, voltage meter pointer, injection pump outlet pressure gauge pointer and inner indicating arrow in the direction of flow of water injection pipeline, etc.

Before completing the virtual interaction script, it is necessary to explicitly turn on the water injection pump control logic: First, in order to prevent the phenomenon of vacuuming and the pump body failure, the booster pump inlet gate valve is in a fully open state, and the vacuum gauge pointer rotates; Secondly, click the green open button of the power control box with the mouse, and the indicator light of the power control box will change from red to green (here the lubricating oil pump and cooling pump have been running before the water injection pump is turned on by default); Thirdly, when the pointer of the voltmeter rotates, the motor drives the pump shaft to rotate, and the pointer of the pressure gauge at the pump outlet rotates, the noise generated during the operation of the water injection pump is simulated, and the arrow indicating the flow direction is generated in the pipe.

Implement the above logic in C# code. And the code is given to the camera object, before and after turning on the water injection pump, some components will have the following changes and the data will be non-quantitative display, to achieve virtual interaction.

When the water injection pump is opened, click on the collecting pipeline and the pipeline is displayed in a translucent state with the collision detection technology. The operator can understand the liquid flow state in the pipeline through the direction of the arrow indicating the movement in the pipe. For the use of pump-controlled pump technology for water injection, the water injection pump outlet gate valve is in a fully open state, so it is not necessary to control it. For the water injection station without pump-controlled pump technology, the operator should adjust it with the outlet gate valve.

3.3. Virtual disassembly function of water injection pump

In the oilfield water injection system, the water injection pump unit in the water injection station is the power source of the system operation, so it is necessary to study and understand the structure and composition of the water injection pump. Through the virtual disassembly function of the water injection pump, users can disassemble the water injection pump in the virtual environment according to the actual disassembly sequence, and understand the internal structure of the water injection pump by recognizing each component. This system takes the high pressure centrifugal water injection pump as the main research object, and the display effect in the disassembly process is shown in Figure 2.
When the user does not disassemble according to the actual disassembly sequence, the system will automatically prompt which part should be disassembled in the next step to give the user timely prompt feedback.

4. Conclusion
In this paper, the virtual reality technology is applied to the field of oilfield water injection. Taking the water injection system of an oilfield in Daqing as the research object, the virtual reality simulation system of oilfield water injection is researched and developed. This system can be updated in real time according to the needs of the field, so as to improve the flexibility of the system and meet the needs of the oilfield water injection simulation optimization software as far as possible.

Acknowledgments
Sincere thanks to the fund project: the national key research and development plan project "Energy and water linkage and key technologies for efficient green utilization" (2018YFE0196000) for the strong support of this paper. In addition, I would also like to thank my friends and authors of the references for their strong support and help in the writing of the paper, which has brought me great inspiration.

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