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Virtual Reality Construction of Petrochemical Industry Safety Based on Three-dimensional Model

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This paper sets to analyze the management of transportation Safety of dangerous goods transportation by the airline companies. It adopts the preliminary hazard analysis to understand the risk factors in dangerous goods transportation for the airline companies, and selects the transportation method of dangerous goods based on the relative weights of the risk factors. The result is reached that the airline companies need to establish a hierarchical analysis approach in dangerous goods transportation with clear-cut management responsibilities. It is the conclusion of this paper that quality inspection on dangerous goods is an important direction for the constructing the transportation safety management system.

1. Introduction

Petroleum and chemical industry is an important energy industry in modern society, which brings great contributions to China’s social and economic development. Petroleum and chemical industry is mainly to deal with petroleum and petrochemical products obtained from petroleum and natural gas through relevant chemical treatment. The raw materials, intermediate products and final products of these petroleum and natural gas contain inflammable, explosive, toxic and harmful chemical components. Therefore, under the background of the continuous expansion of modern petrochemical industry scale, the number of petrochemical safety accidents has begun to increase, which has led to serious adverse effects on the country’s property and people’s safety. In view of this, the modern industry, which is based on the rapid development of modern information technology, attaches great importance to the integration of this technology into its own operational safety management. Therefore, it has become one of the hot spots in the petrochemical safety field in recent years as how to better apply the virtual reality technology to the petrochemical safety field in order to improve the safety management level and the accident emergency treatment level.

In terms of virtual reality technology of the information technology, this study analyzes the application of this technology in petrochemical safety, and proposes the integrated virtual reality platform for petrochemical safety, combining “three-dimensional data management of petrochemical industry,” “three-dimensional scene building of petrochemical safety application” and “release of petrochemical safety application”.

2. Literature review

Virtual Reality, or VR technology, also called spiritual technology, was put forward by American Lanier in 1980s of last century. In particular, virtual reality is a kind of computer to create three-dimensional space. Users can have interaction with space objects, observe the operation of some objects in the space and move freely with the will of the users, thus creating a sense of integration and participation. Yue and others believed that VR technology was the core of computer technology in modern high-tech. It was to build a real view, listen and touch a virtual environment and the necessary equipment integration, as well as a mutually influencing virtual environment, resulting in "immerse" the real environment and feeling (Yue et al., 2010). Liu and others pointed out that VR technology was a frontier technology. Virtual reality integrated computer graphics, GIS (Geographic Information System) technology, computer simulation technology, multimedia technology, artificial intelligence technology, human-computer interaction and sensor technology to simulate the sense of

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human hearing, vision and touch, so that people could immerse in the virtual environment simulated by computer. And it could interact with the machine through language, gesture and so on, giving people a feeling of being on the scene (Liu and Teng, 2014). Cui and others believed that the virtues of virtual reality technology lay in the features of computer and network technology, creating realistic 3D vision, hearing, touch, smell and perception of the world, and allowing users to browse the generated virtual objects and interact from a single angle by using natural skills and related devices (Cui and Xiong, 2014).

With the continuous maturity of virtual reality technology, its application area is gradually expanding, and has been widely applied in all walks of life. Serino and others showed that the implementation of virtual body stimulated through visual tactile could lead to changes in body and object size perception. The purpose was to explore whether virtual reality (VR) was an effective tool for modifying body memory. Studies showed that VR body exchange could cause changes in body memory. This knowledge was useful for patients with diet and weight disorders (Serino et al., 2016). Sun and so on introduced 3D virtual reality technology into visual substation. The Virtual Substation model and the whole scene of the main electrical equipment were established by using the 3DSMAX modeling software. After designing special event response routing and editing the corresponding scripting language, users could interact with virtual objects in the scene model to create feelings and experiences on the ground. Compared with the actual substation, the virtual substation had the advantages of low cost and security of interactive operation so that it was of great significance to improve the technical level of the operators (Sun et al., 2014). Riva and others studied the use of virtual reality (VR) to induce changes in body imagery and behavior of 57 women aged 18 to 45 years of obesity, overeating and other eating disorders. Clinical intervention involved 5 treatments based on VR for two weeks. Psychological tests related to body shape were completed at baseline and after treatment. Studies showed that the overall satisfaction of all patients was improved. It is concluded that short-term treatment based on VIR can be used as a traditional weight loss program as a means of improving physical satisfaction (Riva et al., 2016). Hilfert and other scholars studied the head wear device based on virtual reality, applied virtual reality technology in the construction industry and proposed that important architectural or engineering 3D models were key parts of the planning, construction and maintenance phases, especially in complex or large-scale models, which was one of the key factors that could intuitively perceive all aspects of the scene. The virtual reality's headwear device filled the gap. The head tracking mechanism transformed the motion of the user's head into a virtual camera motion and enabled it to check the model naturally. Unlike the stereoscopic representation of the projector, each individual user could achieve point tracking separately (Hilfert and König, 2016). Moglia and others studied the ability of virtual simulation to acquire clinical robot assisted surgery and the effectiveness of safe execution. The study showed an assessment of the surgical operation of a real patient: the subjects trained on a virtual simulator were better than the control group after traditional training (Moglia et al., 2016).

Americans firstly applied virtual reality technology to petroleum and petrochemical industry. In 1997, Texaco built the world's first special virtual reality center for oil and gas in Houston, which was then widely used by foreign oil companies to improve efficiency and reduce cost and risk. The system could carry out drilling and design, drilling analysis and track tracking in real time, which greatly improved the efficiency and accuracy of oil exploration, and thus greatly improved the efficiency of oil enterprises. In 1993, the Colv Virtual Reality Company in Britain developed a fire evacuation simulation system named Vegas. The system simulated the evacuation in a three-dimensional form, let the users feel the fire field like the scene, and enhance the consciousness of escape and self-rescue. CMR (Christian Michelsen Research) of Norway developed a virtual reality platform named VR Safety for Norway National Petroleum Statoil Hydro in 2008. The VR Safety platform could realize the true three-dimensional visualization of the harmful diffusion effect under different wind speed conditions, and improve the understanding of the harmful gas harm to the operators and managers. Interactive virtual reality training focused on the six steps of leakage, gas diffusion, fire start, explosion, fire disaster, and gas leakage.

Virtual reality technology has also developed rapidly in China. With the continuous improvement of petroleum and petrochemical information level, virtual reality technology has also been widely used in this field. The application of advanced technology has shown great power, and especially the application of virtual reality technology is making an unprecedented revolution in the petroleum industry. In December 2003, the virtual reality system named "Petro-One" was developed and put into use in Sinopec petroleum exploration and Development Research Institute. This system was the first set of virtual reality system in China's petrochemical industry, which brought a "wonderful hand" to China's oil exploration. In 2012, Beijing Shenzhou Anxin Technology Co., Ltd. developed the 3D digital factory system of Qingyang petrochemical company. Based on the establishment of the whole-scene 3D scene, the system constructed an emergency command system combining with GIS technology. The system realized emergency 3D visualization management under accident condition, and simulated emergency rescue and accident drills with three-dimensional interactive method.

At present, there are few researches on the security simulation of virtual reality technology in petrochemical industry. Therefore, this paper builds a three-dimensional model of petroleum chemical industry security model based on the virtual reality technology, which provides reference and help for the research on the security of the virtual reality technology in the petroleum industry.

3. Methods

3.1 Platform architecture design

The design of the petrochemical safety virtual reality platform aims for a complete set of virtual reality solutions for scientific research and training in the fields related to petrochemical safety. The platform covers the entire lifecycle of virtual reality applications in petrochemical industry such as industrial three-dimensional model management, rapid establishment of petrochemical safety-oriented virtual reality application scenarios, and web release of the final application systems.

3.2 System structure and function module

3.2.1Sub-platform of three-dimensional model library management

With reference to the national industry standard, Classification and code for Petrochemical Equipment, and in combinations with the specific characteristics of the three-dimensional model, the petrochemical three-dimensional models are stratified and classified. According to the hierarchical classification method of the petrochemical model, a petrochemical three-dimensional model database is established based on the My SQL database. Based on ASP. Net technology, a visual management platform of three-dimensional model library with B/S structure is set up to realize the management of three-dimensional model, texture and model data.

3.2.2 Visual editing sub-platform

The visual editing sub-platform mainly includes the following modules: model editing module, scene interaction and camera control module, model library access module, safety attribute management module, event triggering module, numerical simulation and special safety visual module, process flow simulation module, two or three-dimensional label/marking module, and tool module.

3.3 Design of petrochemical three-dimensional model library

The three-dimensional model library management sub-platform is composed of user’s role-based access control and permission management module, model category management module, model management module, model data management module and three-dimensional visualization module.

3.4 Three-dimensional modeling and three-dimensional model

A three-dimensional model consists of grids and textures. A grid is a model grid formed by ordered connections of point sets in a three-dimensional space. The point sets include the three-dimensional coordinates (XYZ) of the point, the laser reflection intensity, and the RGB color information, etc., which finally constitute a grid. Grids are generally composed of triangles, quadrilaterals, and simple polygons of other shapes, whose function is to simplify rendering and improve efficiency. The texture includes both the undulating folds of the surface of the object and the colors and patterns on the surface of the object, which is referred to as texture mapping. After the texture is mapped to the surface according to certain rules, the three-dimensional model will be more realistic. Figure 1 shows the comparison between the grid model and model with mapping.

Figure 1: Comparison between grid model and model with mapping

3.5 Classification and coding of petrochemical three-dimensional model

Targeting the petrochemical industry, the petrochemical three-dimensional model library classifies various types of models required by the industry in detail and builds a model library using standardized modeling. The main models of petrochemical three-dimensional model management include petrochemical device model and petrochemical equipment model. The petrochemical three-dimensional model library is divided into four levels: sub-libraries, major categories, sub-categories, and models. Each level is represented by two Arabic numerals. The encoding of the model consists of eight Arabic numerals. The specific structure can be represented by letters: AABBCCDD and their specific meanings are shown as follows. Figure 2 shows the coding of the petrochemical three-dimensional model library.
(1) Sub-library code (AA), which signifies the code of the sub-library code. The device sub-library is denoted as 01, and equipment sub-library 02.
(2) Major category code (BB), which signifies the code of the major category that the model belongs to. Since there is only one refinery unit in a major category in the device sub-library, the code for all refinery units is 01. In the device sub-library, the codes of the major categories of equipment are elaborated in the following part.
(3) Sub-category code (CC), which signifies the specific types of device or equipment that corresponds to the model. For example, in the device sub-library, the code for the delayed coke sub-category is 010106; in the equipment sub-library, the coke drum code is 020205.
(4) Model code (DD), which signifies the code of specific models. This code distinguishes different models under a unified device or equipment category.

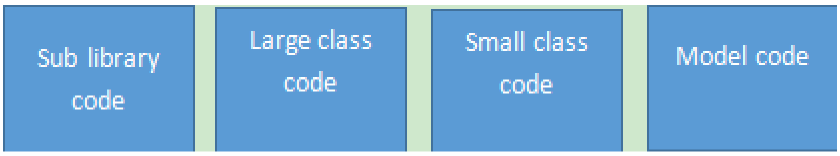

Figure 2: Coding of three dimensional model base of petrifaction

3.6 Classification and coding rules of petrochemical device models

China is one of the earliest countries in the world to discover oil and use oil, with a wide range of petroleum products and relatively complete petrochemical sectors. Thus the oil is also exported abroad while meeting domestic needs. There are 39 kinds of refinery units in China, covering the whole refining process. Table 1 lists all 39 refinery units and their corresponding sub-category code.

Table 1: List of refinery units

Small class number	Device name	Small class number	Device name
one	Fuel oil system	two	Pressing dewaxing
1	Atmospheric pressure	21	Urea dewaxing
2	Electric desalting	22	Paraffin paraffin sweating
3	Electrochemical refining	23	Refining of paraffin and white soil
4	catalytic reforming	24	Paraffin hydrogenation
5	Thermal cracking	25	Paraffin forming
6	delayed coking	26	Lubricating oil hydrogenation

4. Results and Analysis

4.1 Platform development integration and project application

Based on the above platform design and key technologies, this study develops and integrates a petrochemical safety virtual reality platform based on the VRGIS rendering engine, including sub-platform of three-dimensional model library management, visual editing sub-platform and sub-platform of petrochemical safety application

4.1.1 Platform development environment

Hardware environment:
CPU: Intel core2 E7500 or higher versions; Video card: NVIDIA Ge Force 9600 (512 MB) / AMD W9000 or above; Memory: more than 2G; Hard disk: more than 1 TB.
Software environment:

Operating system: Windows XP SP2/Windows 7 Professional; Graphical interface: supporting Open GL 2.0, Shader Model 4.0 or higher versions. Runtime library: Microsoft VS2010 Distribution Runtime Package; Database services: My SQL Version 5.6 or above; Windows components: Microsoft.NET Framework 4.0.
Other requirements:
(1) Graphic display interface restriction: For the sake of code safety and good portability, the software and hardware of the system shall support graphics drawing API of Open GL 2.0 version (or higher).
(2) Graphical hardware restriction: In order to improve the rendering efficiency, the system shall use the GPU acceleration technology, and the graphics hardware needs to support the acceleration of the Shader Model 4.0 version or higher.
(3) Restriction on operating environment and development tools: The platform shall adopt the development kit of VC++ 10.0 or higher versions based on VS2010 SP1, and the operating system shall support Windows XP (SP2) and Windows 7.

4.2 Integration of petrochemical safety virtual reality platform in VRGIS rendering engine

The petrochemical safety virtual reality platform is based on the VRGIS rendering engine, which provides the core engine layer support for the platform, including data management and three-dimensional rendering. As mentioned earlier, all of the three sub-platforms of the petrochemical safety virtual reality platform adopt a unified VRGIS rendering engine, which ensures the consistency of data and effects, and facilitates the sharing of data and the sharing of underlying modules.
The VRGIS rendering engine is based on dynamic link library (DLL) technology. DLL physically divides a huge application into separate files in a natural way and each model is highly independent, thus the upper module can dynamically call the underlying modules to facilitate the model upgrade while facilitating the sharing of models. The VRGIS rendering engine consists of a dozen DLL modules, mainly including rendering module (vg Render Engine. DLL), model management module (vg Model. DLL), GIS module (vg GIS. DLL), database management module (vg Data Base. DLL), model editing module (vg Edit. DLL), etc. The three-dimensional rendering plug-ins and editing platform applications in the petrochemical safety virtual reality platform all use the DLL files under the VRGIS rendering engine and combine their business logic to achieve the final application results. The relationship between the three sub-platforms and the VRGIS rendering engine is shown in Figure 3.

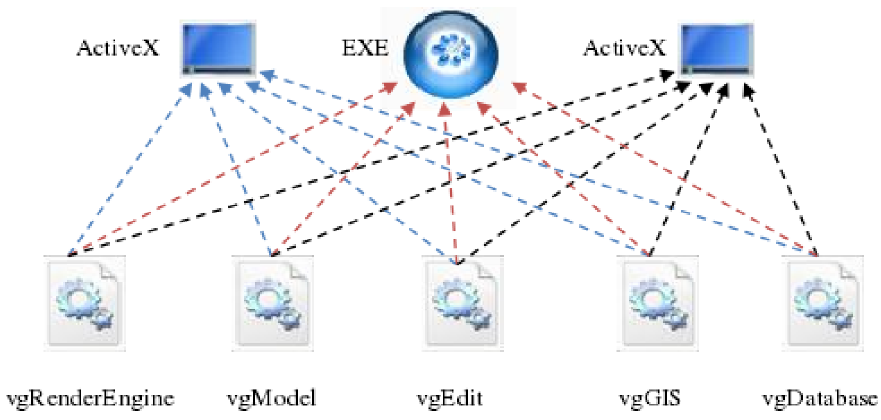

Figure 3: Relationship between the three sub-platforms and the VRGIS rendering engine

4.3 Application of the sub-platform of three-dimensional model library management

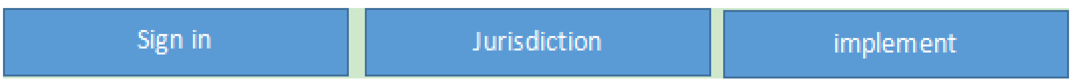

Figure 4: User role permission management page

Figure 4 shows the relevant page of user’s role-based access control and permission management of the sub-platform of three-dimensional model library management. The platform adopts the “user-role-permission” level for management, wherein super administrators can set role permissions and user roles.

Figure 5 shows the related functions of model category management. Figure A on the left is the model list page, wherein the area in the red box shows the model category tree list, through which the user can easily find the desired model based on the hierarchy and click on any node in the list. The model list area on the right shows all model thumbnails under that category. The model category uses a multi-level approach, thus users can right-click on any category node, then the menu will be popped up, and the users can add the same category or sub-categories, or delete the category.

Figure 5: Model category management

5. Conclusions

This study focuses on the application of virtual reality technology, three-dimensional visualization technology, and three-dimensional geographic information system technology in petrochemical safety management, training, scientific research and other applications. In accordance with China's modern petrochemical safety work regulations, this study establishes the petrochemical security virtual reality platform, based on which the overall architecture of the platform and the petrochemical three-dimensional model library are designed. In addition, this study also deals with key technologies such as three-dimensional control development under Active X technology, three-dimensional visualization special for petrochemical safety, safety attribute management design and implementation, and finally introduces the development and integration methods of the platform and demonstrates its application effects. The detailed content is shown as follows.

In this study, firstly, the platform architecture is designed. Then according to the principles of separation of data, engines, and services, the overall platform architecture is designed and built, so that the platform can be ultimately established. Moreover, the platform is divided into data layer, core engine layer, application layer, and presentation layer. Finally, this study introduces the functions of each level of various platforms and establishes a complete petrochemical industrial safety virtual platform.

Reference

Cui H.J., Xiong W.Y., 2014, The Research of 3D Modeling Technology Application in Virtual Reality, Applied Mechanics & Materials, 644-650, 2311-2314, DOI: 10.4028/www.scientific.net/AMM.644-650.2311

Hilfert T., König M., 2016, Low-cost virtual reality environment for engineering and construction, Visualization in Engineering, 4(1), 2, DOI: 10.22260/ISARC2015/0020

Liu H.X., Teng Z.H., 2014, The Exhibition Design and Implementation Based on Virtual Reality Technology, Advanced Materials Research, 998-999, 1270-1273, DOI: 10.4028/www.scientific.net/AMR.998-999.1270

Moglia A., Ferrari V., Morelli L., Ferrari M., Mosca F., Cuschieri A., 2016, A Systematic Review of Virtual Reality Simulators for Robot-assisted Surgery, European Urology, 69(6), 1065-1080, DOI: 10.1016/j.eururo.2015.09.021

Riva G., Bacchetta M., Baruffi M., Cirillo G., Molinari E., 2016, Virtual reality environment for body image modification: A multidimensional therapy for the treatment of body image in obesity and related pathologies, Cyberpsychology & Behavior, 3(3), 421-431, DOI: 10.1089/10949310050078887

Serino S., Pedroli E., Keizer A., Triberti S., Dakanalis A., Pallavicini F., Chirico A., Riva G., 2016, Virtual Reality Body Swapping: A Tool for Modifying the Allocentric Memory of the Body, Cyberpsychol Behav Soc Netw, 19(2), 127-133, DOI: 10.1089/cyber.2015.0229

Sun F.J., Chen H., Liu H.J., 2014, Research of Visualized 3d Substation Simulation Based on Virtual Reality Technology, Applied Mechanics & Materials, 568-570, 1834-1838, DOI: 10.4028/www.scientific.net/AMM.568-570.1834

Yue X.J., Hong T.S., Xu X, Wu W.B., 2010, Study on 3D Virtual Reality Modeling, Advanced Materials Research, 129-131, 1296-1300, DOI: 10.4028/www.scientific.net/AMR.129-131.1296