Design and Implementation of Petrochemical 3D Model Database Platform

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Abstract. In order to meet the demands of petrochemical engineering enterprises for 3D digitalization management of production equipment, and realize rapid building of accident site environment, a set of 3D model database platform facing petrochemical engineering industry is designed and developed aiming at characteristics of standard, regular and repeated model of petrochemical engineering. The 3D model platform is comprised of 3D model data sub-module, interactive editing sub-module, and 3D product application sub-module. It realizes multi-dimensional and integrated information management, and effectively serves equipment management, accident emergency and employee training. With expansion of petrochemical engineering production scale, strengthening of safety requirements, ceaseless improvement of technical grade and gradual increase and complexity of production equipment and facilities, it is necessary to establish a digitalization management system for production facilities and equipment in the petrochemical engineering industry to meet demands of petrochemical enterprises for 3D digitalization management, further dig potentials of petrochemical enterprises in production and management, improve automatic information level, and make information development better serve safety production and accident emergency.

1. Construction target

The continuously developing communication transmission technology, 3D simulation technology, virtual reality technology and GIS technology provide theoretical support for 3D modeling as well as processing, display and editing of 3D models. 3D model becomes the fourth multimedia data type next to images, sound and video, and makes the building of 3D model database possible\textsuperscript{[1-3]}. The 3D model database platform could highly integrate model data, attribute data and application system in each specialty of petrochemical engineering industry, realize visualization and multidimensional expression \textsuperscript{[4, 5]}, and store, sort out and update the data by classifications. The computer virtual simulation technology is used to apply modernized management to facilities in the plant zone, and provide data and platform support for equipment management, accident emergency and employee training\textsuperscript{[6]}. 

2. Overall design

This paper analyzes characteristics of petrochemical engineering model such as standardization regularity and repetition. Based on characteristics of petrochemical model, it classifies various
modules required in details in accordance with SH2202-91 Classification and Code of Petrochemical Equipment, and builds petrochemical 3D model database pursuant to regular modeling method.

The 3D model database platform is divided to three sub-platforms including 3D model data sub-platform, interactive editing sub-platform, and 3D product application sub-platform; in terms of framework design, the platform framework is divided to five layers in accordance with the principle of data, engine and business separation: pre-processing layer, data layer, control layer, render layer and product application layer. The five-layer design keeps integrity and compatibility of three sub-platforms, which share uniform data standard and render engine bottom layer. According to different business demands, user interactive layer and application layer show certain difference.

2. 1 Pre-processing layer
Before the data is stored to database for management, it is necessary to pre-process and classify various types of data [7]. The data is pre-processed to the form that the system supports, and then classified to 3D model data, vector data, landform data, texture data and animation data, etc. [8-10]. The data classification could make data management of model database system more efficient and convenient, and lay foundation for efficient system operation.

2. 2 Data layer
After preprocessing and classification, the data shall be saved in database. The model database uses relational data base management system to apply stable data management, and two independent databases are built respectively, i.e., basic database and attribute database[11,12].

2. 3 Control layer
The control layer is used to display visually the model data in database, and provide a visualized user interface to interact with data in the database layer so as to reach the unified data and visualized system. The control layer contains trigger control, render configuration, interface configuration, script control and camera interaction.

2. 4 Render layer
After the control layer extracted and configured data in the database, the model data will enter the render layer for visualized rendering. According to different data types, the render could be divided to entity render, vector render, GPU texture special effect render [13] and animation render.

Fig.1 Logic structure diagram
2. 5 Product application layer

According to software function division and different applications, the software system is designed to: two software of editing management platform, database and application platform. The latter adopts B/S network structure to realize internal database operation and 3D platform application.

3. Functions and realization

According to functional demands and overall design, the data sub-module, interactive editing sub-module, and 3D product application sub-module share unified engine and data, and they could either interconnect with each other or operate independently. The functional structure diagram can be seen in Fig.2.

3. 1 Data sub-module of 3D model

3. 1. 1 Data format

The model database supports storage format of max, dgn, obj; skeletal animation format of fbx/ms3d, and spatial data such as shape and DEM.

3. 1. 2 Hierarchical structure of module database

Referring to model classification, the model database adopts five-layer hierarchical structure of general database, sub-database, general sub-database, sub-general database and physical model. The first three layers are of detailed structure, which could not be revised by users; the latter two may be revised and added by users. Fig.3 shows the hierarchical structure of model database. The equipment sub-database in the structure belongs to “equipment appearance model” stated in “Model Classification”. The division of equipment sub-database and general and sub-database shall subject to industrial standard SH2202-91 Classification and Code of Petrochemical Equipment \(^{[19,20]}\).
The model database contains seven sub-databases. The relationship between sub-databases can be seen in Fig.4.

The parts in parts sub-database and pipeline in pipeline sub-database are assembled; by sticking to texture in the texture sub-database, a complete equipment model with internal structure is assembled. Then, the complete equipment model is deep-processed, or made to teaching video (animation) for structure analysis and principle display, or installed to application system of certain equipment with the same type of complete equipment.

The equipment in equipment (appearance) sub-database and pipeline in pipeline sub-database are assembled; by sticking to texture in the texture sub-database, a complete facility with relevant structure is assembled. The complete facility could be stored in equipment sub-database as facility model, or used to establish a virtual scene with environmental elements together with landform objects.
of landform sub-database; then, it will be used to set up 3D scene in theme application with the themed models (fire, leakage) in HSE special sub-database, and at last establish the application system with certain function.

3. 1. 3 Model classification

According to purposes, the models contain basic model, appearance model and application model, as shown in Fig.5.

![Fig.5 Pyramid structure diagram of model classification](image)

The basic model contains spare parts, pipeline and texture. This type of model reaches certain use purpose by mutual combination, and is the most fundamental unit in the model database;

The appearance model contains equipment appearance model and landform model, and is used to express environmental and positional information of the model;

The application model contains facility model, equipment complete model and HSE special model [14]. This type of model belongs to the highest level model, and can be used to realize specific application function.

1) The facility model is a large-scale complete equipment model comprised of equipment appearance model, landform features model, pipeline model and texture model;

2) The equipment complete model is a complete equipment model with both appearance features and internal structures comprised of spare parts model, equipment appearance model, pipeline model and texture model;

3) HSE special model is the core of the model database; except the attribute of geometric model, the facility and equipment shall link with HSE attribute of petrochemical engineering industry, and realize 3D visualized expression of attribute. HSE special model centers at accident simulation, and contains fire model [15], leakage model and explosion model. By setting influence factors such as weather conditions and land features, it simulates accident and analyzes influence scope, occurrence and development of accident. The generation process of special model can be seen in Fig.6. ① Analyze relevant mathematical model, including: pool fire model, jet fire model, spark model, BLEVE fire ball model, vapor cloud explosion model, condensed phase explosion model, physical explosion model, Gaussian plume model, and Gaussian puff model [16-18]. ② Model encapsulation (Fig.7): use VS program to realize model encapsulation: GetChihuo; GetShanhuo; GetBLEVE; GetPenshehuo: external calling function of thermal radiation model; GetVCE;GetCPE;GetPhysicalExplosion: external calling function of explosion model; GetVCE; GetCPE; GetPhysicalExplosion: external calling function of Gaussian model; other functions: external calling function of model influence thresholds; ③ Render visualization, warehousing and real-time loading/unloading: import the accident model encapsulated in VS 2012 into Unity 3D, and edit other scripts in U3D to support program operation,
including data initialization and panel support. The effect of visualization can be seen in Fig. 8.

Fig. 8: 3D visualization effect of special model
3. 2. Interactive editing sub-module

3. 2. 1 Functional structure

Interactive editing sub-module is designed according to C/S, and used in collaborative management of module database and collaborative development of application projects, including document management, layer management, model editing, project design, model database retrieval, programming interface, database configuration, network collaborative configuration, and system configuration. The functional structure can be seen in Fig.9.

![Functional structure diagram of visualized collaboration platform](image)

Fig. 9 Functional structure diagram of interactive editing sub-module

3. 2. 2 Work process

The platform work process comprises two main lines, respectively model and model database process, and project design process, as shown in Fig.10. After inputting the 3D model established by 3Dmax into the platform, the editing module will process the model, and the standard inspection module will provide standard inspection. The conforming model may be exported as one part of the module database. Attribute information regarding the model shall be set by model editing module and attribute database communication.

When opening or newly building a project on the platform, the project configuration module will finish configuration of various parameters, and the project design module will call the model database and attribute database so as to gradually finish equipment or facility assembly and combination before final release.

![Work flow chart of interactive editing sub-module](image)

Fig. 10 Work flow chart of interactive editing sub-module
3. 3D product application sub-module

3D application sub-platform is used by final users to upload, browse, operate and manage specific application (product) developed by the interactive editing platform, including network platform and offline platform.

The 3D product platform (network edition) is used to upload, browse, operate and manage the network application project released on the collaborative work platform. The startup process is: to input project IP address to IE browser, and input username and password to enter main interface and operate various functions.

The 3D product platform (offline edition) is used to upload, browse, operate and manage the online application project released on the collaborative work platform. The startup process is: click executable application document (exe), input project IP address to IE browser, and input username and password to enter main interface and operate various functions.

4. Conclusion

Facing the petrochemical engineering industry, this paper classifies in details various models required by the industry, and develops a set of 3D model database by full use of virtual reality, 3D simulation and other advanced technologies. It provides nearly one thousand special equipment and disaster simulation models. The 3D model database stores and manages various equipment data resources in order. It can realize rapid building of application scenes for petrochemical industry, rapid building and reuse of equipment modules, and 3D visualized expression of accident simulation result, and could be extensively applied to equipment digital management, accident emergency disposal and employee operation and training.

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