Discussion on 3D Visualization Model of Geological structure

Bi Ming-li\textsuperscript{a}, Xue Xiao-gang\textsuperscript{b}, Li Cai-hong\textsuperscript{c}, Chen Guo-qiang\textsuperscript{d}

School of Exploration and Maping, Changchun Institute of Technology, Changchun 130021, China

\textsuperscript{a}biminglich@126.com, \textsuperscript{b}xuexiaogang@126.com, \textsuperscript{c}licaihong@126.com, \textsuperscript{d}chenguqi@126.com

Abstract. This is the basis of the formation of the whole 3D geological model. The geological structure surface model subsystem is mainly based on the geological structure surface data provided by the borehole and the virtual borehole. The Delaunay triangulation algorithm is used to construct the TIN model to fit the geometric structural surfaces of various geological objects, such as stratigraphic interface and fault plane. 3D visualization modeling of geological structure is a complex problem, which needs to be explored continuously. The research and application show that the idea of 3D geological modeling based on GOCAD breaks through the limitation of two-dimensional representation of complex terrain surface and underground structure. A more intuitionistic and accurate 3D geological model is provided, which meets the practical requirements and is gradually popularized in application.

1. Introduction

In the 40s, the 3D geological modeling technology was put forward by foreign scholars. In foreign countries, geological modeling has been developed for decades, and China has been developing for nearly 20 years since the introduction of the EsrthVision in the 20s.

In the last 10 years, geosciences have been understood as Geography, Geology, geophysical Geophysics and geodetic Geodesy, etc., because of the increasing research on three-dimensional spatial information. Two tributaries of parallel development have been formed: one is 3D GIS and the other is 3D Geosciences Modeling system 3D GMS. True 3D geoscience simulation, unified representation of ground and underground space, unified modeling of land and ocean, and 3D topological description. Three-dimensional spatial analysis and three-dimensional dynamic process simulation have become the crosscutting technology and hot spot of geoscience and information science.

The fault is a geological structure, generally the main part in the sight of the ground, is a very good guide for prospecting, if you find a fault data model, and can achieve good modeling of stratum model and fault model, two kinds of objects a good expression of the relationship between. For spatial query, topological relations, geometric features, attributes can be visualized with good expression, it is a good help for geological exploration. We used our model of fault data are: the fault is considered as the stratigraphic boundary, constructing fault model; construction of fault model by V section method the use of profile data; contour reconstruction method based on the fault plane construction; construction of small fault plane by the fault and dip fault model constructed by many fault plane; plane frame model based on line; based on body, surface, ring, edge And the fault data nodes in the model. The performance of three-dimensional visualization function of all these fault models only focus on the model, the model of spatial query, spatial calculation, spatial analysis function of geological prospecting are missing, to achieve a fault data model can solve the above problems.
With the application and development of seismic exploration, lateral prediction of oil and gas reservoir, and the application and development of reservoir description technology, the requirements for seismic results are becoming higher and higher, facing the increasingly complex and subtle reservoirs, in order to improve the success rate of drilling. It is necessary for oil and gas exploration workers to provide a new 3D geological structure shape, geological structure shape and attribute characteristics. The 3D visualization technology of seismic exploration is to meet the needs of oil and gas exploration, development and development. Some special processing techniques resulting from the need of spherical physics technology, and provide information for accurate three-dimensional oil-gas reservoir description, At the same time, promote the exploration and development of oil and gas fields.

The 3D visualization technique of seismic exploration is to describe various complicated geological models and 3D seismic data, and to show them in three-dimensional space. It not only enables geologists to understand the occurrence of various geological phenomena more deeply. Develop and influence, and enrich their imaginations, allowing them to soar in geological structures and three-dimensional seismic data, which will improve the accuracy and success rate of seismic exploration and drilling, and at the same time, It is also an important technical basis of seismic imaging processing and plays a vital role in oil exploration and development [1].

3D geological modeling (3D Geological modeling) is also called 3D Geoscience modeling (3D Geoscience modeling). The process of 3D geological modeling is generally summarized: 3D geological modeling is based on the original geological exploration data. Under the guidance of the expert knowledge and experience of the geological engineer, after a series of interpretation and modification, the mathematical model of geological characteristics is established with appropriate data structure. Computer simulation of topological information (relationship between geological objects) and physical properties. The process of forming a complex global 3D model by synthesizing all kinds of information of these objects.

The geological phenomena in the real world are depicted as 3D models by using computer technology, and the characteristics of underground geological phenomena are reproduced intuitively, supplemented by powerful interactivity. Liberating geoscientists from vast amounts of abstract data and the lack of intuitive two-dimensional graphics, The efficiency of geoscience analysis and research has been greatly improved. Hydrogeology, which takes groundwater as the object of study, is an important branch of geoscience. Three-dimensional visualization technology can restore the occurrence state and spatial distribution of groundwater resources. Simulating the temporal and spatial variation of groundwater can assist in hydrogeological investigation and research, and it is of great significance for the rational development and utilization of groundwater resources.

In the past decade or so, the rapid development of China's economy has greatly led to the development of civil engineering fields. The number, scale and speed of large-scale engineering activities have attracted worldwide attention, such as the South-to-North Water transfer Project, the Qinghai-Tibet Railway, and the three Gorges Project. West to East Gas Transmission, Longtan Hydropower Project, Xiaowan Hydropower Project, Jinping Hydropower Project, etc. Most of these giant projects are located in areas with complex geological structures, numerous geological information, selection of project sites, layout of hubs, design and construction of underground projects, etc. The solution of these problems must be based on the comprehensive analysis and grasp of the geological information.

2. 3D geological modeling method
Since 1980s, the application of 3D geoscience visualization systems to geological modeling has become very common abroad, to the United States, France, Canada, Australia, The main western countries represented by the United Kingdom have successively introduced a variety of representative geoscience visualization modeling software, GoCAD developed by Earth Decision Sciences EDS is a new generation geological modeling software with the core of workflow, which has reached the highest level of semi-intelligent modeling. It has the characteristics of strong function, friendly interface, and can run on almost all hardware [2].
Since the birth of GoCAD in 1990, geological modeling technology has made rapid development, and now has been developed to version 2.1.6. With the development of complex structure modeling, complex three-dimensional model mesh generation, reservoir rock physical attribute model, lithofacies model and so on, it can be said that the advanced geological modeling software, represented by Gocad, has greatly improved the efficiency and accuracy of geological modeling. It can meet the modeling requirements of complex geological regions.

In the borehole data, we can find the names of the strata in the depth range, the topological relationship between the strata and faults, the thickness of each formation, and the coordinates of the points set of the upper and lower interfaces. The characteristics of lithology at various thickness points and other relevant information. The generalized triangular prism can reflect the possible skew in the course of drilling construction, so it can well describe the characteristics of the boreholes. The upper and lower triangular surfaces of the generalized triangular prisms are used to represent the upper and lower layers of the strata. The side represents the relationship between the strata, and the volume represents the entity of the geological body. It is good to build fault models through borehole data, but generally there are very few boreholes falling on the fault, so that very few data are used to describe the fault. In order to express the fault model accurately, we use the existing data resources of strata and faults and use the spatial interpolation method to virtual borehole data, which can be used as the data of fault modeling, which can increase the precision of fault modeling.

![Figure 1](image)

Figure 1. The side represents the relationship between the strata, and the volume represents the entity of the geological body

The traditional two dimensional information expression mode is transformed into two dimensional and three dimensional expression, which is complementary to each other. According to the different professional data, the corresponding three dimensional spatial model is established to provide the 3D display of the model. The inquiry and analysis can provide information support for understanding the three-dimensional geological structure, geological structure and activity of the city, and provide auxiliary decision for the underground safety management of the city.

Hydrogeology is a subject that takes groundwater as its research object. It mainly studies the distribution, movement and formation of groundwater, the physical properties and chemical composition of groundwater, the evaluation, exploitation and rational utilization of groundwater resources. The adverse effect of groundwater on engineering construction and mining and its prevention and treatment.

Groundwater is water that exists in cracks in crustal rocks or in soil voids. Unlike rock masses, groundwater has the characteristics of space-time variation, from spatial flow transfer, to solute migration in water, heat transfer, and then pollution diffusion.

The state of groundwater resources is constantly changing, and the surrounding stratigraphic environment is also changing due to the constant changes of groundwater. While paying attention to the spatial distribution characteristics of groundwater resources, hydrogeological research works are
concerned about the spatial distribution of groundwater resources. More attention is paid to the changing characteristics of groundwater. Groundwater storage conditions are affected by the surrounding stratigraphic environment, and the existence of groundwater will also have an impact on the surrounding stratigraphic environment. At the same time, groundwater is also polluted by the environment. Geological hazards and other problems affecting the survival of human beings are closely related, and hydrogeological research is of great significance to production and life.

![Figure 2. The state of groundwater resources is constantly changing](image)

With the development of human economy and the progress of human civilization, the rational development and utilization of urban underground space has become an increasingly important issue in all countries and regions of the world. Europe, America, Japan and other countries and regions have been in this field earlier. During the past half century, with the development of economy and urban demand, China has made rapid progress in this field.

Compared with the scale of urban underground space development in full swing, the information construction of urban underground space is relatively lagging behind at present. The lack of systematic information materials often results in the destruction of the geological environment of the city, causing geological disasters and the destruction of underground pipelines [3].

All of these have put forward new and higher requirements for the construction of urban underground space informatization, which has become an important part of the effective use of underground space to solve the modern "urban disease". Means. On the other hand, With the rapid development of information technology and the popularity of the Internet, the demand for underground spatial information sharing is increasingly high. Through sharing, it has become a consensus to excavate the value of underground spatial information to the maximum extent. The expression of urban underground spatial information is a key link to realize the sharing of urban underground spatial information.

In the virtual three-dimensional geological environment, the display of geological bodies can be more intuitive, clear and accurate, which is more helpful for geologists to deeply understand and analyze the formation, evolution and development of geological bodies in engineering areas. It is instructive and helpful to further reveal the geometry of hidden geological structure, judge the law of fault movement, clarify the contact relation of strata, and study the law of geoscience in depth. In particular, the 3D geological model can also improve the spatial imagination of geologists, and it will be more intuitive and reasonable for designers to understand the geological spatial relationship.

GOCAD software has powerful functions of 3D modeling, visualization, geological interpretation and analysis. It can be used for surface modeling and entity modeling, as well as for the design of spatial geometric objects and the representation of spatial attribute distribution. The spatial analysis function of the software is powerful and the information expression mode is flexible and diverse. Therefore, the introduction of GOCAD into the three-dimensional modeling of hydropower engineering geology is in line with the actual hydropower engineering.

3. Present situation and trend of 3D Visualization Technology
From the beginning of the end of 80s, the seismic exploration of three-dimensional visualization technology has been rapid development. Through the research and development of more than ten years, there have been a number of visualization software. There are relatively well-known foreign Landmark, EarthCube and OpenVision, GeoQuest’s GeoViz and DGI’s EarthVision, which basically represents the
highest level of 3D seismic exploration the application of visualization. These packages can be 2D seismic, 3D seismic, logging curve, geological stratification, well trajectory, network level, three-dimensional display complete fault plane, the user can use the mouse to control the rotation angle to observe the geological target, intuitive and convenient.

In the domestic oil companies, geophysical company, seismic software commonly used computing center and other units are mostly imported from abroad, and to explain the system of Landmark company and GeoQuest company in the majority. These interpretation system has better visual function, the 3D visualization of the complexity in the country has seen good with independent intellectual property rights of the seismic exploration of 3D visualization system.

The research on 3D geoscience visualization in China started late, but it has also made a lot of beneficial exploration. In recent years, the National Natural Science Foundation of China has made great efforts to support the research of geoscience visualization. "3D modeling and graphic display of complex geological bodies", "Geophysical theory of oil storage and mapping method of 3D geological images", "dynamic modeling and visualization of geoscientific space-time information" [4]. Professor Zhong Denghua of University [5] used the NURBS surface modeling technique to fit the complicated geological surface.

A water conservancy and hydropower engineering geological modeling and analysis system is developed and applied to Longtan, Jinping and Xiluodu. In the 3D modeling and analysis of large water conservancy and hydropower geological engineering and cavern, such as Baihetan, the 3D geological system of hydropower project GeoEngine 2006 is the combination of Huadong Survey and Design Research Institute of China Hydropower Consulting Group and Geoscience of China University of Geosciences.

Information Institute and Wuhan Dakundi Science and Technology Co., Ltd. based on independent intellectual property rights based on the GeoView3D platform to complete the development of professional geological modeling software. In 1996, the Institute of Geophysics of the Chinese Academy of Sciences and the Shengli Oilfield Administration Bureau were in the National Natural Science Foundation's key project "complex Geomorphology". Began tracking GoCAD. Changchun University of Science and Technology developed the GeoTrans GIS 3D GIS software system on Titan GIS, a Apollo company. RDS developed by Petroleum University and SLGRAPH developed jointly by Nanjing University and Shengli Oilfield are all used to visualize 3D petroleum exploration data.

The developed 3D visualization geological information system (GeoView) can realize the management of true 3D geoscience information [6]. Calculation, analysis and evaluation decision support. During the "eighth Five-Year Plan" period, China developed and developed three-dimensional geological modeling software for reservoirs, but there is a big gap compared with the similar software abroad. Seismic software commonly used by geophysical companies and other companies are imported from abroad and are mostly interpreted by LandMark and GeoQuest companies.

Figure 3. The data source of 3D fault modeling is generally from geological observation point set

The data source of 3D fault modeling is generally from geological observation point set, borehole point set, section point set, plane point set [7]. The location of the observation point, the strike of the fault plane, the tendency, the dip angle, the distance between the fault sections, the nature of the fault, the
characteristics of the fault plane, and when the state of the fault plane does not change much, use one point to solve the problem, if it is very complex. It is necessary to collect the data at the key points.

The geological characteristics of the deep underground are usually derived from the borehole data according to the geostatistical method. The borehole data include the hole orifice coordinates, the depth of the fault, the borehole inclination, and so on. The missing or duplicated thickness of the bottom layer. From the borehole data, the nature of the fault, the fault spacing, the variation of the fault, etc can be determined.

The set of section points is the data collected from the geological profile of a particular location and direction obtained from drilling or seismic exploration. A fault usually appears in a straight line or curve shape on a profile. A set of parallel or nearly parallel sections can describe the spatial position and spatial morphological characteristics of the fault.

A set of planar points is a set of points on the intersection line between the fault plane and the upper and lower surface of the strata of different depths. These intersecting lines reflect the spatial shape and extension of the fault. These four sets of data points represent indirectly the structural characteristics or spatial patterns of the fault, and to build a fault model, they are based on these data sets. The suitable data model is found, the corresponding mathematical transformation and discretization operation are carried out, the data set of hybrid fault model is constructed, and the model is constructed.

Three-dimensional modeling of groundwater is the basis and research focus of three-dimensional visualization of hydrogeology. The current research work mainly includes two aspects: entity modeling of groundwater resources and three-dimensional modeling of various temporal and spatial characteristics of groundwater.

The entity modeling of groundwater resources is based on hydrogeological survey data, profile map, borehole data, hydrogeological map and GIS data, including aquifer modeling, regional hydrogeological modeling, groundwater storage environment modeling, etc. It is used to depict the distribution and occurrence characteristics of groundwater resources and to realize the visualization of data. The modeling of temporal and spatial variation characteristics of groundwater is based on hydrogeological survey data, dynamic monitoring data, numerical simulation results and expert analysis data. Spatial and temporal models of groundwater flow field, transport and pollution diffusion are established, and visualized simulation and analysis are realized.

At present, hydrogeological 3D visualization is mainly carried out in the existing groundwater numerical simulation and visualization software environment, modeling and 3D visualization application. Especially the 3D modeling of regional hydrogeology based on GIS data is the current hydrogeology in China.

The degree of 3D visualization of hydrogeology in China is far from that of 3D visualization of deposit rock mass. At present, it focuses on 3D modeling of water body, numerical simulation of groundwater and regional author: application of groundwater resources distribution modeling.

Researcher Zhang Yongbo of the Institute of Hydrogeology and Environmental Geology of the Chinese Academy of Geological Sciences has carried out extensive and in-depth research and published related monographs on three-dimensional modeling methods of hydrogeology, and has proposed a method for three-dimensional modeling of groundwater systems. Professor Wu Qiang of China University of Mining and Technology has carried out a series of research work on numerical simulation and visualization of groundwater, and put forward a method of visualization dynamic simulation of groundwater seepage field

The study of 3D geological modeling mainly reflects the shape and distribution of geological structure, while urban 3D geological modeling not only reflects the underground structure, but also shows a large number of buildings on the surface.

Landscape environment and public facilities, the establishment of a unified above ground and underground three-dimensional environment, so that the staff in a realistic urban geological environment engaged in various planning and design. Research activities such as resource management have changed the traditional geological research methods. However, because of the data model used in the above ground and underground models, the data structure is different.
The problem of spatial scale accuracy is different, resulting in the unified representation of surface and underground space is still a scientific and technological problem in the field of three-dimensional geoscience simulation. Virtual reality technology is a visual operation and interaction of complex data. The introduction of this method provides powerful technical support for solving this problem. Using the real-time 3D simulation modeling tool MultiGen Creator to build the surface scene model, and build the surface scene model based on its OpenFlight API and multi-layer TIN modeling method. The stratigraphic model realizes the unification of the two data structures and completes the integration of the surface and underground models.

Because the geological structure is dominated by stratified strata, the stratigraphic model is used to represent the 3D simulation of the geological structure of underground space. Borehole core data obtained by qualitative drilling is the main data source for 3D geological modeling [3], which includes lithology. Fault features, Soil quality and other characteristic data, therefore, the borehole data combined with other geological data to establish stratigraphic model. First, study regional geological data, extract information to establish geological information database, mainly including strata and exploration drilling. Information; then model the model according.

4. Discussion on 3D Visualization Model of Geological structure
In the past decade, many experts and scholars have done a lot of beneficial exploration of 3D spatial information in the field of Geosciences (GEO Geography, geological Geology, geophysics Geophysics and geodetic Geodesy) and formed two major combinations.

For the development of the tributaries of the three-dimensional geographic information system 3DGIS; the 3D Geosciences Modeling System (3DGeosciences Modeling System, 3DGMS). The two major tributaries of the 3D spatial modeling methods as the core research content, put forward 20 kinds of spatial modeling methods, Wu Lixin, history of the divided into three categories: Modeling system: Based on surface model (Facial Model); based on the model (Volumetric Model); the hybrid model based on (Mixed, Model) are shown in table 2-1.

It can be seen that the modeling method is the fundamental difference between the 3 dimensional data model, that is to say the 3D model directly determines the 3D spatial modeling methods. From the third chapter of the analysis, the boundary representation is still the mainstream 3d modeling technology, can have the explicit expression of the target body, side. Surface geometric elements, the drawing BRep said form faster and easier to determine relationship between geometry elements, these characteristics have important significance for the engineering geological information visualization, but also conducive to the meshing program to establish numerical calculation model [7].

In addition, although the boundary expression method is not conducive to the spatial analysis, but the actual demand from the point of view, an important goal of 3D engineering geological modeling has three: one is to achieve the geological data for geological information visible, and the two-dimensional GIS source early in the management of computer graphics, the use of computer technology to 3D geological information visualization another is to use; the database technique to realize the storage and management of spatial information and attribute information; in addition, the element directly used in numerical calculation. These requirements, using the boundary expression method combined with 3D data structure good can be fully realized, and the need for 3D spatial analysis places, can be devoted to the study of data support the structure and spatial analysis algorithm for rapid analysis.

The 3D modeling of fault model is a kind of structure which is difficult in all geological structure modeling. We use special 3D processing visualization technology. We use tin surface method to solve the modeling of 3D fault model. First of all, the simple single fault is solved.

The existence of fault leads to the dislocation of geological body, that is, the discontinuity of mark surface. The fault plane is regarded as a space geometric surface with zero thickness. The tin surface of the fault plane and the related marker surface can be established separately. Here, the key technique is to deal with the shape of the discontinuous mark surface on both sides of the fault. In this paper, two methods, "local method" and "integral method", are used to treat the mark surfaces on both sides of the fault separately.
The existence of fault leads to the dislocation of geological body. The integral method refers to the unified treatment of the corresponding mark surfaces on both sides of the fault. It is divided into two situations according to whether there is a tangential fault relationship between multiple faults. One is that there is no tangential fault relationship between faults, which can be treated separately by local method or integral method, and the other is that there is a cutting relationship between faults. The relationship between the faults has a time series. The tin plane of the most advanced fault and the whole tin plane of the secondary fault are made first, and then the edge line of the tin plane of the cutting fault on both sides of the most advanced fault is calculated and adjusted. This method is applied to the process until the edge line of the tin surface on each side of the fault is made.

Because of the discontinuity, inhomogeneity and uncertainty of the spatial distribution of rock and soil media, the intersecting erosion between strata and the complicated relationship between geological entities, in 3D stratigraphic information system, how to divide stratigraphy is a key problem in 3D stratigraphic modeling. In 3D geological modeling, we assume that natural strata have the same spatial stratigraphic distribution as sedimentary strata, but, The concept of stratigraphic sequence relation in geological modeling is different from that in geology.

The stratigraphic sequence relation in geology is divided according to the sequence of stratigraphic formation time, but in 3D geological modeling, The stratigraphic sequence is divided according to the upper and lower relationships of the strata recorded on the borehole (based on lithology). When the local layer is not reversed, the two are the same; when the inversion occurs, On the contrary, the stratigraphic division should be based on the theory of appropriate geological interpretation methods. Up to now, no breakthrough has been made in this field at home and abroad, usually by experienced geological engineers based on borehole data. Combining logging data with seismic data, the spatial distribution of formation is determined by artificial interpretation and inference, and most of the work is done on two-dimensional plane map.

5. Summary
The 3D visualization is an interpretation tool, but also a result expression tool. And the traditional interpretation method completely different, 3D interpretation is the routine of each layer through each one on seismic profile, each fault after pick up to complete through the combination of three-dimensional space. The three-dimensional visual interpretation is a direct interpretation of strata structure in three-dimensional space based on seismic reflectance data from the underground interface body transparency in the use of various parameters, lithology and sedimentary characteristics. The three-dimensional scanning and tracking technology can make the personnel quickly selected targets, combined with fine calibration of drilling, can help explain the geological phenomenon of personnel quickly and accurately describe the complex.

The 3D visualization is based on the attribute data transparency of the underground interface is assumed the reflectivity of underground interface of the original, real 3D model, in essence, it is the structure in the three-dimensional space, formation and amplitude attribute synthetic composition. Whether it is to do three-dimensional regional analysis, or specific foreground evaluation (including the fluid interface identification) are available through this, "see" a way to quickly complete. Based on the
three-dimensional visualization of three-dimensional pixels, each data point is converted into a three-dimensional pixel (voxel size approximate surface element spacing and sampling interval). Each pixel has a three-dimensional numerical corresponding to the original the 3D data matrix, a three color (red, green, blue) values and a dark variable, the variable is used to adjust the data transparency. In this way, each seismic trace is converted into a three-dimensional pixel column.

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