CONSTRUCTION AND APPLICATION OF THE GEOTECHNICAL AND GEOLOGICAL SPATIOTEMPORAL BIG DATA PLATFORM IN XIONGAN NEW AREA

Zhang X. [1] , Gong X. [2] *, Du Y. N. [2] , Dong T. [3] , Wang Q. [4] , Li B. B. [2] , Yan X.R. [2]

[1] Planning Research Center of Xiongan New Area, Xiongan New Area, Hebei, China, zhangxi-bj@163.com
[2] Xiongan Urban Planning and Design Institute Co., Ltd., Xiongan New Area, Hebei, China, gx941008@126.com, 1158447097@qq.com, 948718763@qq.com, 2304060725@qq.com
[3] The Bureau of Natural Resources and Planning Bureau, Xiongan New Area, Hebei, China, 358239585@qq.com
[4] Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences, Shijiazhuang, China, wangqian452@126.com

KEY WORDS: Xiongan New Area, Geotechnical and geological information, Geological spatiotemporal Big data, Sharing service, Integrated management, Underground digital base

ABSTRACT:

As an important foundation for the construction of smart cities, spatiotemporal Big data plays a significant role in promoting intelligent urban management and enhancing urban governance capabilities, among which geotechnical and geological data is an indispensable component. Currently, with the implementation of geological investigation and underground space development in Xiongan New Area, a large amount of geotechnical and geological data has been accumulated. However, these data have the characteristics of multiple sources, multiple categories, multi-dimensions, and multiple formats, resulting in isolated and dispersed data, poor integration, and difficulty in achieving data sharing and comprehensive application. In response to the above issues, we have utilized new technologies such as the Internet of Things, Big data, and cloud computing, as well as key technologies such as integration, modeling, visualization, and sharing of geotechnical and geological spatiotemporal Big data, to construct the geotechnical and geological spatiotemporal Big data platform system with the "Three Ones" as the core, namely "a net", "a database", and "a information system". The integrated application of multi-source and heterogeneous geotechnical and geological Big data has been achieved, and a three-dimensional underground digital base has been built in Xiongan New Area. Through the integration of three-dimensional spatiotemporal big aboveground and underground data, the perspective management and auxiliary decision-making of aboveground and underground integration have been achieved, providing strong support for the high-quality development of smart citiy in Xiongan New Area.

1. INTRODUCTION

The construction of smart city urgently needs the support of spatiotemporal data resources above and below the ground. As an important part of the spatiotemporal Big data, the geotechnical and geological data has the characteristics of high input costs, wide application service fields, long-term reuse, etc, which is a huge information treasure house, bearing immeasurable social and economic value (He et al., 2020; Ma et al., 2022). As an important basic resource for urban planning, design and engineering construction, the geotechnical and geological Big data is of great significance for supporting and guaranteeing urban planning, construction and safe operation and maintenance, and can provide scientific basis for urban safety, construction layout and functional zoning, construction of megaproject, development and utilization of underground space, prevention and control of geological disasters and other decision-making work (Shi et al., 2020; Ma et al., 2022; Tan et al., 2022). In the face of many complex problems brought about by urban sustainable development, it is necessary to fully tap the potential of geotechnical and geological Big data, comprehensively use Big data, blockchain, cloud computing and other information technologies, build a management platform for geotechnical and geological Big data, and achieve integrated management of convergence, resource integration, open sharing and other aspects of geotechnical and geological Big data.

Both at home and abroad attach great importance to the information sharing and service of the geotechnical and geological Big data (Wang et al., 2020; Jiang et al., 2021), and apply technologies such as the Internet of Things, artificial intelligence, blockchain, etc. to the construction of information resources and the construction of sharing service platforms. For example, the Big data service platform of Xiamen geology has established the Big data specification system of Xiamen geology based on the Geological survey database of Xiamen city (Wang, 2022), and has developed a rapid real-time update 3D geological modeling subsystem. The evaluation subsystem for the development and utilization of two-dimensional and three-dimensional integrated underground space integrates functional modules for engineering geology, hydrogeology, and professional analysis and evaluation. The construction of these platforms can effectively provide shared geotechnical and geological services for the government, professionals, and the public. However, in terms of how to produce reliable and standardized geotechnical and geological results, and how to construct multi-scale multi-precision engineering lithology attribute integrated 3D geological model and Big data achievement sharing still need further exploration.

In response to the above problems, based on multi-source, heterogeneous, multi-scale, spatio-temporal and multi-dimensional the geotechnical and geological Big data, such as basic geological data, engineering geological data, hydrogeological data, geophysical and geochemical exploration data, and geotechnical monitoring data, and with the help of the Internet of Things, mobile Internet, and spatio-temporal Big data technology, Xiongan New Area builds a spatio-temporal Big data platform of geotechnical and geological Big data that integrates data collection, information extraction, knowledge discovery, decision generation, and rapid services, realizing the integrated management and sharing application of multi-source, multi-dimensional, geotechnical and geological Big data, building a three-dimensional underground digital base in Xiongan New Area, and provide strong support for the high-quality development of the smart city in Xiongan New Area.

2. OVERALL ARCHITECTURE

Relying on new infrastructure such as supercomputing cloud and block data, utilizing information technologies such as the Internet of Things, Big data, and cloud computing, with "a net", "a database", and "a information system" as the core, and supported by standard specification systems and security guarantee systems, the comprehensive and integrated Xiongan New Area geotechnical and geological spatiotemporal Big data platform has been built, which includes the entire process of "data collection, information extraction, knowledge discovery, decision generation, and rapid service".

2.1 A Net: comprehensive monitoring net for geotechnical and geological Environment in Xiongan New Area

Through the deployment of IoT monitoring equipment and the application of new generation mobile communication technology, a real-time comprehensive monitoring network for geotechnical and geological environment has been established, which monitors real-time geological information such as field construction quality, groundwater level, stress changes, foundation pit deformation, and ground settlement. Application modules such as monitoring data analysis reports, real-time generation of warning maps, production and release of warning information are provided to timely and accurately reflect the current situation and changing trends of the underground environment, providing scientific basis for government refined regulation.

2.2 A Database: 3D geotechnical and geological spatiotemporal database

Based on the unified spatiotemporal framework, data format standards, and resource directory system of Xiongan New Area, using spatiotemporal Big data management technology, massive geological data such as basic geological survey data, engineering investigation data, geological monitoring data, and geotechnical and geological achievement data are integrated dynamically, logically organized, physically separated, stored, and applied for service management, forming a high-precision and multi-scale three-dimensional geological model across the entire region, and constructing the three-dimensional geotechnical and geological spatiotemporal database.

2.3 A Information System: geotechnical and geological information business application system

The construction of the geotechnical and geological information business application system has achieved the full process and integrated management of engineering investigation data, geotechnical engineering monitoring data, and groundwater dynamic monitoring data through "collection, submission,change, and application". Through effective integration with the BIM comprehensive management platform in Xiongan New Area, it has provided integrated basic floor data information services aboveground and underground for urban planning, construction, and operation management.

2.4 Standard specification system and safety guarantee System

By establishing unified technical regulations, database standards, and management norms, the production, collection, construction, sharing, and application of geotechnical and geological achievements have been standardized, ensuring the smooth operation of the platform. The security guarantee system provides technical support for the stable and reliable operation of the platform in terms of data, network, and system security.

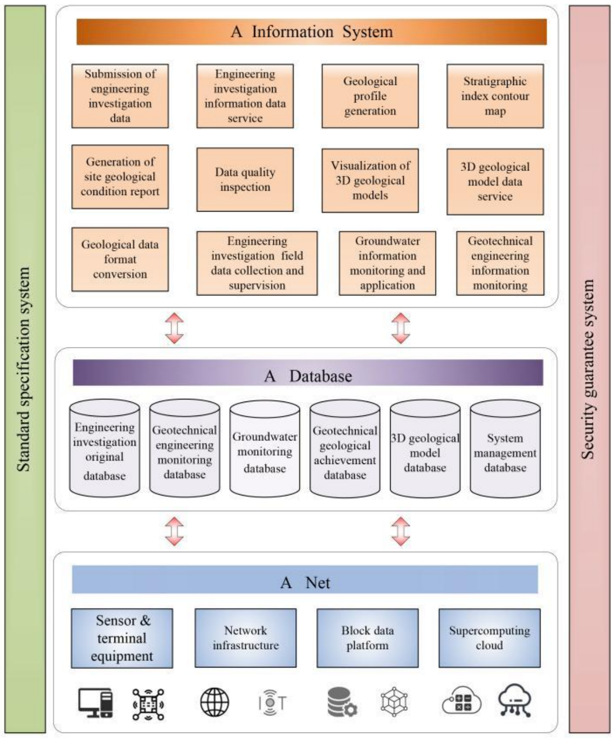

Fig.1 Overall framework diagram of the geotechnical and geological spatiotemporal Big data platform

3. DATABASE AND FUNCTIONAL MODULE DESIGN

3.1 3D spatiotemporal database

3.1.2 The structure of Database

The database includes all kinds of structured and unstructured data, spatial data and non spatial data. Based on the unified data standard system, the Technology roadmap of unified physical distribution and logic, the unified platform data catalog and metadata specification, a data classification system with complete content, authoritative standards and dynamic freshness is formed, and six kinds of databases are constructed: (1) Engineering survey field original database, which mainly stores project data, drilling data, field description original data, test data, abnormal handling data, on-site photos and videos, etc; (2) The geotechnical engineering monitoring database which mainly stores project data, monitoring data, inspection monitoring data, working condition log data, and warning and disposal data; (3) The groundwater monitoring database which mainly stores groundwater monitoring well data, groundwater level change data, annual and monthly groundwater report data, etc; (4) Geotechnical and geological data achievement database, which mainly stores basic geology, engineering geology, hydrogeology and other relevant achievement data maps, engineering survey project data, drilling data, stratum data and test data, and engineering survey achievement report documents; (5) 3D geological model database, which mainly stores regional engineering geological model data, site geological structure model, and site geological attribute model; (6) The system management database which mainly stores user data, unit data, role permission data, module menu data, and log data.

3.1.2 Database storage design

By establishing a complete set of data standards (classification, structure, coding) and organizing them according to the principle of "sub library big class small class", the data is classified and refined according to its purpose and type, enhancing the logicality of the entire database, improving data access efficiency, and enabling users to easily extract various types of information and achieve overlapping calls of different types of data. Different strategies for organizing and storing data for different types of data are adopted (Lemon et al., 2003). The spatial data and its corresponding attribute data are stored in the MySQL database using the MapGIS spatial data engine; Structured data is directly stored in table form in MySQL and Sqlserver relational databases; Unstructured file data uses the path of database to store files, and OSS Cloud storage is used to store actual files.

3.1.3 Data flow design

According to the overall structure design of the database and the sharing scheme for each data usage, each database can only be directly accessed by the corresponding subsystem. Data fusion and comprehensive analysis are exchanged through data interfaces. The newly generated work result data is stored separately, and the blood relationship between the data before and after processing is recorded and recorded by adding labels, thus achieving orderly flow, derivation, and reproduction of data within a controllable range, ensuring that all data is managed, managed, and well managed throughout the entire process, and ensuring the quality and accuracy of the data.

3.2 Platform module functional design

The platform construction includes five subsystems: engineering survey drilling data collection subsystem, engineering survey information management subsystem, 3D geological data service and visualization subsystem, groundwater information monitoring subsystem, and geotechnical engineering monitoring information management subsystem.

3.2.1 Engineering survey drilling data acquisition subsystem

Taking the registration and filing of engineering survey project as the starting point, it applies satellite positioning, personnel checking, on-site photo and video recording, and standardizes the content of data collection of field work, so as to incorporate the survey unit and practitioners into the unified management, and realizes the all-around and whole-process effective supervision of the survey field work process. In order to meet the requirements of different personnel and different scenarios, it is divided into three parts: PC management terminal, field data collection APP and survey quality supervision APP. PC management terminal mainly includes functions of unit management, personnel management, project management and abnormality warning. Data collection APP and quality supervision APP have the main functions of opening and positioning, cataloging description, final hole sealing, data uploading, data querying, project (borehole) checking and borehole acceptance.

3.2.2 Groundwater information monitoring subsystem

Through the deployment of 108 eyes, 41 groups of shallow groundwater monitoring wells and intelligent sensor water level thermometers, real-time updating of groundwater level changes can effectively and accurately grasp the spatial and temporal distribution of the shallow groundwater level and the characteristics of the changes, which mainly includes the basic data management, information query, information dissemination and statistical analysis, report generation and automatic early warning and other functional modules.

3.2.3 Geotechnical Engineering Monitoring Information Management Subsystem

Through automatic monitoring equipment or manual monitoring upload filing, geotechnical engineering monitoring data remittance and unified management, project supervision of automatic warning - on-site disposal - elimination of alarms and monitoring data visualization query of the three major business process management, mainly including the monitoring unit filing and acceptance, project supervision, monitoring data uploading, monitoring information management, history of project management and other functions.

3.2.4 Engineering Survey Information Management Subsystem

On the basis of completing the archiving and management of the remittance of engineering survey results, it realizes the global visualization management of the distribution of geotechnical and geological data in the new area, which mainly includes six modules, including the remittance of survey results, application for geological data, survey business management, geological application service, unified user management, public service platform, etc., and provides users with geotechnical and geological information query, the generation of multiple types of drawings and superimposed analysis, the computation and analysis of the basic conditions of the site, and the generation of reports, etc., and provides users with a wide range of geotechnical and geological products and services.

3.2.5 3D geological data service and visualization subsystem

The subsystem utilizes knowledge-driven multi-scale gridded 3D geological modeling technology to complete the construction of geotechnical and geological models, adopts MongoDB to store and manage massive raster model data, and realizes model updating through a combination of automatic updating and human-computer interaction. WebGL technology is used to build the framework of 3D visualization system, display the 3D geological framework model and engineering geological stratigraphic structure model of the new area, establish the 3D stratigraphic structure model and attribute model results of different planning units, and form a series of application services, including 3D model service, 2D map service, geological data service and analysis of geological conditions of the site.

4. KEY TECHNOLOGIES

4.1 Sharing mechanism of the geotechnical and geological spatiotemporal Big data

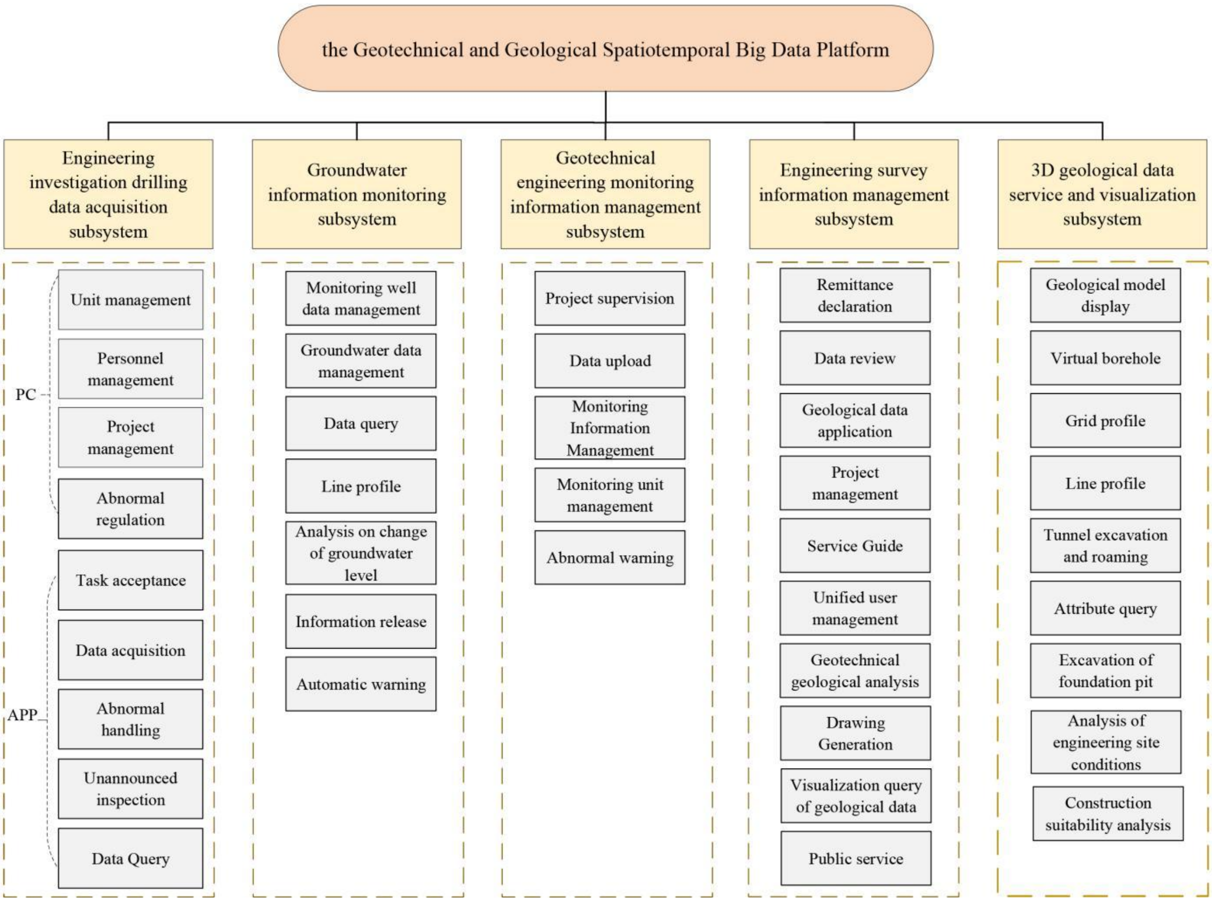

Fig.2 Schematic diagram of basic functional modules of the platform

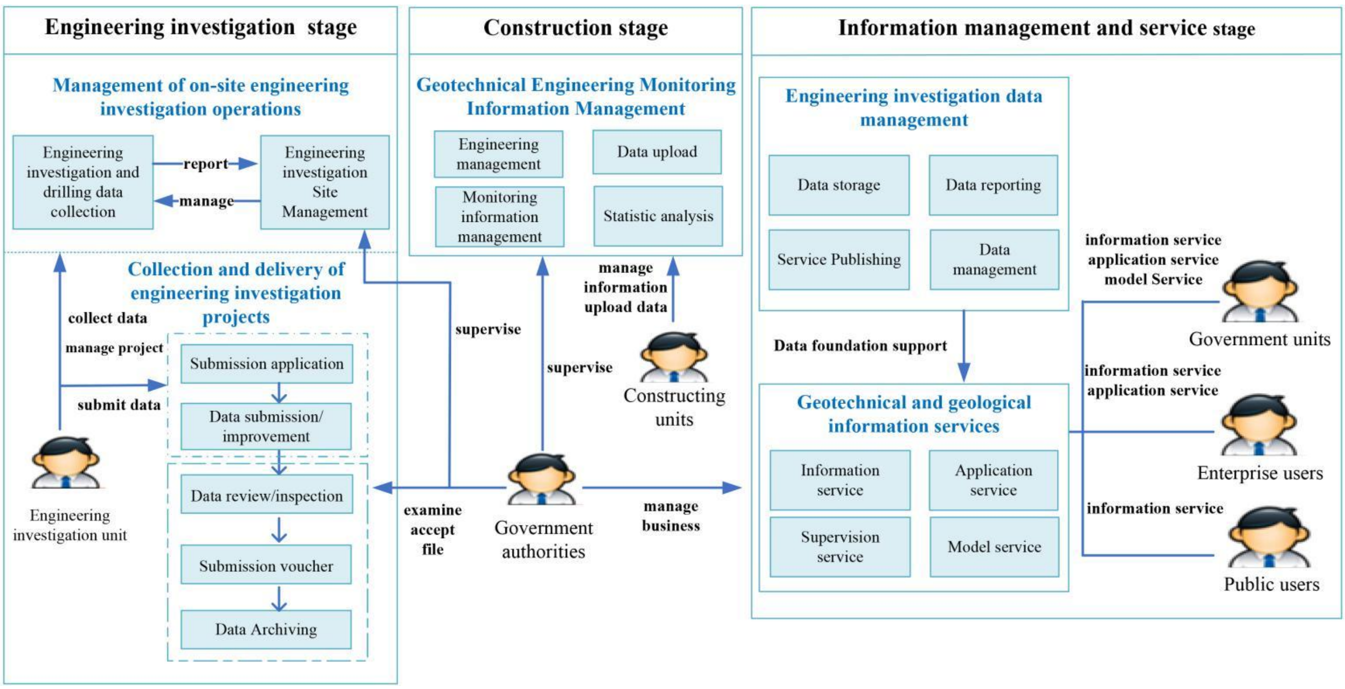

Fig.3 Data Sharing Frameworks of the platform

Through the development of relevant measures, implementation rules and technical procedures for geotechnical work in Xiongan New Area, and the establishment of a geotechnical and geological information business application system, a full cycle and full process recyclable time-space Big data sharing mechanism is established.

The measures mainly stipulate the responsibilities of relevant units, among which the construction unit, as the main person responsible for collection and delivery, needs to submit the results of engineering survey projects to the competent department online. The submission certificate will be one of the requirements for handling the completion acceptance of engineering construction project archives. The survey unit needs to record the original field data of engineering survey through the terminal equipment and upload it to the information platform. The accompanying implementation rules provide a detailed description of the relevant content and format requirements.
The technical regulations are for professional technical personnel to use and stipulate the requirements for the division of shallow geological reference layers within 100m and the construction of engineering survey project databases, in order to ensure mutual invocation and comprehensive analysis among different survey projects.

4.2 Integration and sharing technology of geotechnical and geological spatiotemporal Big data

Based on the SOA service framework, different data storage, query and release schemes are formulated for structured data, file data and spatial data. With the help of MapGIS platform, block data platform, model data conversion and other technologies, multi-source, multi-category, heterogeneous Big data sharing and services are realized.

In terms of data aggregation, it supports the aggregation and access of various geological Big data, such as 2D data (vector, grid), 3D data, Internet of Things data, data services, database data, etc. The aggregation methods mainly include online or offline access of real-time sensors, continuous sorting and warehousing of stock data, sporadic collection and sorting, and regular collection with geological survey units.

In terms of data management, it can support customizable and configurable dynamic directory trees, enabling the addition, deletion, modification, and query of directory trees; Data can be queried, counted, filtered, and mapped based on spatiotemporal and attribute features.

In terms of data sharing and exchange, a unified data sharing and exchange channel has been constructed among various departments, using professional data format conversion tools to classify, organize, and share services based on factors such as data types, service objects, and application scenarios; At the same time, different data sharing capabilities are provided for government departments, industry users, and the public to meet the diverse needs of various users for geological information.

4.3 Knowledge-driven multi-scale grid based 3D geological modeling technology

Different from the traditional 3D modeling method based only on stratigraphic correlation and geological structure (Wu et al., 2005; Qu et al., 2008; He et al.,2009; Liu et al., 2022), the platform adopts the knowledge-driven multi-scale grid 3D geological modeling technology, introduces the analysis of sedimentary environment and sedimentary facies in Xiongan New Area, integrates multi-source, multi-source and multi class geological data, establishes a 3D geological model for the whole area of the new area, and divides the urban underground space within the depth range of 0-100 in Xiongan New Area into four levels of 3D grids. According to the principle of unified grid splicing, a multi-scale and high-precision urban geotechnical geological model and attribute model system is developed.

The basic data source is the borehole and the profile established based on the borehole, and the multi-source and multi class geological data, such as Quaternary strata sedimentary laws and sedimentary microfacies, achievement analysis maps and physical and mechanical properties, are fused, analyzed and processed through unified data coding, and the borehole, profile layering information and sedimentary environmental boundary information are distributed in the three-dimensional space in real coordinates, The 3D geological model of Xiongan New Area is generated after the correction of stratum level with constraints and topological reconstruction.

Grids of different sizes and specifications are used in the vertical and horizontal directions, respectively corresponding to the four levels of urban planning management units of the whole area, planning area, management and control unit and project site. In accordance with the 3D geological model and the principle of unified grid splicing in Xiongan New Area, the Kriging interpolation algorithm is used to build a multi-scale and high-precision integrated 3D geological model of engineering lithology and attributes with the lithology and physical and mechanical parameters of the borehole stratum as the attribute values.

4.4 3D Visualization Technology of Geological Models in a Full Network Environment

Relying on multi-scale high-precision grid, the distributed storage mode of grid model is carried out (Cheng, 2009; Wu et al., 2021), and the visualization technology of grid model is improved by building a detailed Hierarchical database model, multithreading call and other technical methods (Xu, 2009; Li, 2014), to optimize the visualization scheduling efficiency under the network environment of 3D geological model, and greatly improve the display performance and response speed of 3D geological model. A Hierarchical database model model (LOD) is built which mainly includes model simplification and optimization of hierarchical organization. In terms of model simplification, redundant vertices are removed and texture information is merged to reduce the amount of model information transmission. In terms of hierarchical organization, the scheduling information of the corresponding level is read based on user viewpoint parameters to optimize data in scenarios at different levels. The above methods can significantly reduce the number of grids and ensure that the geometric form and texture accuracy of the data basically meet the original visual effects, while also ensuring the loading efficiency of data in different levels of scenes.

5. APPLICATIONS AND SERVICES

5.1 Engineering investigation stage

Before the launch of the survey project, the project leader needs to register and record the project on the system. Technicians receive tasks on the data collection app to conduct field construction operations, collect and input geological data, undisturbed sampling data, drilling cycle data, in-situ test data, and other on-site data information, and take photos and videos of key nodes. Compared to traditional working methods, the use of dropdown boxes for inputting data on terminal devices such as mobile phones has made core logging work faster, more standardized, and accurate. It can not only improve work efficiency, but also greatly reduce the possibility of data fraud, solving the pain points of difficult supervision, single methods, and untimely implementation in the past. At present, survey units participating in the construction of Xiongan New Area have started to pilot the use of the engineering survey field supervision subsystem, which has generally received good response, strong operability, and has promotion value.

After the survey project is completed, the survey unit organizes the results data in a unified format and uses a database conversion tool to automatically generate database files that meet the standards. The electronic results collection and submission work is carried out on the online collection and submission platform, and the system automatically performs data inspection and manual secondary verification before issuing the submission vouchers. Compared to traditional project archiving, a unified and standardized database file effectively avoids creating "data silos" and reduces the cost of data secondary cleaning. More than 90 survey projects have been conducted or completed on the online remittance platform, with a total of over 30 remittance vouchers issued.

5.2 Construction stage

Before starting construction, the monitoring unit registers and records the project on the platform. When the monitoring work starts, the system automatically analyzes and calculates the monitoring data from automatic monitoring equipment or manual monitoring. If the warning value is exceeded, the system will remind the monitoring unit and the construction unit to handle abnormalities.

The platform not only displays real-time monitoring data of foundation pit engineering for government departments, but also provides monitoring units with tools for data analysis and organization, greatly improving their understanding and predictive ability of safety risks, and assisting in the construction of high standards and quality. In addition, through the classified collection, sorting, long-term accumulation and deep excavation of engineering monitoring data, regional experience indicators of Xiongan New Area can be formed to guide the subsequent engineering excavation construction.

5.3 Information management and service stage

5.3.1 Provide geological application services to the public

The system can provide the public with geological data query services such as engineering geology, basic Geological survey and groundwater in Xiongan New Area, as well as data application analysis services and download services based on the geotechnical and geological Big data.

5.3.2 Provide specialized geological data services to legal entities

The legal entity can submit the application download service online through the system, including the drilling data around the project site and the site geological condition report. At the same time, during the stage of submitting site selection opinions for engineering construction projects, the system can automatically generate site geological condition reports based on spatial range maps (SHP or DXF format), and actively push them to the construction unit.

5.3.3 Provide the geotechnical and geological data management services to regulatory authorities

The system can provide visual display of geotechnical Data and information visualization based on a single map, and provide relevant analysis tools, mainly including query management of project information, drilling information and groundwater information, drilling histogram, geological profile, stratum index contour map and site geological report analysis generation, single pile bearing capacity, foundation settlement calculation, liquefaction discrimination calculation and other functions.

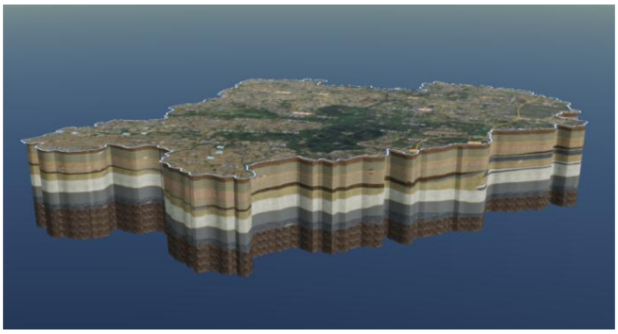

Fig.4 Three-dimensional geological model of Xiongan New Area (0～10km)

And it can comprehensively display the regional 3D model, standard stratum model and geological lithology model under different precision and scale, and provide analysis tools such as attribute query, virtual drilling, grid profile, foundation pit excavation and tunnel roaming. In combination with the vector maps of 2D geological achievements, it provides two-dimensional and three-dimensional integrated spatio-temporal data information services for urban planning, engineering construction and auxiliary decision-making (See Figure 3 for details).

6. CONCLUSION

Through the construction of geotechnical and geological spatiotemporal Big data platform in Xiongan New Area, the two-dimensional and three-dimensional integrated geotechnical and geological spatiotemporal database has been established. The integrated management and sharing application of multiple types, sources, and formats of geotechnical and geological Big data have been achieved, and application services such as underground spatial data sharing and underground integrated collaborative planning have been achieved, promoting the circulation and flow of resources the geotechnical and geological Big data, and providing diversified basic data floor services for government departments and the public. Next, based on the geotechnical and geological spatiotemporal Big data, we will integrate and integrate urban Big data to build a unified spatiotemporal benchmark and interconnected three-dimensional digital base, forming a comprehensive solution integrating spatio-temporal Big data convergence, sharing and exchange, application mining, safety supervision and other capabilities.

REFERENCES

Cheng K., 2009, Research and Implementation on the Algorithm of LOD Model Simplification[D]. *Shenyang: Northeast University*.

He Z.W.,Wu C.L., Tian Y.P., 2008: Three-dimensional recon-struction of geological solids based on section topology reasoning. *Geo-spatial Information Science*, 11(3): 201-208.

He Z.l., Zhu P.f., Bai Y., Cao K., Kong W.h., 2020: 3D solid modeling method for complex geological bodies. *Geology and Exploration*, 56(1): 0190-0197.

Jiang Q.Y., Huang M.J., Yue Hui., 2021: Design and implementation of urban geological information management and service platform in Guangdong Province. Urban Geology, 04: 479-486.

Lemon A M, Jones N L, 2003: Building solid models from boreholes and user-defined cross-sections. *Computers and Geo-sciences*, 29(5): 547-555.

Li C.L., 2014: Study on Algorithms for Three-dimensional Modeling of Complex Strata [D]. Xuzhou: *China University of Mining and Technology.*

Liu G.B., Rong K., Tang L., Wang W.M., Zhou W Q，Han B.L., Liu K.，Huang H., 2022: Integration and application research of smart management and service platform for Shenzhen urban ecological big data. *Acta Ecologica Sinica*, 42(24): 10051-10059.

Ma Z., Huang Q.B., Lin L.J., Zhang X., Han B., Xia Y.B., Guo X., 2022: Practice and application of multi-factor urban geological survey in Xiongan New Area. *North China Geology*, 45(01):58-68.

Ma S.Z., Zhu J., Ma X.C., 2022: Research on 3D visualization of borehole data based on lithological stratification model.*Natural Resources Information*, (6):7.

Qu H.G., Pan M., Ming J.,Wu Z.X., Sun Z.D., 2008: An Efficient Method for High-Precision 3D Geological Modeling from Intersected Folded Cross-Sections. *Acta Scientiarum Naturalium Universitatis Pekinensis*, 44(6):915-920.

Shi X.D., Zhao Y.T., Wu K.J., 2020: Research on scientific planning methods of underground space in megacities in era of ecological civilization: a case study of Beijing City underground space development. *Tunnel Construction*, 40(5): 611.

Tan Y.J., Guo M.Q., Wang P., Huang Y., Li S.F., Huang B., 2022: Construction technology and application of "transparent" underground space. *Science of Surveying and Mapping*, 47(8): 18-24.

Wang W., Jiao F.X., Chen L., Zhu Y.X., 2020: Research and application of geological data integration and shared service patterns-A case study of Taizhou city. *Land and resources informatization*, 04:50-55

Wang L.F., 2022: Application of Xiamen geological big data in underground space planning and evaluation. Journal of Geological Hazards and Environment Preservation, 33(4), 6.

Wu Q., Xu H., Zou X.K., 2005: An effective method for 3D geological modeling with multi-source data integration. *Computers and Geosciences*, 31(1): 35-43.

Wu L.W,Cui B.,Yu W., 2021: Design and Key Technologies of 3D Visualization for Spatio-temporal Data of Smart City. Geospatial Information, 19(07): 9-11.

Xu W.J., 2017: Study on the 3D Visualization of Seawater Based on GIS[D]. Xuzhou: *China University of Mining and Technology*.