Research on methods of designing and building digital seabed database①

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Abstract

With a review of the recent development in digitalization and application of seabed data, this paper systematically proposed methods for integrating seabed data by analyzing its feature based on ORACLE database management system and advanced techniques of spatial data management. We did research on storage structure of seabed data, distributed-integrated database system, standardized spatial database and seabed metadata management system in order to effectively manage and use these seabed information in practical application. Finally, we applied the methods researched and proposed in this paper to build the Bohai Sea engineering geology database that stores engineering geology data and other seabed information from the Bohai Sea area. As a result, the Bohai Sea engineering geology database can effectively integrate huge amount of distributed and complicated seabed data to meet the practical requisition of Bohai Sea engineering geology environment exploration and exploitation.

Key words: digital seabed, database, spatial data engine (SDE), ORACLE

0 Introduction

With the development of "Digital Earth" and "Digital Ocean", advanced spatial technology has been applied to the storage and management of seabed data, which can integrate and apply the multi-source, multi-standard, multi-specialty and multi-format seabed information dynamically to improve the efficiency in utilization of these seabed information and further provide better services for marine scientific research and marine resource exploration. Now, the digitalization of seabed information and construction of "Digital Seabed" database have been undertaken by many countries and many kinds of seabed database system have been constructed[1]. More and more researches have been focused on "Digital Seabed"[2-10] and related theory and technology are getting rapid development.

However, according to questionnaire survey, the seabed database systems that have been built are mainly for a certain specialty field or for the application demands of one specialty. These database systems are developed based on different software platform and distributed in different departments, so the structures, standards and applications of the seabed data are diverse. This makes it very difficult to sufficiently share and utilize the precious seabed information among these databases in different departments, which will cause great waste of valuable seabed data resources. Therefore, we need to establish the standards of data structure and design a framework of seabed database based on the data features and application requirements of "Digital Seabed" to integrate and manage the complex seabed information effectively.

With the advanced technology of spatial information management, this paper designed the framework of Digital Seabed Database and systematically proposed methods for integrating seabed data. Then, this paper did research on storage structure of seabed data, distributed-integrated database system, standardized spatial database and seabed metadata management system in order to make it efficient and convenient to organize, share and apply the seabed data and provide good service for the exploration and exploitation of seabed resources. Finally, the technology and methods proposed in this paper are applied to the design and development of the Bohai Sea oilfield paradigm area information system to store and share the seabed information from the Bohai Sea seabed.

1 Data analysis

"Digital Seabed" database mainly integrates and manages all kinds of information under the sea floor including geological data like sediment properties, stratum distribution, geological calamity, etc., and geophysical data like gravity, magnetism and so on. The features of seabed data are listed as follows:

(1) They are widely distributed geographically.

(2) Their coverage density is relatively low because

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of the limited marine surveys.

(3) The investigation methods are not standardized.

(4) There are many subjects involved in these data, which are characterized by multi-source and heterogeneous formats.

(5) The volume of data has increased rapidly due to the application of advanced technology and equipment.

Now, inputing, managing, querying, displaying and analyzing of the seabed information are playing a valuable role in marine development, marine management and so on. Therefore, we need to integrate and manage the seabed information that is of long time span, large, spatial coverage and complex feature so as to make effective and dynamic data access and demonstration.

2 "Digital Seabed" database structure

According to the features of seabed data, "Digital Seabed" database was designed and constructed based on ORACLE and SDE. The seabed information was stored in attribute database and spatial database respectively, and the metadata engine was utilized to realize the integrity and management of multi-source and heterogeneous data (Fig.1).

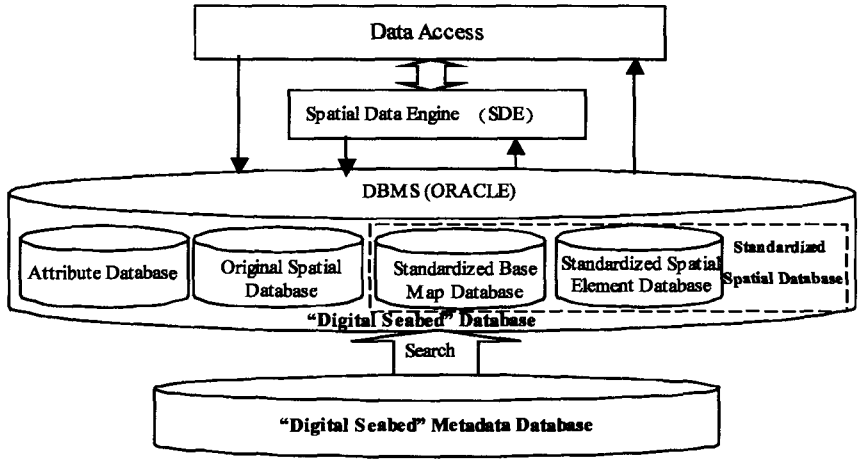

Fig.1 Structure of "Digital Seabed" database

2.1 Database management system (DBMS)

DBMS is a data management layer between users and operation system (OS). It takes charge of database construction and maintenance to make administrators and other users manage and operate data conveniently and guarantee the safety and integrity of database.

ORACLE is an object-relational database management system and it can provide powerful function of data storage, distributed management and network communication, especially for spatial data[11]. So it can meet the needs of integrating and managing the heterogeneous seabed information.

Oracle database is divided into several tablespaces logically and data are physically stored in data files associated with related tablespaces as shown in Fig.2[11]. Taking advantage of tablespace management mode, seabed data are classified and each class is stored and managed in individual tablespace (Fig.3).

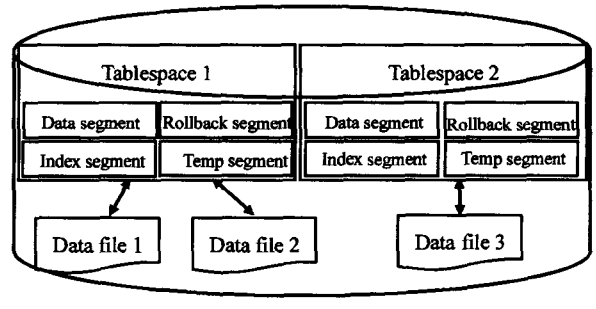

Fig.2 Relationship among database, tablespace and data file

2.2 Combination of distributed and integrated structure

As discussed above, seabed data are basically distributed in different departments and some of them have high security. Considering these features, "Digital Seabed" database adopts both distributed structure and integrated structure to manage and protect the seabed information (Fig.4). As shown in Fig.4, the integrated database manages all sharable data and part of private data that can be accessed by the specified rights. The dis-

tributed databases respectively store their own private data by applying distributed technology[12-13] to manage and share the seabed information in different departments.

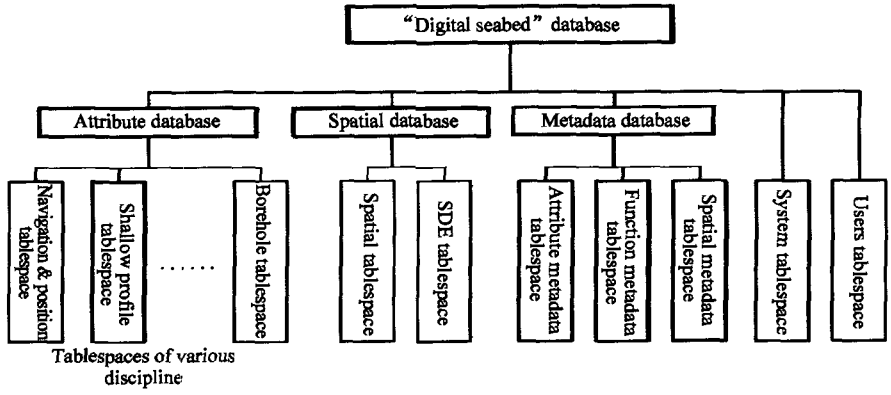

Fig.3 Classification of "Digital Seabed" database tablespace

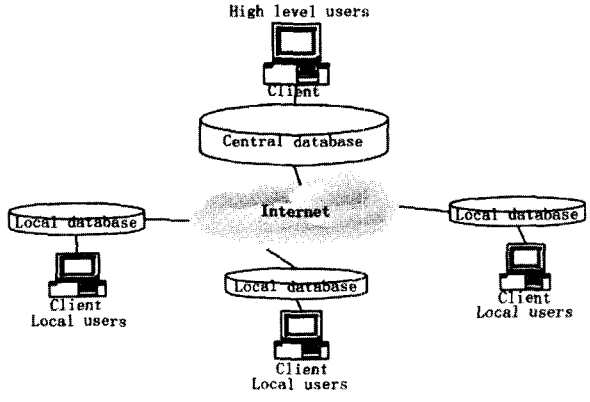

Fig.4 Distributed-integrated database system

2.3 Seabed attribute database

Seabed attribute database mainly stores marine survey information involving many subjects. Marine survey information basically comes from every seabed investigation project, so the data are organized by project code in attribute database and separately stored in different tablespaces related to their subjects.

The seabed attribute database is analyzed and designed by the approach of "conceptual structure design-logical structure design-physical structure design-security design" (Fig.5).

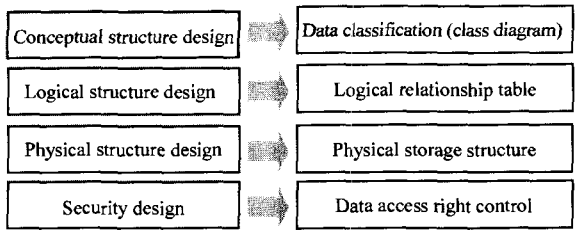

Fig.5 Design of "Digital Seabed" attribute database

For its multi-discipline and heterogeneous features in structure, the seabed attribute database is designed and analyzed from general to detail and object-oriented modeling methods like UML[14] are utilized to model the relationships between seabed objects..

This method has been applied to the analysis and design of the Bohai Sea engineering geology database to realize the storage and management of the Bohai Sea seabed data that mainly includes marine engineering geology data[5].

2.4 Seabed spatial database

Besides attribute information, there are lots of spatial data including maps, charts, images, etc. Now, these spatial data are basically stored and managed by files, which have different spatial scale, spatial standards and spatial structures and they are likely to be destroyed either naturally or artificially.

In recent years, the storage and management of spatial information has developed to be an important research area and constructing spatial database based on commercial DBMS like ORALCE, SQL Server, etc. has become a tendency[15, 16]. By applying technology of SDE and standardized spatial database, this paper designed and constructed seabed spatial database to integrate and manage the multi-source and heterogeneous seabed spatial information.

· SDE

Presently, in commercial DBMS, the spatial data are mainly stored in two ways. One is that the GIS commercial company develops SDE based on their own GIS software to manage spatial information like ArcSDE in ESRI Inc.[17]. The other way is that the commercial DBMS company provides the spatial plug-in for their DBMS products to manage spatial data like ORACLE 9i Spatial

plug-in in ORACLE Corp.[18]. In this study, the seabed spatial database is designed and constructed by the technology of SDE to realize the integration and management of seabed spatial data.

According to the classification of spatial structure[19], the seabed spatial information mainly involves vector structure and raster structure. Vector seabed spatial data models generally represent discrete seabed spatial elements that can be described by point (like borehole, water depth point, etc.), line (like isobaths, boundary line of stratum, etc.), polygon (like block of sediments, area of magnetic or gravity anomaly, etc.) and note (like labels of depth value, etc.). Spatial data in vector structure are stored in one or more pares of (x, y) coordinates in database, which is easier to represent the topological relationships of spatial elements in less storage space. The raster seabed spatial models basically represent continuously distributed spatial objects like remote sensing raster. It generally divides space into cells of uniform size representing spatial resolution and the cell is displayed in different colors according to its average attribute value.

Seabed spatial data, either in vector model or in raster one, are classified into layers and managed by SDE, which brings spatial elements with the same attributes to one layer and all features in layers are indexed to optimize spatial search and retrieval. Indexes are created by dividing the layer into regular grid cells sizes according to the geographic area. Index information, grid cell information and attribute information of seabed spatial features are managed by a set of tables associated by Object_ID (Fig.6).

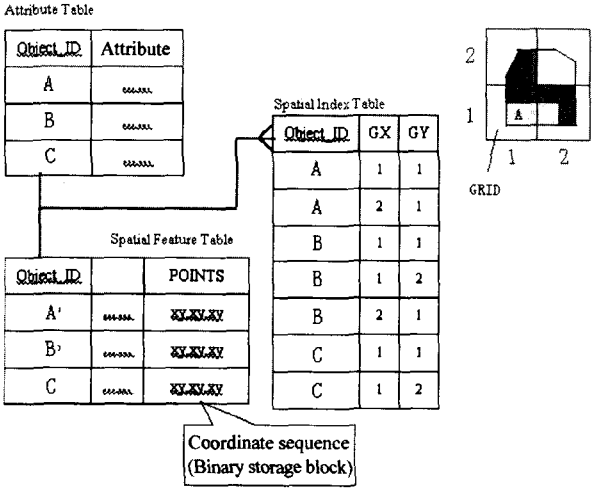

Fig.6 Vector structure of seabed data

Attribute table maintains the attributes of the seabed spatial elements. For the elements with complex attributes, the attributes are managed in the outside attribute database and associated with attribute table by key code.

Spatial feature table stores the shape geometry of the feature and related information such as area, length, type and so on.

Spatial index table contains records of spatial features organized by an index grid cell to facilitate spatial data access.

After spatial rectification, raster layer in seabed spatial data is sliced into $n \times m$ grid cells in uniform sizes and each grid cell is stored in binary large object block (BLOB) field of database through SDE. Additionally, lossless compression and pyramid algorithm are applied during raster data storage to improve the efficiency of raster management, access and display (Fig.7).

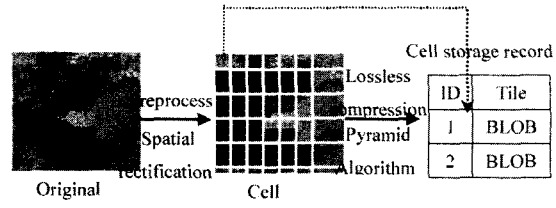

Fig.7 Storage of seabed grid data

· Standardized spatial database

Because seabed information basically comes from marine survey and research by various departments, different methods and equipment are applied and the spatial standards like spatial scale, projection, etc. are heterogeneous. To solve the problem, seabed spatial database is designed to consist of two parts, comprehensive spatial database and standardized spatial database (Fig.8).

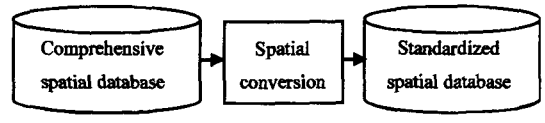

Fig.8 Transformation from comprehensive spatial database to standardized spatial database

Comprehensive spatial database mainly manages the original heterogeneous spatial data while standardized spatial database including standardized base map database and standardized spatial elements database stores the standard spatial information by spatial conversion. In this way, seabed spatial features can be easily and rapidly organized, queried, analyzed and displayed in standard marine map through standardized spatial database and the original spatial elements can be addressed and applied by comprehensive spatial database. By doing so, temporary spatial conversion during spatial operations can be avoided and rapid spatial management, query, analysis and display can be realized.

2.5 Seabed metadata management system

In order to make better maintenance and management for "Digital Seabed" database, we analyzed and designed the seabed metadata standards and constructed metadata database to record and describe the formats, contents, relationships and features of the datasets. "Digital Seabed" metadata database mainly includes attribute metadata database, spatial metadata database and system function metadata database (Fig.9).

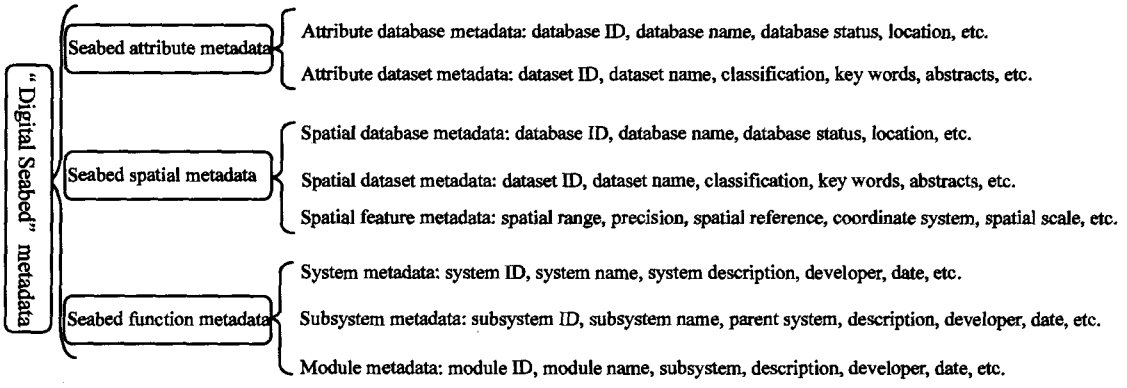

Fig.9 System of seabed metadata

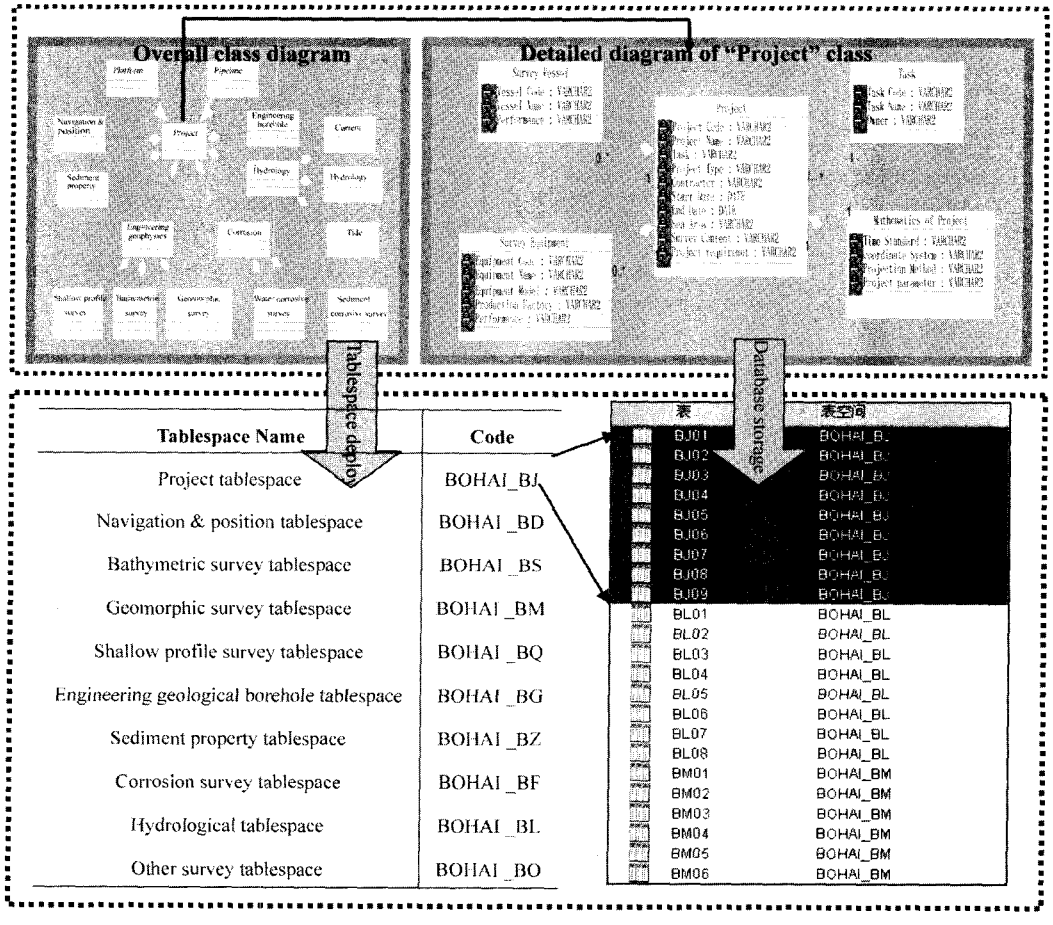

Fig.10 Design of Bohai engineering geology database

3 Application paradigm

The Bohai Sea is the only inner sea area of China and there are plenty of resources such as oil and gas under the seafloor. As far back as 1950s ~ 1960s, China has started the exploration and exploitation of oil and gas in the Bohai Sea area. During the long-term exploration, we have collected large amount of marine engineering geology information, which includes many kinds of marine engineering geology data such as marine geophysics, marine engineering geology borehole, sediment properties and some other basic information about marine survey and exploration. These marine resources exploration data are playing an important role in safeguarding the ocean engineering projects including the construction of marine petroleum platform and the pipeline laying.

Based on the "Digital Seabed" database technical scheme as discussed above, we designed and built the Bohai Sea Engineering Geology Database basically including marine engineering geological borehole and marine geophysics in the Bohai Sea area to organize and manage all seabed information such as bathymetry, geomorphology, sediment property, shallow stratum, marine engineering construction, etc., and provide services for safeguarding ocean engineering and marine resources exploration in the Bohai Sea area.

According to the workflow of marine engineering geological survey in the Bohai Sea area, seabed information is analyzed and designed from general to detail with UML and the tablespaces are assigned based on the logical models (Fig.10). Meanwhile, ArcSDE of ESRI Inc. is applied to realize the seamless integration of spatial and attribute data of the Bohai Sea engineering geology to meet the practical needs.

Based on the database, the paradigm system is designed and developed to provide powerful services for the ocean engineering construction and marine resources exploration in the Bohai Sea area (Fig.11).

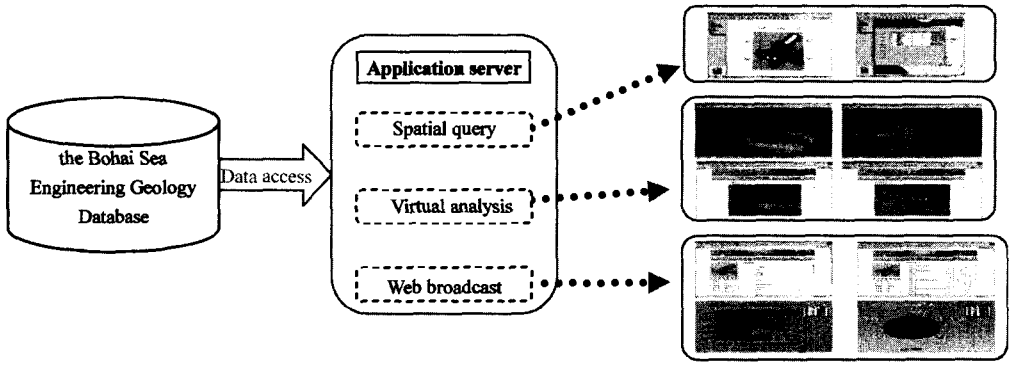

Fig.11 Integration and display of Bohai engineering geology database

4 Conclusion

Based on the advanced technology of database and spatial management, we studied the integration methods for the seabed data and designed the "Digital Seabed" database to store and manage the multi-source, heterogeneous and large amounts of seabed information.

For practical application, we applied the "Digital Seabed" database technology in the construction of the Bohai Sea engineering geology database to manage the seabed information of the Bohai Sea area such as bathymetry, geomorphology, sediment property, shallow stratum, marine engineering construction and so on. The Bohai Sea engineering geology database can make efficient storage and access for distributed and heterogeneous seabed information to provide powerful services for the ocean engineering construction and marine resources exploration in the Bohai Sea area.

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