*Journal of Ocean University of China* (Oceanic and Coastal Sea Research)
ISSN 1672-5182, July 30, 2007, Vol.6, No.3, pp.226-230
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# Marine Engineering Geological Exploration Information System (MEGEIS): A GIS-based Application to Marine Resources Exploitation

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(Received November 4, 2005; accepted December 7, 2006)

**Abstract** Based on the ArcGIS geographic information system and the ORACLE database management system, this paper reports our studies on the technology of Marine Engineering Geological Exploration Information System (MEGEIS). By analyzing system structure, designing function modules and discussing data management, this paper systematically proposes a framework of technology to integrate, manage, and analyze the seabed information comprehensively. Then, the technology is applied to the design and development of the Bohai Sea Oilfield Paradigm Area Information System. The system can not only meet the practical demands of marine resources exploration and exploitation in the Bohai Sea oilfield, but also serve as a preparatory work in theory and technology for the realization of the 'Digital Seabed'.

**Key words** geographic information system (GIS); Digital Oilfield; marine resources exploitation; Digital Seabed; Marine Engineering Geological Exploration Information System (MEGEIS)

**DOI 10.1007/s11802-007-0226-z**

## 1 Introduction

Marine engineering geological exploration has undergone a long development for about half a century. As far back as 1947, the United States began marine engineering geological work for the exploration and exploitation of oil and gas in the Gulf of Mexico. Marine engineering geology exploration mainly includes comprehensive investigation and assessment of information on marine geophysics, marine boreholes, marine geotechnique and some other basic information on marine engineering survey and exploration. These data can offer indispensable geotechnical parameters or indexes for ocean engineering design and have been playing a very important role in the security assessment in ocean engineering construction and ocean resources exploration and exploitation (Gu, 2000; Zheng, 1985a, b).

With the wide use of advanced computer technologies and spatial information technologies 'Digital Oilfield' is under construction in China. However, the databases that have been developed are mainly on oil and gas exploration or exploitation, and there are yet few marine engineering geology databases and relevant information systems in use. The features of marine engineering geological exploration data, which are listed below, make it difficult to build an information system to integrate, manage and share them effectively:

1) They are widely distributed geographically.

2) Their coverage density is relatively low because of limited marine surveys.

3) The investigation methods employed are varied and not standardized.

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

5) The volume of the data has increased very rapidly with the wide use of advanced technologies and equipments.

These features have seriously restricted the improvement of the efficiency in marine engineering geological investigation and research and influenced the security assessment in the exploration and exploitation of marine resources. There have been some researches and discussions to make more efficient use of the data (Pan *et al.*, 2002; Hu *et al.*, 2001; Wang *et al.*, 2000) in recent years, but there has not been an appropriate approach to integrating and applying them.

A geographic information system (GIS) is an organized

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collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Chen *et al.*, 1999). And ORACLE is an object-relational database management system that offers powerful functions such as data management, parallel response and network application to meet the complicated demands of users (Ding, 2001).

Based on the powerful ORACLE database management system and advanced GIS theory and technologies, this paper proposes a technological solution for MEGEIS that can manage, analyze and display the multi-sources and heterogeneous data of marine engineering geology. Then, the proposed technology is applied to the construction of the Bohai Sea Oilfield Paradigm Area Information System, which can not only make a remedy for the lack of the marine engineering geological exploration database system in the 'Digital Oilfield' of China, but also benefit the scientific research and security assessment to meet the practical demands of the marine investigation and marine resources exploration and exploitation in the Bohai Sea area.

## 2 System Design

### 2.1 System Architecture

MEGEIS has a three-tier architecture that combines with 'Browser/Server' structure and 'Client/Server' structure to take advantage of both types of system frameworks (Fig.1).

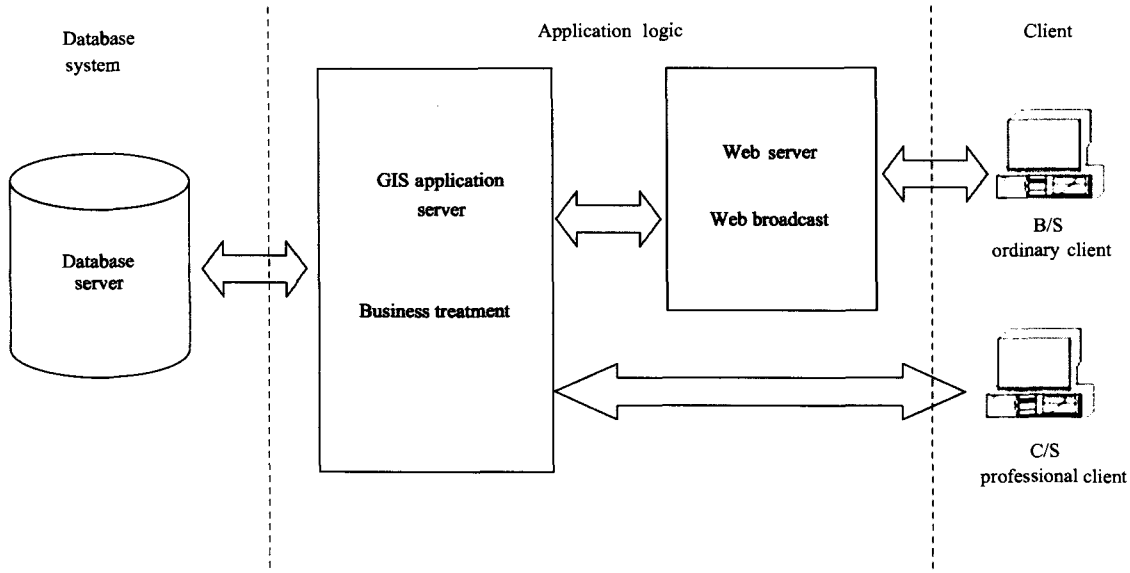


Fig.1 The system architecture of MEGEIS.

Tier 1 The Client can be divided into two kinds, the ordinary client (B/S client) and the professional client (C/S client). Based on graphical web browsers such as Internet Explorer, the ordinary client can do some simple operations that do not need high system performance through Internet to meet the demands of convenient public data sharing. But the professional client needs to install other application software which has powerful functions to complete complex spatial computations such as spatial analysis, spatial simulation, spatial decision-mak ing, *etc.*

Tier 2 The Application Logic includes GIS Application Server and Web Server. The GIS Application Server can provide powerful services for clients to manage, query and analyze the multi-sources and heterogeneous marine engineering geological exploration data, while the Web Server responds to HTTP requests from clients by interacting with the Database System (tier 3) and applying logic to the results returned.

Tier 3 The Database System is an ORACLE database management system that stores marine engineering geological exploration data and meta-data. Through the Application Logic, the Database Server can meet the clients' needs for managing and sharing data effectively and rapidly.

This architecture can make system expand and upgrade conveniently. When users want to upgrade or update the system, it is not necessary to consider the transformation of the Client and the Database System. The only thing needed to do is to add some modules to the Application Logic that can be requested by hundreds of clients. However, if there are demands for higher performance such as huge data-flow or complex spatial analysis, the Client needs to install professional software linking to the Database System directly to accelerate the data computation and transfer of the system.

By adopting both 'B/S' and 'C/S' system structures, MEGEIS can meet the practical demands of the users and provide them with convenient means to fulfill their responsibilities (Table 1).

Table 1 Classification of users' responsibilities

| User type | Responsibilities | System structure |
|---|---|---|
| System manager | System maintenance, data protection, client's authority assignment | C/S |
| Professional user | Data input, query and analysis to providing reference for research | C/S mainly, B/S partly |
| Executive officer | Querying and analyzing data for synthetic assessment and decision-making | B/S mainly, C/S partly |
| General user | Public browse and query | B/S |

## 2.2 Module Design

Based on the marine engineering geological exploration database and ArcGIS system, MEGEIS can input, manage, query, analyze and display the seabed information to meet the practical needs of ocean engineering or ocean exploitation. The structure of MEGEIS modules is shown in Fig.2.

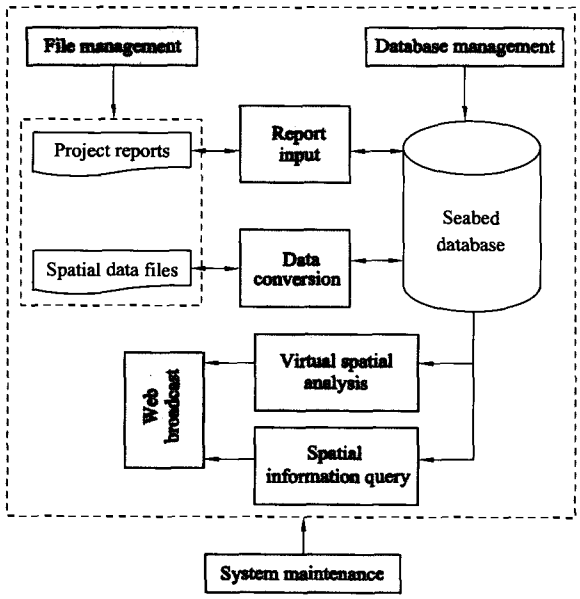


Fig.2 Modules relationship in MEGEIS.

System maintaining module can manage and maintain MEGEIS to guarantee its safe running. It mainly consists of system logging function, module management function, users management function, metadata management function, data dictionary management function, *etc.*

Report input module can input the paper-made or digital projects into database in a standard format to make information more convenient and flexible to share and apply.

Data conversion module can realize the conversion and transformation of multi-sources and heterogeneous seabed data for proper use.

File management module can manage all the files such as references, reports, spatial data files and system design or development documents in database.

Database management module can provide database construction and maintenance services for users.

Virtual spatial analysis module can show the complicated geological spatial structures and ocean engineering constructions to users in three-dimension with virtual reality technology by integrating information on the topography of sea floor, remote sensing, sediment property, geological calamity, engineering construction, *etc.* It can provide users with convenient and direct operation and visualization in 3D to make visual comparison, analysis and assessment of complex spatial seabed data.

Spatial query module offers spatial querying and analyzing services in several ways such as roaming and operating directly on the map, inputing commands in text format, *etc.* For some subject-oriented operations, the system can manage, integrate and share different information of related subjects based on pre-assigned spatial coordinates and create subject-oriented maps according to the querying results automatically.

Web broadcast module provides services through network, such as user management, file management, spatial querying, attribute querying, 3D geological model display, charts of geotechnical log, test results, *etc.* Users are assigned different rights of information access to guarantee the safety and security of data.

## 2.3 Data Management

MEGEIS adopts the ORACLE database management system to store and manage heterogeneous and large amounts of marine engineering geological exploration data as shown in Fig.3.

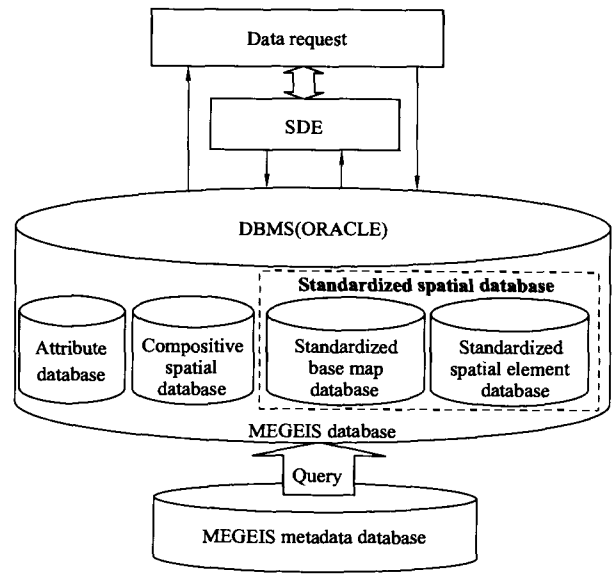


Fig.3 Structure of MEGEIS database.

### 2.3.1 Combination of distributed and integrated database structure

The marine engineering geological exploration data are mainly kept in distributed departments and some data are strictly secret. In order to manage and protect these data, this paper proposes a solution based on distributed and integrated structure to design MEGEIS database (Fig.4).

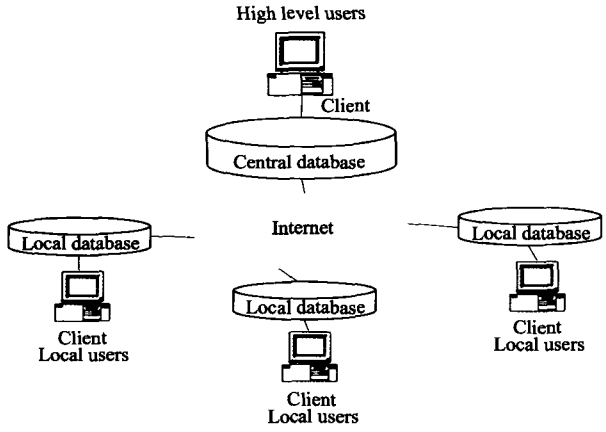


Fig.4 Distributed-integrated structure of seabed database.

In Fig.4, central database stores and manages all the data that can be shared at different security levels for those who have the corresponding rights to access the data, while local distributed database manages and shares the secret data in local departments to protect their benefits.

### 2.3.2 Management of metadata database

In order to share the seabed information resources between different departments, this paper designs the MEGEIS metadata database to manage subject metadata, spatial metadata and function metadata. With these metadata, users can understand the basic information about MEGEIS so as to choose the useful information and functions to meet their demands.

### 2.3.3 Spatial Data Engine (SDE)

SDE is an open tool that allows one to store and manage spatial data in the chosen DBMS such as Oracle, Informix, IBM DB2, Microsoft SQL Server and so on. In the condition where there are many heterogeneous database systems running in different departments, the SDE can provide a common model for spatial application. This allows users to take full advantage of the facilities of chosen DBMS to integrate spatial information with the attribute datasets (Robert, 2001).

### 2.3.4 Standardized database

Because of the difference in the coordinate systems and units used in different marine engineering geological exploration projects, we design a composite spatial database and standardized spatial database to store and manage these heterogeneous seabed spatial data. The standardized spatial database stores the standardized marine engineering geological exploration spatial data converted from the heterogeneous spatial data, while the compositive spatial database manages the original multi-sources spatial data in different standards. By this means, the system can avoid the instant spatial transformation during the course of application, which can improve the performance of the MEGEIS system.

## 3 Construction of the Bohai Sea Oilfield Paradigm Area Information System

The Bohai Sea is the only inner sea of China with plenty of resources such as oil and gas below the seafloor. In as far back as the 50-60's of the 20th century, China began oil and gas exploration and exploitation in the Bohai Sea area. During the long period of exploration, large amounts of marine engineering geological data have been accumulated, including data on geophysics, boreholes, sediment properties, geotechnique, *etc*. These data have been playing an important role in the Bohai Sea engineering projects including the construction of marine petroleum platforms and the pipeline laying.

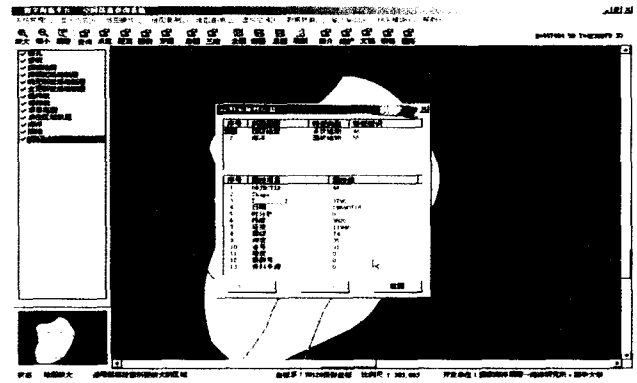

Fig.5 Interactively querying seabed information.

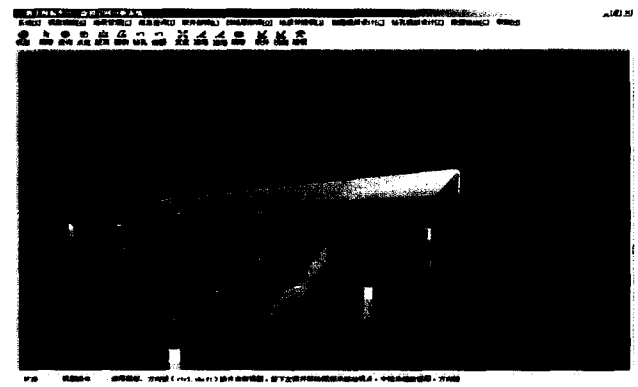

Fig.6 Virtually spatial analyzing.

By the MEGEIS technology discussed above, we constructed a database to integrate and manage these spatial

data and attribute data based on the ESRI® ArcSDE™ and ORACLE DBMS. The data stored in the database include information on seafloor topography, geomorphology, sediment properties, shallow stratum structure under the seafloor and marine construction. The volume of the data is close to 1 TBytes. The database is installed in different departments so that the distributed-integrated database system can be described and managed by the metadata database and can be shared by users with different access rights.

Based on the database, we designed and developed the Bohai Sea Oilfield Paradigm Area Information System with advanced GIS technology to effectively manage, interactively query (Fig.5), synthetically analyze, multi-dimensionally display (Fig.6) and dynamically web-broadcast (Fig.7) the Bohai Sea engineering geological exploration data.

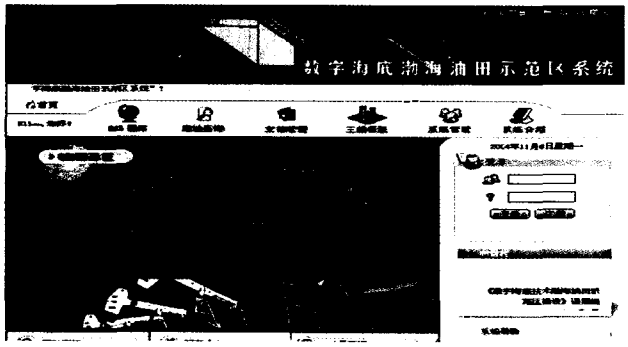


Fig.7 Web broadcast of demonstration zone of Bohai oilfield.

## 4 Conclusions

According to the practical needs of marine engineering geological exploration, this paper proposes a technology system of MEGEIS that has been applied to the design and development of the Bohai Sea Oilfield Paradigm Area Information System. Presently, the system is being run in marine oil field departments such as China National Offshore Oil Corporation (CNOOC), Liaohe Oilfield Branch Company of PetroChina Company Limited and Shengli Petroleum Administrative Bureau of SINOPEC. It can not only realize the integration, management and share of multi-sources and heterogeneous seabed information, but also can provide intelligent spatial analysis and decision-making services for scientific research and marine engineering planning of the Bohai Sea area. Additionally, this system is a remedy for the lack of a marine engineering geological exploration database system in the construction of 'Digital Oilfield' of China.

## Acknowledgements

This study was supported by the '863' Hi-tech Research and Development Program of China under the contract No. 2001AA602019 and '973' Program of China under the contract No. 2002CB412409.

The fist author would like to extend his thanks to Dr. Zhou Wensheng for his help in the program development for the system.

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