BUILDING A GAS HYDRATE INFORMATION SYSTEM IN CHINA

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ABSTRACT

Gas hydrates, low molecular weight gas molecules trapped in water-ice "cages," have gained international attention over the last few years for energy, safety, and environmental reasons. In 2000 CODATA (Committee on Data for Science and Technology, International Council for Science) established a task group for Data on Natural Gas Hydrates, which aims to develop a comprehensive information system of all aspects of natural gas hydrates. As important participants of this task group, Chinese scientists have constructed a gas hydrate information system in China. Now they are developing the data-based research support system of gas hydrates based on the existing gas hydrate information system. In this paper, the authors introduce the idea of constructing a data-based research support system of gas hydrates in detail, including the high level framework design of constructing this system, system platform and functions, and database designs. We believe this system will definitely facilitate the data sharing and scientific research of gas hydrates.

Keywords: Gas hydrate, Information system, Database, Metadata, Research support

1 INTRODUCTION

Gas hydrates, low molecular weight gas molecules trapped in water-ice "cages," have gained international attention over the last few years for energy, safety, and environmental reasons. Methane, the essential component of natural gas, is the most common gas trapped in gas hydrates. The volume of methane in one hydrate unit perhaps contains the equivalent of 164 volumes of methane gas at standard pressure and temperature (Davidson et al., 1978). Kvenvolden (1993) estimates the amount of methane stored in hydrate form on continents and on the ocean floor at roughly 10^{19} g. If this estimation is correct, then the amount of methane stored as methane hydrate totals approximately twice the amount of carbon in known fossil fuel deposits worldwide.

The major issues about gas hydrates can be divided into three categories: energy resources, safety hazards, and environmental problems (Boatman et al., 2000). Methane hydrates may represent a potential energy resource because natural gas is an important clean energy. For many years, oil and gas companies have recognized gas hydrates as a hazard because they may plug pipelines and wells. Gas hydrates in ocean sediments can affect seafloor stability, which makes them a safety concern for oil and gas production equipment. Methane hydrates also raise environmental concerns. Studies have shown that they may play a role in climate change and serve as a source of sustenance for sensitive ocean floor biological communities.

It is necessary and urgent to develop a global comprehensive information system for gas hydrates to share the scientific data and achievements on gas hydrates. In 2000 CODATA (Committee on Data for Science and Technology, International Council for Science) established a task group for Data on Natural Gas Hydrates, which aims at the development of a comprehensive, disinterested information system of all aspects of natural gas hydrates. A project to develop its own information system for gas hydrate was initiated by the Chinese National Committee for CODATA in 2004, corresponding to the objective of CODATA Task Group Data on Natural Gas Hydrates.

In this paper, the authors introduce the ideas of constructing an information system of gas hydrates in detail, including the high level framework design for constructing this information system, system platform and functions, and database designs. This system will be an aid to the construction of a comprehensive global gas hydrate information system.

2 GENERAL FRAMEWORK DESIGN

A gas hydrate information system is a sophisticated, interdisciplinary, comprehensive distributed database system platform, an important part of the Global Gas Hydrate Information System (GGHIS), which has the following aims: to efficiently manage and use scientific data on gas hydrates; share scientific research achievements and avoid unnecessary duplicate research; establish the fundamental experimental platform on which virtual experiments, deposit estimating, and exploitation simulation can be done; publish research data on gas hydrates and provide data services for researchers; connect directly to the Global Gas Hydrate Information System (GGHIS); share scientific data, techniques, and achievements of gas hydrate research from international advanced countries; facilitate international exchange and cooperation in the gas hydrate research domain; improve the international competitive ability of China; and provide technology supports for the exploitation and use of gas hydrates in China.

The construction of a gas hydrate information system is a sophisticated scientific project, which needs the cooperation of various experts from a variety of research domains. To facilitate the construction of this system, we establish the software and hardware environments and information service platform according to the "Four-Layers" model. In the "Four-Layers" model of a gas hydrate information system, the first layer consists of the hardware and network environments, called the Physical Layer, including the Chinese Science and Technology Network (CSTN), a super computer, and TB-level storage devices. The second layer, called the Data Layer, consists of databases, metadata databases, and DBMS, including a variety of resources and the metadata describing those resources. The third layer is called the Application Layer. It directly links the lower Data Layer and the upper Service Layer. This layer provides all kinds of data models and algorithms via data analysis, data-mining, and data integrating and also provides the advanced programming interface (API) for its upper Service Layer. The Service Layer is the fourth layer of the system. It is the top layer and provides the user interfaces for computer programs with a distributed data-sharing and information service. Furthermore, during the process of the construction of the gas hydrate information system, we focus on two kinds of support work: technology supports and management and policy supports. Fig. 1 shows the general framework of construction of a natural gas hydrate information system.

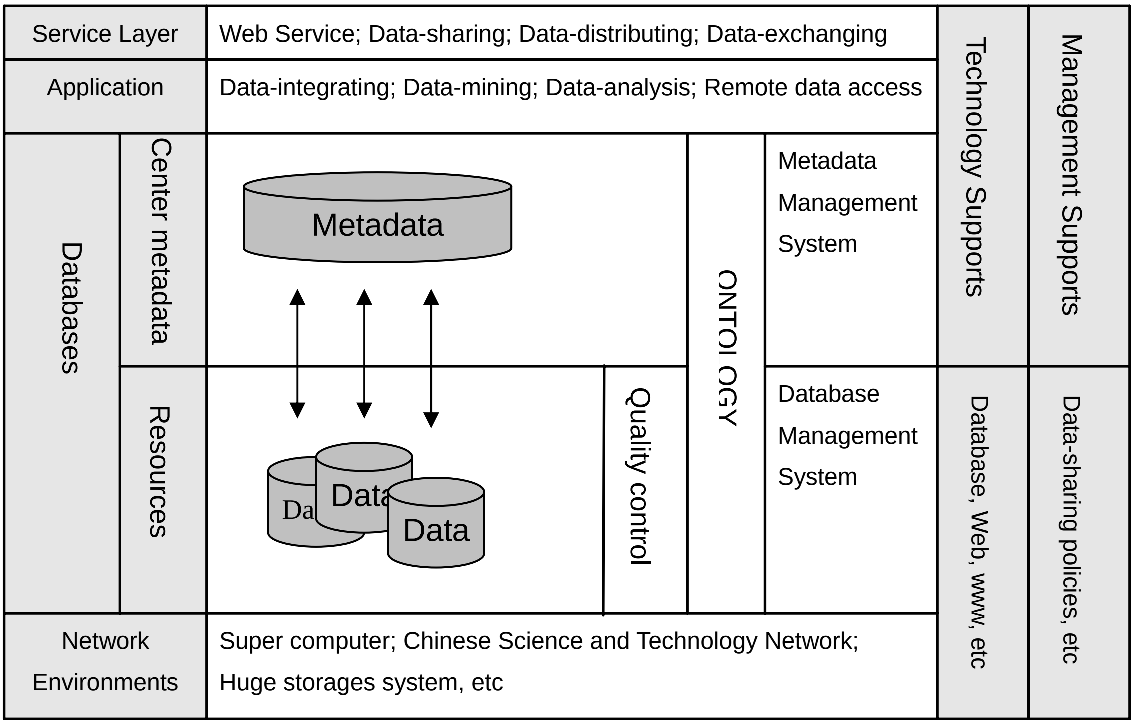

Figure 1. General framework of construction of a gas hydrate information system.

3 SYSTEM PLATFORM AND FUNCTION DESIGN

The gas hydrate information system platform needs to provide data services and support for natural gas hydrate researchers, model-based basic research on natural gas hydrates, a virtual research environment for exploitation and application research, and use JAVA middleware, metadata technology, XML related technique, WEB Service technology and GIS technology to construct the application services system. The system should include at least eight function subsystems: a data service subsystem, a data application subsystem, a databases or metadata registry subsystem, data harvesting and integrating subsystems, data import and export subsystems, a subsystem for system monitoring and controlling user access, a DBMS subsystem, as well as a system security control subsystem. Figure 2 shows the platforms and functionality of a gas hydrate information system.

3.1 Data Services Subsystem

This subsystem mainly provides data services to natural gas hydrate researchers and environmental policy makers. It provides a unified data access service interface, providing users with keyword retrieval and categories index services based on the ontology of gas hydrate science. The user only has to submit simple questions, and the intelligent agent function of the system will process and query according to the gas hydrate ontology, returning the final results to users. At the same time, the system offers users GIS retrieval and other data and knowledge services.

3.2 Data Application Subsystem

This subsystem uses modern computer tools to achieve basic research on natural gas hydrates and data models for applications and reserves. The system provides a virtual laboratorial environment for researchers that comprises the major user service functions together with a data service subsystem. The researchers can perform computer simulations of natural gas hydrate formation and dissociation, equilibrium simulation and prediction, 3D simulation, calculation of deposits, and simulation of exploitation processes, as well as visualization, etc.

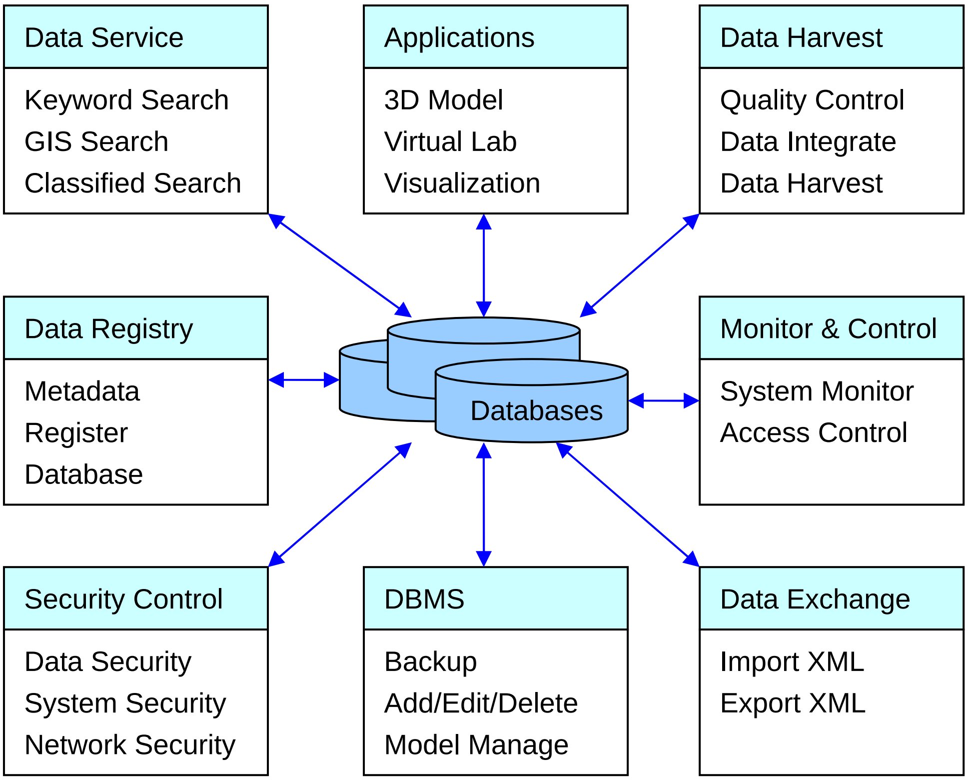

Figure 2. Platform and function of gas hydrate information system

3.3 Data Harvest and Integrated Subsystem

The Data Harvest and Integrated Subsystem automatically establishes the mapping from user database structures to the central metadata database structure, as well as automatically linking to user databases to acquire related data. This subsystem proceeds to make the necessary transformation of data automatically acquired from the user database after duplicate checking and imports them to the central metadata database.

3.4 Database and Metadata Registry Subsystem

All users (within the task team and outside the non-task team) can submit and register databases and metadata standards (in the form of XML SCHEMA) to the portal website via the Database and Metadata Registry Subsystem. This subsystem has two main functions: databases registry and metadata registry. The system can automatically integrate users' relational data bases according to database information or metadata information the user has registered and, finally, provides various data services and applications via the Data Service Subsystem and Data Application Subsystem.

3.5 Monitor and Control Subsystem

This subsystem primarily provides safe access to databases, ensuring the stable operation of the whole system by means of two functional modules: system monitoring and user access control. The system monitoring function records all data-based operation activities for users of the gas hydrate information system, including all the operations executed by the system administrator and data administrator. User access control adopts single-point log-on technology to provide hierarchical and classified management for users of the system and data, saving the records of all operations of users in the system, tracing how users used the data, and tracking and barring access of those users who maliciously attack the system or misuse data.

3.6 DBMS Subsystem

JAVA middleware technology, which is based on B / S mode, is used to manage the distributed DBMS Subsystem, the basic maintenance of databases (including adding, altering, deleting, and indexing data), the database backup and disaster recovery, as well as collect, manage, and integrate gas hydrate data based on a gas hydrate ontology. It also provides dynamic management of data models, making real-time additions and deletions to alter the data models.

3.7 Data Exchange Subsystem

In order to implement data exchange and sharing with international natural gas hydrate databases, this subsystem provides data import and export functions based on XML.

3.8 Security Control Subsystem

The Security Control Subsystem consists of three parts: data security, system security, and network security. Data security provides the ability to recover data when disasters occur. System security allows this system to recover from abnormal situations and records user operations. When this system restarts, it executes halted tasks. Network security prevents malicious attacks.

4 DATABASE DESIGN

In the course of over 20 years of constructing scientific databases at the Chinese Academy of Sciences (CAS), we have tried to identify the rules of database design and construction. We have accumulated a rich experience and worked out a set of standardized workflows for database designing. We have divided the designing of scientific databases into three stages: content analysis, construction information modeling, and database design. Stage 1, mainly involves experts in a specific domain and metadata analysts completing the metadata specification for a specific field of study. Stage 2 consists of metadata analysts and modeling experts using the metadata specifications from stage 1 as the foundation for constructing informational models of data for a discipline. Stage 3 involves information modeling experts and database designers decomposing and integrating information models to complete the design and construction of the database. The three stages supplement each other, and the previous phase is the precondition and foundation for the next stage. Fig.3 shows the workflow of the CAS standardized database designing.

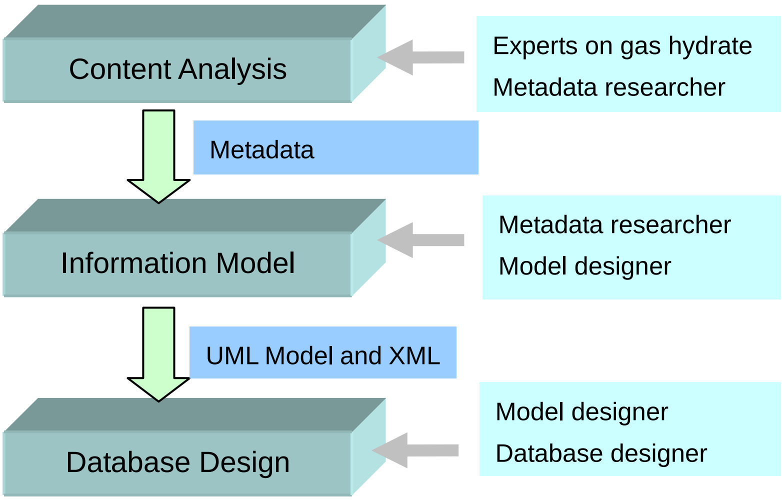

Figure 3. Workflow of standardized database designing

Gas hydrate research is an interdisciplinary scientific domain that includes geochemistry, geophysics, geology, geochemistry, physics-chemistry, etc. The data types of gas hydrates are complicated and generally can be divided into three types: numerical value data, factual data, and literature data. Numerical value data describe some features of gas hydrates in numerical value formats, such as equilibrium and crystal structure. Factual data come from geographic exploration, research of seafloor disasters, environment protection, etc. and consist of papers, reports, maps, charts, and files with special geography data formats. Literature data consists of papers, periodicals, books, and patent literatures related to gas hydrates. Basically they are a kind of factual data. It is necessary to make gas hydrate metadata specifications to describe such complicated and various data to provide technology supports for data integration and use.

By adopting the above workflow, we have analyzed the formats and characters of data on gas hydrates and then carried out a simple gas hydrate metadata specification. Following this specification, we have finished the design and construction of several databases on natural gas hydrates, including the central metadata collection, material properties, crystal structure, phase balance data, and patents. .

5 CONCLUSIONS

We have adopted JAVA and C3.NET based on the ORACLE9i database to construct the China Information System of Gas Hydrates (http://www.gashydrate.csdb.cn/), to realize the data service and DBMS subsystem. The system is at present comparatively small in scale, and the system functions need further improvement. Many policy and technology issues need to be studied and discussed, and more international exchanges and cooperation are required to jointly push the construction of a global gas hydrate information system and promote the domestic and international sharing of the gas hydrate information resources. Such cooperation provides strong data support for China and the world in the study and survey of gas hydrates, as well as providing technical support for the policy makers of environment protection and related researchers.

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