FOUNDATION FRAMEWORK FOR CITY UNDERGROUND SPATIAL DATA

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ABSTRACT:

The foundation framework for underground spatial data aims to establish the platform for the underground spatial data sharing and integrating. The reasons lie in that: a) the long-term development of city construction has accumulated abundant underground spatial data and information; b) the development and utilization of city underground space demands for clear, detailed and visualized comprehensive city underground information. Based on the analysis of the characteristics, the foundation framework for city underground spatial data can be established by taking the regional geology data as its background, bedrock borehole as its skeleton, Quaternary borehole as its brace, engineering borehole as its contents and other data captured as its complementarities. Some key issues, such as multi-scale, multi-semantic, data dynamic updating must be solved. The foundation framework for urban underground spatial data offers not only uniform spatial coordinate and semantic system, but also the platform for comprehensive displaying and analysing the spatial data to support the mineral resources exploitation, geological disaster precaution and the urban underground space exploitation, plan, development and utilization.

1. INTRODUCTION

Digital Earth, Digital City and Digital Ming (Wu etc., 2000) demand for three-dimensional geo-scientific spatial data integration and integral visualization. For the difficulty and high cost to capture the underground spatial data, it is necessary to integrate all the underground data to comprehensively analysis and describe the characteristic and relationship of the underground spatial objects. Many times the need for data integration is so demanding that it does not matter if some details are lost, as long as integration achieved (Frederico T., 2001， 2000), because “we have a lot of data but we are information poor (Nghi, 2001)”. The spatial data integration needs the foundation framework containing variety kinds data (NSFC, 2001). The general three spatial data framework is the basic for the underground spatial visualization (Simon, 1994).

However, the researches on general spatial data foundation framework usually pay attention to the geographical spatial data foundation framework. It aims to set up a uniform space-time positioning criteria with the characters of three dimension, dynamic, practical and high precision, so as to achieve the seamless integration for the multi-source data (Chen, 2002). The research on the foundation framework for city underground spatial data was neglected. This paper discusses the necessity to establish foundation framework for city underground spatial data as well as its characteristics, main contents and key issues. Besides, the application and value of the foundation framework are discussed.

2. NECESSITY OF THE FOUNDATION FRAMEWORK FOR CITY UNDERGROUND SPATIAL DATA

The spatial data framework from global, national to the regional scale, prefers to the foundational geographical spatial data. The foundational framework data mainly includes the contents, such as topography, geographical name, administration bourn, road traffic, water system, land cover, cadastre, habitat and remote sensing image et al.. It contains the two or three dimension geometry, attribute and correlativity information on the nature, economy, human culture and environment. The foundation framework can help the people to integrate, to retrieve and to show the interested information on nature, economy, human culture and environment according to the geographical coordinate and spatial location, and to analyze and to simulate the spatial distribution features, operational conditions and changing tendency (Chen, 2002; Chen, 2001; Chen, 1999).

For the spatial data foundation framework to have general sense, it should include the underground spatial data. According to spatial cognition, each data belongs to certain spatial level, namely over-ground, surface and underground. The traditional foundation framework only includes the data of two spatial level, over-ground and surface. The underground data are missed or neglected. But actually, the three spatial levels are spatially correlated and interacted. If any level of spatial data is missed, the geographical spatial data framework must be imperfect.

The reason for the establishment of foundation framework for the underground spatial data includes:

Firstly, the city has accumulated abundant data and information, which provides for the data basic for the framework. Limited to many factors, such as data capturing method, cost and technique, the collection of the underground spatial data is much more difficult. The size of data set is the key to establish the foundation framework of underground spatial data. The data and information include city geology, underground engineering, civil defense engineering etc..

Secondly, the exploitation and development of the city underground space and the precaution of the city geological disaster are the motivation to establish the framework. Because of the complexity of the spatial geometry shape and the relationship between the underground spatial objects, it is difficult for the data captured by the single method to reflect exactly the existence condition and distribution of the underground objects. The key to solve the problem is to integrate all the underground spatial data based on the foundation framework. Only if the data are integrated, the structure, stratum, mineral distribution, underground water, underground engineering facility and underground construction condition can be understood well. It is important to guarantee and to provide technical support for the exploitation and the development of the city underground space and for the precaution of the city geological disaster.

Only in condition that the uniform foundation framework for city spatial data is established, the spatial precision of the underground irregular objects and its attribute accuracy could be reached. It means that all the information items, such as sample value, observation value, body data and variable data, must precisely locate in the orthogonal coordinate (Simon, 1994). Then, it would be possible to establish the spatial data-integrating model to effectively express the geo-characters and geo-process. The data-expression consistency, data-system consistency and content consistency on the same space level (Li etc., 2001)is important during the process of the cognition.

3. CHARACTERISTIC OF THE CITY UNDERGROUND SPATIAL DATA FRAMEWORK

The foundation framework for city underground spatial data sets up not only the uniform locating system for the underground spatial data, but also a platform for spatial data to analyse and visualization. Comparing to the geographical data and map data, the city underground spatial data is much more complex for the variety of the data capturing methods, the discrepancy of data explanation and the contradiction of data sets. The data sets of city underground include not only the geological investigation data, topographical surveying data, remote sensing data, borehole data, geophysical data, geo-chemical data and hydrologic data, but also city underground pipe network data, city underground engineering data and underground civil defence data. All the data have different spatial expressional contents. For example, the borehole data and profile data emphasize particularly on the vertical distribution of the spatial objects, while the hydrological contour map, city underground pipe network distribution map and civil defence distribution map emphasize particularly on horizontal description of the spatial objects. Besides, the geophysical exploration data is another important data set, which has the three-dimension character.

The characteristics of the foundation framework for city underground spatial data include:

a) Three dimensional: the city underground objects distribute along not only the vertical but the horizontal direction, as in figure 1. The roof and the floor contour maps of rock stratum are overlapped and its boundaries are enveloped to form a digital three-dimension stratum. For the traditional geological methods, the exploration information is projected to a two-dimension plane so as to obtain an isoline map, contour map, profile and comprehensive histogram. Here, the three dimensional geo-objects are turned to two-dimensional object and its third dimension elevation is treated as attribute information. This not only makes the spatial data spatio-temporal non-sequence, which causes the spatial data to be multi-semantic (Li etc., 2001; Lu F etc., 2001), but also make it difficult to divide and to describe the spatial objects (Chen, 2002).

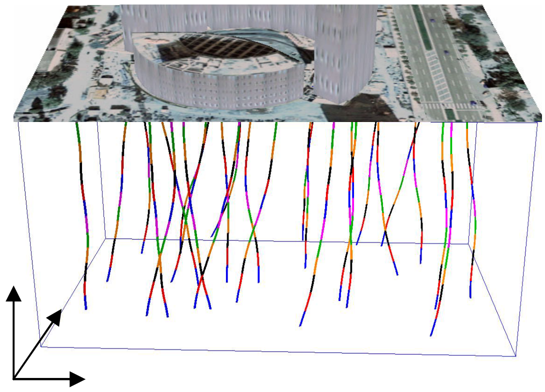

Figure 1. Three dimension body of the borehole data set

b) Dispersive: limited to the methods, techniques and device to capture underground spatial data and to the complexity of the distribution of the underground objects, the underground data is dispersive. In most situations, the underground object have to be geometrically simplified represented. For example, a point is used for representing a line, a line for a surface and or a surface for a body. Besides, the underground data at the un-sampled district have to be deduced by the sampled data with the geo-cognition as the premise and the geo-law as the reference. In fact, both in the geological research field and the geo-science three-dimensional modelling domain, the deduced data is a kind of important data.

c) Grey: Even if the underground space is a black box with distinct information, but the limited captured data by different methods make it to be a grey box with indistinct information. Up to date, it is much more difficult and impossible to get fine data as precise as that of human body in medicine study. For geo-spatial data, the sufficiency and completeness of the data so-called is defined according to the certain reference criterion or work purpose. The foundation framework for city underground spatial data is a reference criterion, which control the integral characters and tendency of underground spatial objects and neglect the particular features of individual geo-object.

4. CONTENTS OF THE CITY UNDERGROUND SPATIAL DATA FRAMEWORK

As in figure 2, the foundation framework for city underground spatial data takes the regional geology data as its background, bedrock borehole as its skeleton, Quaternary borehole as its brace and engineering borehole as its contents, and other data as the complementarities.

The regional geology data mainly include topography, geomorphy, water system, mine resource, rock distribution, geological structure, soil, traffic and boundary, which is the background content. It is the indivisible component of the national basic geographical framework, and is also the bridge to connect foundation framework for city underground spatial data.

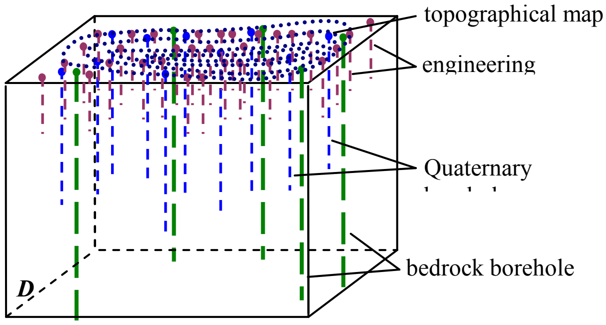

Figure 2. Scheme of city underground spatial data fundamental framework content

The basic borehole generally refers to the deep geological resource exploration drill and hydrological drill, whose goal is the geological general investigation or resource prospecting.The borehole data reveal the information such as stratigraphic sequence, geological structure, magnatic intrusion, mine resource distribution and so on. These kinds of borehole have great drill footage, and rich stratum information. Because of the high cost, except for the mine resource developing districts have dense drills; generally deep drill hole is sparse, as the green line shown in the figure 2. In a word, the data of basic borehole act as the skeleton of the foundation framework for city underground spatial data in that it controls the large-scale geological structure, stratum distribution, mine resource distribution and groundwater resource distribution in the city area.

The Quaternary period is the special geological period related to human civilization and human community. The Quaternary stratum, especially the continental deposit, is the important place for the evolution of human community. The Quaternary borehole data not only record the general borehole informationsuch as stratum information, period, embedded depth and the depth of stratum, lithologic profile, lithologic description, depositional sequence and sedimentary facies, but also record the test information such as palyno-combination, clay mineral, chemical analysis, geochronology, paleomagnetism etc.(Yu J etc., 2004). In the city area, these kinds of borehole are denser than basic borehole, and contain more abundant information. It can be taken as the brace of the foundation framework for city underground spatial data.

Large-scale engineering have accumulated a lot of materials and data by way of the engineering borehole. The engineering borehole data not only include the basic engineering-drill information such as drill site, borehole elevation and lithologic character etc., but also include rock and soil mechanics parameters such as water content, void ratio, modulus of compression, cohesive force and coefficient of permeability etc.. The drill footage is sallow and the distribution of is dense, because these kinds borehole guide directly the practical engineering constructions and impact human being's common life and production activity. Therefore, the engineering borehole data is an important content of the foundation framework for city underground spatial data.

Because of the great precision of the borehole data, which directly reveal the underground space information, it is the reason why the borehole data is chosen as the chief contents of the foundation framework. Anyway, other data captured from Geoengineering, Geophysics and Geochemistry method could be acted as complement. The frame data mainly control the integral characteristic and tendency of the underground space information, and the complement data describe the detailed information of the underground objects.

5. KEY ISSUES OF THE CITY UNDERGROUND SPATIAL DATA FRAMEWORK

The characteristics of the foundation framework for city underground spatial data determine that it must be established on the three-dimensional geo-science platform. The basic of the framework is the borehole data. Ususally, the relationship of the drills cannot be completely reflected at the two-dimension plane, which only describe the relationship of the borehole at the same profile, as showing in the figure 3. For the expression of the complex underground objects and their relationships, it is demanded to understand data relation between the borehole and the others surrounded it, as in figure 1. The integration of spatial representations is seen as a central task for the integration of 3D data (Breunig, 1999). The foundation framework for city underground spatial data, which acts as the platform for spatial data integrating and sharing, should meet the necessary of the four goal-levels of 3D geosciences spatial modeling (Wu etc., 2005). That is to say, 3D modeling techniques, 3D visualization and 3D spatial analysis is the key issues, which determine the establishment of the platform. Although present geo-science modeling techniques can achieve the functions such as simple visualization, spatial measurement and geo-statistics, it cannot yet support the engineering design,

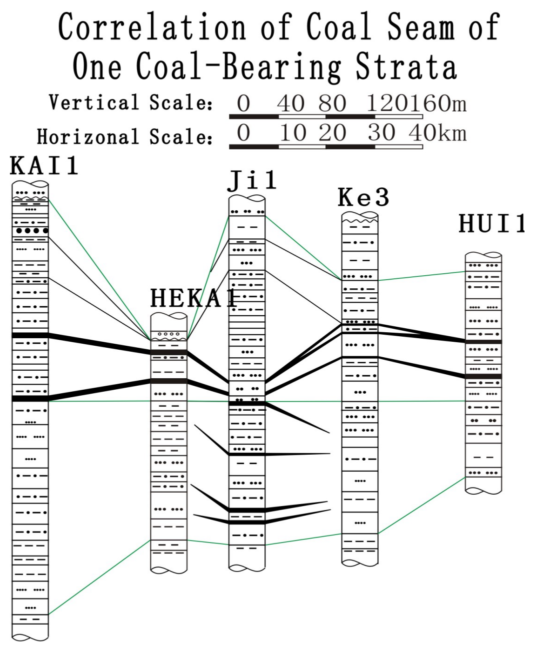

Figure 3. Data relationship and the scale of the borehole

underground spatial analysis and the dynamic updating.

As in figure 3, two spatial scales in vertical and horizontal direction must be marked on the map in either 2D or 3D environment. The geo-spatial objects and phenomena present varieties shapes and structures, which should be abstracted into different scales according to the shape of themselves or the practical necessary. The shape and structure of the underground objects vary in different direction. For example, most strata have planar shape, and the depth is named as thinness as related to the planar. The scale in vertical direction is different with that in horizontal direction. For example, as to the "correlation of coal seam of one coal-bearing strata "in figure 3, the vertical scale is 1:2000 while the horizontal scale is 1:500000. Therefore, different scale, even the great difference, may exist together in the same environment. This brings confliction with the traditional scale problems, such as multi-scale diversion, endless zoom, and information extraction under different scales. On the one hand, the long-time production activity have accumulated abundant data and information for the establishment of the framework, on the other hand it cause the new problemfor data updating. For the high cost of techniques and finance, usually a particular project t collects only certain data with certain method. Although the data can be complement to existed data sets, it maybe contradicts with them. A lot of data and information are deduced by the real exploration data and information. The accuracy and the preciseness of the deduced data fully depend on the original data and the experience and knowledge of the operators. So the new exploration data maybe verify or overthrow the formerly deduced data. That is to day, the updating of the city underground spatial data is not the simple operation, adding or updating, but to solve the data contradiction and correct the error information and data. Hence, the traditional spatio-temporal data model cannot be applied for the dynamic updating and historical data record of city underground spatial dataA new spatio-temporal model should be developed to meet the characteristics of underground spatial data characteristic.

Usually, the underground objects are the simple objects with large-scale shape. The objects for topological operation are usually the simple objects or the complex objects composed of simple objects. Anyway, traditional researches on spatial topological relationship are based on four geometric elements, i.e., point, line, face and body. The topological problem should be researched deeply, such as topological query and analysis between the simple objects, simple objects and complex objects, complex objects. Besides, some problems on the completeness, consistency of the topological relationship, topological optimisation, the definition and expression of the new topological relationship, the design of the new topological storage structure should be focused on.

6. VALUE OF THE CITY UNDERGROUND SPATIAL DATA FRAMEWORK

The foundation framework for city underground spatial data is not only a platform for the uniform coordinate, semantic expression and data integrating, but also a platform for the comprehensive display and analyse on underground data.It provides an effective way to integratemulti-source data to control and to analyze the geological structure, stratum, mine resource and ground water distribution, and helps to decrease the exploration cost, to cutthe blindfold investment and to lower the investment risk. Besides, the framework can also help to figure out potential city geological disaster, and support to the precaution, prevention and cure of city disaster, especially geo-based disaster.

In a word, the foundation framework for city underground spatial data not only support the underground mine resource development and groundwater protection, but also set up a basic platform to support the assessment of urban underground space, city planning and engineering design. It can further guide the scientific utilization of urban underground space and city establishment, and serve for the city sustainable development.

7. CONCLUSION

The background of the foundation framework for city underground spatial data is the geographical spatial foundation framework. It is the complement for the geographical spatial foundation framework. The basic theory and technique determined by the characteristic of city underground spatial data framework, i.e., three dimensional, dispersive and grey, are different from that of traditional information framework. For the borehole data have better precision, it is taken as the chief contents to develop the framework. According to the drill types and data content, bedrock borehole, Quaternary borehole and engineering borehole are respectively taken as the skeleton, brace and contents of the framework. Although, as part of digital city and digital mine, correlative researches have achieved a lot, the research on the foundation framework for city underground spatial data is at the starting line. A lot of theoretical and technical issues waiting for solving, including the bridge to connect with the geographical spatial foundation framework, the foundation database system, the network exchanging service system, the data policy, the data rules and standard system, and the organizational structure system.

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