RESEARCH ON THEORY AND TECHNOLOGY OFGEO-SPATIAL INFORMATION GRID

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1 Introduction

Cartographers have been long acquainted with geo-spatial information grid which is a position service including ancient measure method using mile square and recently UTM grid in America.

Traditional data access can not satisfy well the needs of user. While users want a worldwide position service, traditional product (paper map and image map) is only available with some a scale or a resolution. Now there are abundant digital cartographic products, an effective data management method is necessary for the integrated display of worldwide data with kinds of scale and resolution. Such a method can not work out using traditional map subdivision or image subdivision but a series of work involved with more effective coordinate reference of single origin point, common ellipsoid surface of the earth, data subdivision and meaning unification of spatial data.

Meanwhile the service mode of cartography changes with the development of information technology. Such as grid environment, platform of different structure, and distributed storage promoted the service platform of geo-spatial information grid. But the short of safety protection procedure put the stand-alone platform service into a great difficulty.

This paper studies the organizing and expressing technology of geo-spatial information in grid environment using computer grid.

2 Combined Division Method of Global Geo-spatial Information Grid

Traditionally, geo-spatial information is organized by map scale, longitude and latitude based-on map projection and is divided by map sheets. Such data structure can not satisfy geo-spatial information service over a network. Hence it is necessary to break the limitation of traditional 2D projection and scale to facilitate the research on multi-level structure of geo-spatial information grid which is based on geocentric coordinate system (and earth ellipsoid surface). Only by such research, geo-spatial data can fulfill better the information requirement over a grid network.

The core of geo-spatial information grid division is: to divide the global space into grids of different level of details and set a covering relationship between neighboring levels.

The ways of grid division of the earth surface are mainly categorized into 2 groups:

One is the global discrete grid system. It is arranged by polygon level and divided by regular shape. Octahedral-Quaternary Triangular Mesh and Sphere Quad tree are typical of this kind. Their characters are the seamless division of the earth surface and multi-level layers. Such characters can avoid the influence of projection on global spatial data and make every grid isotropical.

Another is to divide the surface using geographical coordinate system, such as ellipsoidal quad trees and global quad trees system.

The division method based on polygon can create grids that are similar in shape and isotropical. But the mapping between polygon and sphere is complicated. It costs much a lot to transform from kinds of coordinate system to such grid data. While the grid research based on geographical coordinate system is relatively simple. And it is convenient to transform from kinds of data to the grid data that is divided by longitude and latitude. Because the area differences and shape differences between the grid in high latitude and in low latitude is great.

Our solution is:

To divide the grids using normal cylindrical equidistant projection if the latitude is lower than 45 degree. The grid coordinate (x, y) is a simply linear function of longitude and latitude. On the projected plane, the distance is equal if the interval of latitude or longitude is equal. The layer spacing is diploid in the multi-layer grid. The layers are arranged by quad tree and it is convenient to combine a large amount of map data with a variety of geographic data.

To divide the grids using polar azimuthal equidistance projection f the latitude is higher than 45 degree. This division method is advantageous for the management of the data in the two polar. The surface of projection is a tangent plane of the polar area. The grids form polar-concentric circles and the distance is equal if the interval of latitude is equal. It avoids the data redundancy caused by the division of equal latitude or longitude interval. In order to manage the data effectively the projection coordinate should be transformed to square.

As shown in Figure 1, this solution takes advantages of the both projection methods and divides the earth surface into 6 basic parts including 4 parts of rectangular grid between latitude of 45 degree north and 45 degree south and 2 parts of triangular grid in two polar.

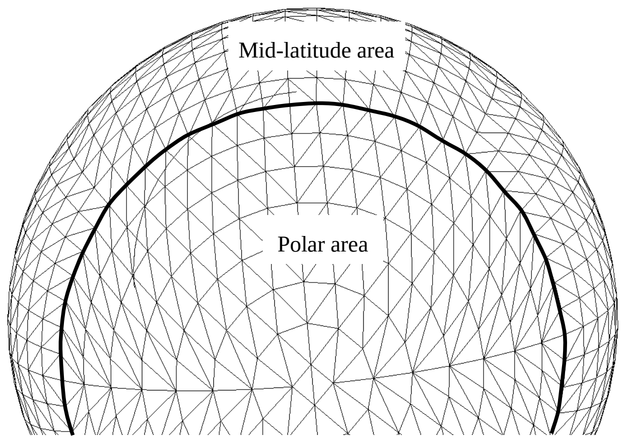

Figure 1 Continuous display of data in mid-latitude area and polar area

To store global geo-spatial data by this grid division method can deduce storage space 25% less than the division using equal longitude and latitude. And it improves the data management and rendering ability and facilitates the network transmission.

3 Technologies of Transformation from Traditional Geo-spatial Data to Geo-spatial Information Grid Data

It is hard for different kinds of spatial data to form a unique access of spatial dataset for users. The 4 drawbacks of geo-spatial information service over network are: different spatial reference system; different data format; different semasiology; and different temporal reference system. These 4 drawbacks and the unique access must be handled to realize “offering service according to the user’s requirement”.

3.1 Coordinate Transformation of Spatial Data

It involves a lot of theories and technologies such as transformation between different map projection or different zone division, transformation among different 3d rectangular coordinate system, different 2d rectangular coordinate system and different curve coordinate system to assign coordinates of different coordinate system, different map projection and different spatial reference system to a pre-defined geo-spatial reference system. The coordinate transformations can fall into 2 kinds according to the spatial reference system it referred to: one is the transformation of the same spatial reference system viz. inner coordination transformation; another is the transformation between different spatial reference systems.

3.2 Semasiological Expression of Spatial Data Based-on Ontology

It is far not enough to just using semasiology to research the share and inter-operation of geo-spatial information. So we introduced ontology to the characteristic of geo-spatial information to categorize geo-spatial information and built an ontological geo-spatial information model.

The semasiology of spatial data is defined by professions. And the isomeric semasiology is deduced from the relatively independent conceptions of different domains. While it is default in some a domain, users of the other domains may misunderstand or be unable to understand it. In order to enable the communication based-on semasiology between users of different domains we introduce the ontological theories of semantic element parser and conception grid as tools to record and describe the conception system of different domains, and to express explicitly and formally the abstract rules and description rules that is default or implicit in professional domains. This process is fundamental for the semasiology-based integration and inter-operation of geo-spatial information system.

The ontology-based arrange of spatial data is to add a logical layer which is a description table of geographical ontology to the data model. The description table of geographical ontology takes the geographical entity of primitive data as description unit, set the unique ID of each geographical entity as a pointer that links the corresponding geometric attributes including points, lines and areas. By this way the relationship among basic semantic element, meanings and topological relation is set up. The advantage of this method is to keep the primary data unchanged and facilitate the transform the primitive data to ontological data.

3.3 Integration of Spatial Data Format

There are mainly 3 integration modes of multi-source spatial data: data format transformation mode, data inter-operation mode and direct data access mode.

Data format transformation mode means to transform the data of other kinds by specified transformation program to the designated format and copy the data in database or file system.

Data inter-operation mode means that users acquire information they need in databases of different structures and distributed computation. OpenGIS consortium (OGC) made uniform rules of data inter-operation. This made the support of different spatial data formats possible.

Direct data access mode means to access and analyze the data of other software formats directly in GIS software.

In the integration of spatial data format, the complicated attribute data can be handled by metadata and geometric data by data intermediate. In the integration of vector data format there are some rules that must be obeyed: maintain the format of data attribute and the integrality of data items; integrate the data using non topological structure.

3.4 Description of Temporal Feature of Spatial Data

Spatial and temporal change is an essential character of geographical entity and phenomenon. The design of spatial data model in traditional geo-spatial information service neglected the spatial and temporal character of geographical phenomenon. The influence of time over spatial data includes: the spatial data that describe objective world change as time passes away; the spatial references change as time passes away.

By controlling the timestamp-based edition of spatial data we can set multiple datasets for one region. When user asks for the spatial data of specified time we can offer the spatial data of that time or the proximal time.

We add the issue time as a timestamp to the spatial references such as geodetic coordinate system, coastal zone, and altitude datum. When we store spatial data into database, the timestamp of spatial reference is stored as metadata of spatial data.

4 Geo-spatial information Service Based-on Distributed Computing Grid

4.1 Database Creation of Geo-spatial Information Grid

The database of geo-spatial information grid comprises three parts: spatial data storage server, metadata catalog server and load balance server.

The spatial data storage server deals with all the interaction between client and physical storage. It stores all the spatial data in physical storage device in object-based mode and manages them. The whole distributed storage system of geo-spatial information may be made up of many storage servers that is distributed over the local area network, located in different place, belonging to different unit, and managed by different administrators. Client computer and metadata server can access every storage server through standard TCP/IP communication protocol or the protocol designed by our system. In order to improve the parallel speed of the access of spatial data, we can divide a spatial data file into server data lines by file division program and then store them by RAID algorithm in distributed server.

Metadata server deals with the management of metadata. It creates and manages the file distribution view by which user can access spatial data objects. Through the management of the access of file and catalog by metadata server, the distributed parallel storage system of spatial data can control the user's manipulation of file system and catalog including creation, deletion, and modification of file or catalog. Once be connected with the virtual storage system, users can access data they want directly. No connection with metadata server will be made again except that user want to modify the naming space. The load of metadata server can decrease by doing that.

There must be a good load balance server cluster for the distributed parallel storage model of spatial data. The cluster should assign the load appropriate for the number and quality of server nodes. This is a good way to realize the efficiency of high-end server by low-end servers. The distributed parallel storage model is built upon many control servers and real spatial data servers. The real spatial data server is actually responsible for data provision. The load balance server assigns the wide area network users' IP-based requests to the real spatial data servers.

4.2 Geo-spatial information Service in Grid Environment

Technically the grid service can be understood as an application program. Its interface can be called by on any platform, in any operating system, by any program that is coded in any program language. The specification of OGE Web service specifies the interface of Web service operation. So the realization of this interface is crucial to the creation of the application program of Web service.

The technical routine of the creation of geo-spatial information service is shown in Figure 2. It is made up of 3 parts:

Part 1: geo-spatial information component based-on COM+ packing. It packs the functions of geo-spatial information service such as map drawing, spatial data engine into COM+ components, and registers them in COM+ container for user's calling. It can make direct use of present work. And by taking advantage of object container of COM+ component, the efficiency of geo-spatial information component is improved.

Part 2: a service issue layer which is made by packing the COM+ based geo-spatial information component into geo-spatial information service according to the OGC specification. It means to construct a geo-spatial information service based on WSDL.

Part 3: transform the service based on Web Service to the geo-spatial information service based on WSRF in grid environment. WSRF.NET is an implementation of WSRF specification on Microsoft .NET platform. It also has some features. It supports 2 kinds of service: Web service resource which is created by Factory mode and obeys WSRF specification totally; light weight service which has partly interface of Web service resource but no internal status data of itself.

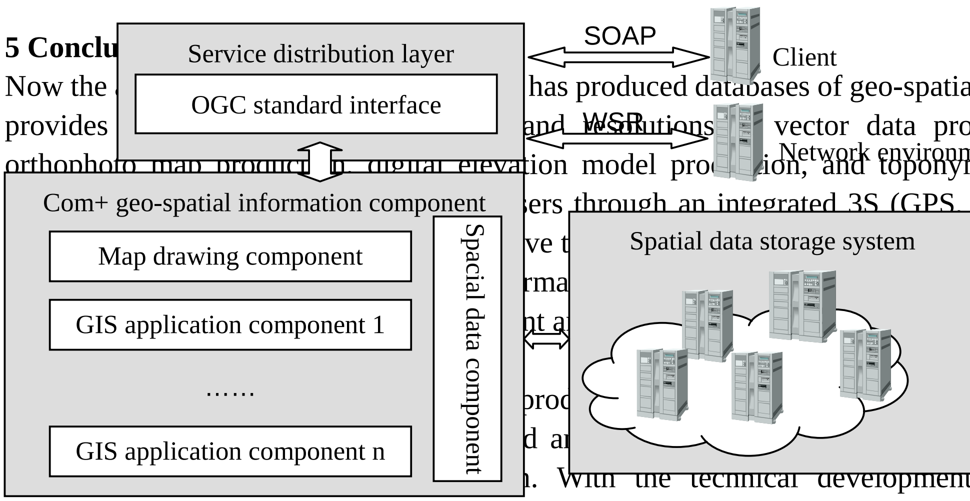

Fig.2 Construction of geo-spatial information service

5 Conclu

Now the has produced databases of geo-spatial data. It provides and resolutions vector data production, orthophoto map product digital elevation model prod ion, and toponymic data sers through an integrated 3S (GPS, RS, and ve t l data at rma sionally nt a

prod ized the d a to the . With the technical development of the geo-spatial information grid it is predicted that there will be a change on the application mode of geo-spatial information in 2015 and 2020.

In 2015, being possessing data will be replaced by being provided with service. At least 50% of geo-spatial information users can get geo-spatial information service from network without possessing a lot of production of geo-spatial data. They will not need to care where the geo-spatial data is stored and who manage the geo-spatial information service.

In 2020, the being provided with data service will be replaced by being provided with knowledge service. About 80-90% of geo-spatial information users can get geo-spatial information service from network without possessing a lot of production of geo-spatial data. The user’s require of geo-spatial information will change into different levels. More users will transfer their need from data service to knowledge service. The function of geo-spatial data providers will change into 2 parts. One is for geo-spatial data update. The other is for spatial knowledge mining and abstraction from geo-spatial data. And there will be more platforms for data mining, knowledge service and online customized service.