IS GEO-SERVICES READY? ----ON GENERALIZED AND SPECIALIZED SPATIAL INFORMATION GRID

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ABSTRACT:

After the setup of spatial data infrastructure (SDI) and national information infrastructure (NII) in many countries geo-services become one of the most important and attractive tasks. With the integration of GPS, GIS and Remote Sensing (RS) we can principally answer any geo-spatial related question: when and where what object has which changes? An intelligent Geo-service agent would provide the end-uses with the most necessary information in shortest time and lowest cost. Unfortunately it is still a long way to reach such demand. The central component in such Geo-Services is the integration of spatial information system with computer grid via wire- and wireless communication networks. This paper will mainly discuss the grid technology and its integration with spatial information technology, expounding potential problems arisen and possible resolutions. A novel categorizing of information grid in the context of geo-spatial information is proposed: generalized and specialized spatial information grid.

1. INTRODUCTION TO GEO-SERVICES

Much progress is being made in the field of geospatial data acquisition and utilization. However, in many cases these is not fully utilizing such spatial data and information, partially due to the fact that they are acquired and managed by independent public sectors, which provides individual services to particular users. The importance of SDI information sharing across different organizations has been recognized by both governmental agents and private sectors, effective approaches to mine adequate and useful information from them are still lack.

The backbone characteristics of geo-services aim at providing basic services to those who mostly need them. These end users may distributed over different public sectors in different regions, and in some cases they may globally distributed such as the member countries of CEOS. In Vogele, T., etc (2003), they summarized the following four types of basic geo-services in the context of Geo-Share Project carried out by United Kingdom, Germany, Norway and the Netherlands:

Web Map Services (WMS): a Web Map Services produces map renderings of geo-referenced data. It is important to note that a "map" in WMS is simply a visual representation of geo-data that does not contain the data itself. A map may be rendered by WMS in raster based image format or as vector based graphical elements in the Scalable Graphics and Computer Graphics Metadata File formats. The Web Map Services Specification is an approved specification by Open Gis Consortium (OGC).
Web Feature Services (WFS): a Web Feature Service provides an assess to geospatial data stored in a geo-databases through stateless HTTP requests. The results of such requests are returned in GML format, an XML-based geospatial vector data exchange format. Like WMS, WFS implements an approved OGC implementation specification.

Geodatabases: the related geodata have to be stored in geodatabases as for meaningful WFS and WMS integration. Currently available geodatabases overcome the separation of geometric and attribute data and the object-relational schema used to modeling is much closer to OGC concept of geographic features.

The intelligent category services: it plays an important and central role in GeoShare Network. It is used to manage the metadata descriptions of services, datasets and data collections in the network. The ICS is thus will provide a detailed inventory of all registered resources, and queries to ICS are the basis for the retrieval and selection of task-specific data and services.

Besides web-services there are many tools for LBS (Location based Services) and MLS (Mobile Location service) through mobile communication networks. Fig.1 shows its configuration and several application interfaces.

In order to meet the basic pre-requisite of above mentioned geo-services, at least the following listed problems need to be solved:

- The mechanism and approach with which intelligent services provided, including the modeling of intelligent services work flow, tasks allocation, intelligent search and system structure of intelligent services platform
- The standard of spatial information services and interoperability. With such standard, interoperability across information boundaries becomes possible;
- The semantic model of spatial information services. This includes ontology based semantic model and spatial information service mode
- The implementation of spatial information services on different terminates, such as notebook computer, mobile phone, palm, TV set, telephone, desktop computers, etc.

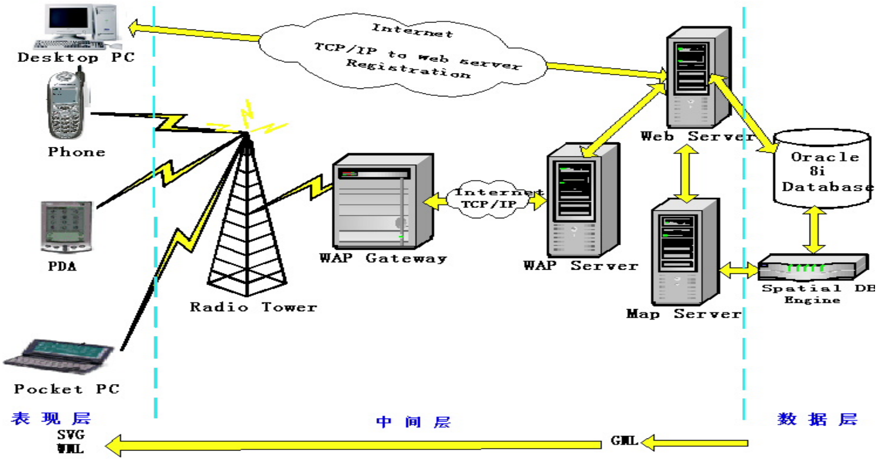

Figure 1. System configuration of LBS

The central component in such Geo-Services is the integration of spatial information system with computer networks. Due to the prosperity of information grid, it has been the backbone technique in the third generation of Internet. Spatial information grid aims at solving the above listed problems by the integration of grid technology and spatial information technology. This is believed to be the main trend of spatial information science in the next 20 years. The GEOSS-10 Year Implementation Plan passed trough by the Minister Summit from more than 50 countries and organized by GEO is the preclude of such a trend.

The key issue in such Geo-services is the automatic and real time transformation from sensor web through information extraction and knowledge discovery to intelligent service in order to provide the most necessary information to different end users with the shortest time and the lowest cost.

This paper will mainly discuss the grid technology and its integration with spatial information technology, expounding potential problems arisen and possible resolutions. A novel categorizing of information grid in the context of geospatial information is proposed: generalized and specialized spatial information grid.

2. GRID TECHNOLOGY----THE THIRD SURGE OF INTERNET

Grid technology has emerged as an important new field, distinguishing it from conventional distributed computing by its focusing on large-scale resource sharing, innovative applications and in some cases, performance orientation.

Three hierarchies can be defined in grid: computing grid, information grid and knowledge grid. Computing grid is the fundamental layer, providing infrastructure to higher levels, namely information grid and knowledge grid. Information grid will provide end users an intelligent processing platform in order of clearing up information isolated island, so users can distributing, processing and acquiring information easily. Knowledge grid will provide end users an intelligent process platform in order of clearing up knowledge isolated island, so users can distributing, processing and acquiring knowledge easily.

Current researches on grid technology mainly focus on grid computing, information grid and grid services.

Grid computing is a virtual and high performance computation environment by connecting various computers (include computer groups), databases, mass storage, peripheral equipments which are distributed in geographically different regions. Its applications include distributed computing, high input and output computing, collaboration engineering and database browsing. It can be defined as a "seamless integration and collaborated computing environment" across a wide region.

Information grid provides an intelligent data processing and information extraction platform to end users based on currently available network infrastructure, protocols, Web and database technology. Its object is to establish a new generation Internet-based information processing platform and software infrastructure, which is built above OS and Web. Within such a platform, information processing is distributed, collaborated and intelligent. Users can access all information by only one interface. The highest goal of information grid is to service on demand and to service by one-click-is-enough. The system structure, information representation, meta-information, information connectivity and consistency, information security etc. are research hot topics of current information grid.

Due to its potential innovative applications, research on grid technology is witnessing its prosperity. Industry circle as well as governmental division and academic communities are all pay much attention to it. The international organization OGSA (Open Grid Service Architecture) is now making service protocols and standards. An independent non-profit organization GCF (Global Grid Forum) is established for related research works.

In summery, grid is a new technology based on Internet, which merges high speed Internet, computers, large scales databases, sensors and remote equipments into one computing environment. It provides researcher as well as common users more resources, functionalities and services. People use Internet for receiving and sending emails, web browsing, while grid gives people more powerful functions for sharing computing resources, storing resources, data resources, information resources, knowledge resources, expertise resources and any other type of resources.

Grid is a type of infrastructure with resources sharing as its backbone characteristics. Grid computing in the other hand implements resource sharing and problem solving collaboratively among many virtual organizations. Grid computing is a new type of software structure, which organizes lots of low cost storage modules and servers into a virtual computation environment , using these resources effectively and transparently. Any node in the grid can share services such as data storage, computation, databases and location based services. Presently, grid computing is applied to many fields such as simulation, medicine, geosciences, bio-science and military and has achieved results much better than conventional distributed technology.

3. GENERALIZED SPATIAL INFORMATION GRID

3.1 Background

Human lives in the interaction of four spheres, namely lithosphere, hydrosphere, atmosphere and biosphere, ranging from space, underground and undersea. More than 80% of natural and social phenomena are closely related with spatial location. In order to acquire temporary changing geographic information, with information technology, communication technology, space-borne and air-borne remote sensing and satellite navigation positioning systems have been developed rapidly since 1970's, which at last leads to a new subject called geo-spatial information science (i.e. geomatics or geoinformatics) with GNSS, GIS and RS as its central components.

According to the ISO's definition, geomatics is "a discipline related to spatial data acquiring, measuring, analyzing, storing, managing, displaying and applying", it is belongs to information science and technology.
Fig.2 shows the airspace-borne spatial information systems

From Fig2, it is obvious that these systems can theoretically answer what changes of objects (what object) have taken place at what time (when) and what place (where). However, the state-of-the-art of spatial information systems can not meet the requirement of seamless integration and collaborative computing that grid technology requires, so it can not answer the above 4W yet. Main problems are the follows:

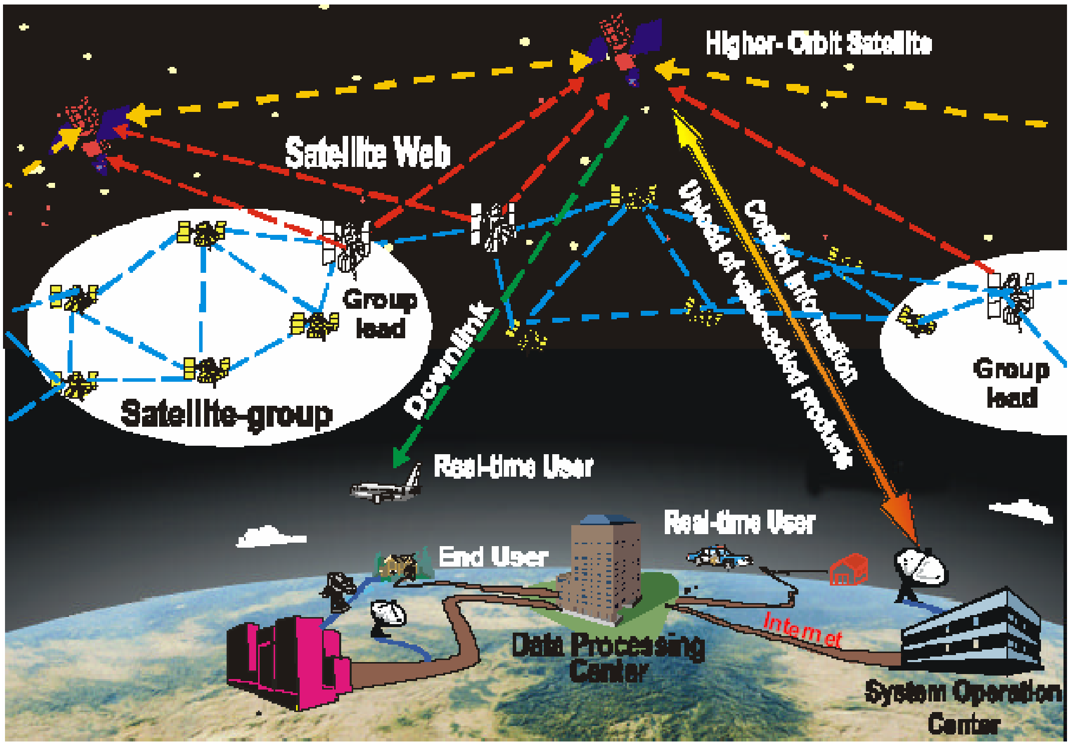

Figure 2. Aerospace-borne spatial information systems (from Zhou)

(i) The flow of data processing - information extraction - knowledge discovery - application services is serial and separately. Data acquires in point mode or area mode, none of them has the ability of on-orbit processing or real time computing. Information processing is carried out in a single computer with human-machine interaction. Data mining and knowledge discovery are still in naïve stage. Application services are isolated, lack of intelligent service in network environment.

(ii) The level of sharing and utilizing satellite resources is very low. There is still very difficult for intelligent data processing, information extraction and knowledge discovery both in theory and algorithm, leading to huge in data while lack of information.

(iii) Earth observation systems are usually isolated, lacking of multi-platform, multi-sensor, multi-resolution and multi-temporal integrated system

(iv) Lacking of application oriented grid system of real time satellite deployment, data integration, automatic information extraction and intelligent services. The integration of geospatial information system and communication system is not enough.

In order to solve them, the integration of grid technology with geospatial information system is presented as a salient problem, which leads to the generation of generalized information grid.

3.2 Definition and Tasks of Generalized Spatial information Grid

We give the following definition to generalized spatial information grid in the context of grid technology and geospatial information system:
Generalized spatial information grid is a kind of real time/near real time spatial information system supported by information grid. It runs in the environment of information grid with an integrated mode of data acquisition (from space-borne, air-borne and ground-based sensors), information processing, knowledge discovery and intelligent geo-services.

To establish such a grid, we face the following tasks:
(i) All weather, all time and all aspect spatial data acquisition by resorting to space-borne, air-borne and ground based sensors.

(ii) Seamless hinge from sensors to application service by resorting to integrated information grid made up of satellite communication, data relay network and ground based wire and wireless computer communication networks.

(iii) Implementation of quantitatively, automatically, intelligently and real-timely grid computing in the generalized information grid, extracting information and knowledge from data.

(iv) Intelligent services to any end-users, providing the most useful information to most eagerly needed users with most fast speed.

3.3 Basic Components of Generalized Spatial Information Grid

To accomplish the mentioned tasks above, a generalized information grid needs at least the following components:

(i) Smart sensor web

Current sensors are specific equipments for data acquisition, and usually task-specified. The raw data acquired are transferred to ground receiving station, processed by specific software system and retrieval information required by end users. Such a workflow is composed of separated processing units and many include human-machine interactions. Real time processing is impossible in such a workflow.

It is believed that an intelligent sensor web with lowest cost and combination of large and small scale should be established in the near future, with the development of sensor technology, computer hardware and software and communication technology. Such a web will be pervaded everywhere data acquisition is required. In Neil Gross (1999): “in the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies--even our dreams.” Vincent Tao (2004) proposed a conceptual framework of such a web, he pointed out that it should be interoperable, intelligent, dynamic and measurable.

In the context of generalized spatial information grid, we believe an intelligent sensor web should have the following features: (1) it is a network composed of touched or untouched sensors that is pervasive everywhere and possesses functionalities of data acquisition and communication,（2）it has the ability of on-board data processing so as to provide user-required data real timely,（3） such an intelligent sensor web should be embedded into global information grid and provides intelligent services to various users according to their specific requests.

(ii) An intelligent data-information-knowledge transforming system based on grid computing

The volume of data acquired by such a multi-sensor web is huge, from level TB to PB. To preprocess and post-process such data needs to extract both semantic and non-semantic information, as well as intelligently mines user required knowledge from them. The author had already discussed this issue about ten year ago and a recent review and further discussion was presented in 2004.

A salient problem in current Earth observation is “rich of data, barren of information, lack of knowledge”. Grid computing brings new prosperity for solving this problems, however, the following listed issues must be considered in the context of grid computing:

- Automatically and real-timely determine the space location and attitude of sensors under a unified spatial-temporal datum
- Mathematical modeling for reversing physical and geometrical features from data by both touched and untouched sensors, and unified methods for solving
- Real time updating and fusion of multi-sources spatial data;
- Intelligent information extraction methods and grid computing approaches for multi-sensor and multi-platform remote sensing imagery;
- Spatial data mining and knowledge discovery from huge volume spatial databases.

We have to break through key techniques of spatial-temporal datum, physical principle of remote sensing imaging, pattern recognition, computer vision and data mining in order of solving the above mentioned issues, to realize unified reversing physical and geometrical features and quantitatively, automatically and intelligently process data.

(iii) New generation of GIS suitable to grid computing environment

It is well known that GIS is a spatial information system that can acquire, store, manage, analyze, descript, display and distribute geographic and location related data. Data acquired by the intelligent sensor web described above will be the data source of GIS after they are preprocessed and information extracted. Knowledge discovered from them will form knowledge base of intelligent GIS.

As an information system for data storage, representation, analysis and application, GIS has been evolved from a single system to network system: WebGIS and mobile-GIS as two typical modes. The next generation of GIS should be Grid-GIS. In the next section we will discuss various problem arose from conventional GIS when it is embedded into grid computing environment.

(iv) Intelligent geo-service agents

The concept of geo-services has been introduced in section 1. As one practitioner of geo-services, Europe Space Agency made the Global Monitoring of Environment and Security Plan to promote sustainable development and global governance in Community territory and globally requires high quality, timely and independent information. The establishment by 2008 of a European capacity for GMES will contribute to securing the provision of such information. Such a capacity encompasses a wide range of information sources; making full use of Earth based in-situ monitoring capacities as well as airborne and space-based Earth observation. A typical example was the Earthquake rescue in Algeria 2003. By using SPOT image before and after the earthquake, ESA delineated the destroyed area quickly and estimated the population of people suffered from the earthquake, providing exact information for earthquake rescue. JAXA (Japan Aerospace Agency) also pays much attention to establish quick respond Earth observation system. Japan Fishery Information Center (JAFIC) provides fishery information to fishing vessels in the sea near Japan on near real time. They has set up a Decision Support System for guiding oceanic fishing by monitoring the change of oceanic environment, which influences the clustering of fish groups so as to delineate the location of them. Near real time applications with MODIS/AIRS using the EOS Direct Broadcast are widely used in USA for water quality monitoring, fire monitoring, air quality and polar winds by NOAA, NASA and many related organizations.

4. SPECIALIZED SPATIAL INFORMATION GRID

We referred specialized spatial information grid to the new generation GIS integrated with computing grid environment.
Geographic information represented by paper maps has a history more than several thousands of years. It is natural for people thinking about "digitized map" when digital computer appears, this leads to the approach of using points, lines, polygons and volumes in coordinates to represent spatial elements. However, digital map is not the unique way to represent spatial data in a computer, it is definitely not the unique way in information grid environment.

4.1 Challenges to Current GIS in the Computing Grid Environment

From the viewpoint of resources sharing and collaborative computing, though GIS has evolved from running in a single computer to Web GIS , Mobile GIS and Grid GIS, the following four issues can not meet the requirement of computing grid.

(i) Challenges caused by temporal datum inconsistency

It is true that different thematic information in the same region may be acquired in different times. These data cannot be overlaid simply, if only suitable interpolation or extrapolation models are used to transform the data sets into temporarily consistency. For instance, when statistical analysis should be carried out using datasets of land use, level of economic development, population etc. from different provinces, which are certainly acquired in different times and influenced by local or governmental policies, the first step shall be unifying these datasets to a common temporal datum.

(ii) Challenges caused by geodetic datum inconsistency

Various coordinate systems, projection types are used. In China, 54 Beijing coordinate system, 80 Xi'an Coordinate systems, geographic coordinate system and geo-central coordinate system are used simultaneously. There are still many local coordinate systems to meet different applications. Inconsistency of geospatial datum is obvious. When geospatial datum changes, all dataset attached should be changed at the same time.

(iii) Challenges caused by data format inconsistency

Geospatial data are acquired by different organizations using different hardware and software; this leads to various in data formats. More over, spatial data are very complex in relationship, non-structured, huge volume, multi-scale and time-dependent. All these give challenges to data sharing. Presently, interoperability standards are not operational yet, neither does data organization and management. Such a situation brings great difficulties for information sharing through information grid.

(iv) Challenges caused by semantic inconsistency

When experts from different disciplines interpret a remotely sensed image during setting up a professional GIS, it would get quite different explanations for the landscape involving in the image. Such differences cause semantic inconsistency. No correct results exist if we ignore this inconsistency. For instance, if a slope area with meadow and scattered trees is considered, it can be regarded as slope grassland in the eyes of an agronomist, while it is an adapted forestation area explained by a forestry expert. When integrate an agricultural information system with a forest information system, an ontology based semantic translator is needed to eliminate semantic gaps.

4.2 Definition of Specialized Spatial Information Grid and its Functionalities

We have to re-consider the representation of geospatial data in a digital computer if grid technology is concerned. It is obvious that digital map is not the unique way for representing. Innovative approaches should be further studied in order to solve the four inconsistencies mentioned above. For this objective, we proposed spatial information multi-grid (SIMG) and referred to it as the definition of specialized information grid.

The core of SIMG is: demarcating global and national wide into several layers of grid according to the size of latitude and longitude mesh, the coarser grid contains several finer grids. Each grid is located by the latitude and longitude coordinates at the central point, and recording elemental items closely related to the grid such as latitude and longitude value, coordinates of geo-central coordinate system and coordinate values under different projection types). Each object located in a grid records relative distance to the central point, with the datum of Gaussian or other type of coordinate system. The grid size is dependent upon the level of economical development and object density: where the objects sparsely distributed coarse grid is given while finer grid is used when the objects are densely distributed.

The system structure of SIMG should be related with the demarcating of administrative territory, and the establishment of a national wide SIMG shall consider the information infrastructures of provincial and municipal level.

At least the following functionalities are necessary of SIMG in grid technology:

(i) SIMG should be a new generation of spatial information product. Traditional digital map products are suitable for spatial analysis, but not for spatial statistics. SIMG is an indispensable product that can be used together with traditional digital products and can be converted from and to GIS data, while suitable for spatial statistics.

(ii) SIMG should be a powerful tool for interoperability. In order to deal with the four consistencies mentioned in the last section, SIMG can be used as an approach for this, by making use of Web Services protocols and standards of grid computing.

(iii) SIMG should be the method for data representation and organization under the temporal-spatial coordinate system in the future. In SIMG, only the coordinates of central point in the grid should be considered, since measurements in the grid such as area, angle and length can be regarded as constants. This can avoid the tedious converting calculation from different coordinate systems.

5. FINAL REMARKS

In order to provide best geo-services to as many as end users, this paper discusses conceptual framework for integration of grid technology and geospatial technology, both are research topics in academic communities as well as industrial circle. Two novel concepts namely generalized and specialized spatial information grids are proposed. We believe this will helpful for the integration of grid computing and geo-spatial information technologies. Various Earth observing systems and spatial data infrastructure will play central role in the sustainable development with the help of spatial information grid.

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