SPATIAL INFORMATION GRID AND ITS APPLICATION IN GEOLOGICAL SURVEY

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ABSTRACT:

With the increasing application requirements of spatial information, traditional spatial information techniques can not solve current application problems. As novel technologies that can implement sharing of enormous distributed resource, Grid and Web services provide an effective and efficient way to share and integrate spatial information on the web. Hence, an innovate framework, i.e. *Spatial information Grid* (SIG), is proposed. We put research emphasis here on system architecture of SIG in order to provide technical foundation for succeeding research of SIG. Furthermore, we discuss service composition technology and introduce a workflow model which called SRN. Finally, we illustrate application patterns of SIG and present an application example in geological survey based on SIG framework to validate the practicability of SIG.

1. INTRODUCTION

It is estimated that more than 80 percent of information that human beings have collected and applied relate to spatial character. As a kind of basic and important resource, spatial information, including remote sensing images, GPS data, digital maps, DEM data, 3-D geographic models, and so on, is widely used in used in many aspects of socio-economic activities, ranging from environmental management, city planning to military operations (Longley et al., 1999). With the increasing application requirements of spatial information, traditional spatial information techniques can not completely solve some problems such as distributed enormous data, complicated processing, heterogeneous structures, and etc, which are obstacles to realize sharing, integration and collaboration of spatial information. So it is imperative to introduce new techniques to manage, process, and integrate distributed heterogeneous spatial information.

As novel technologies that can implement sharing of enormous distributed resource, Grid and Web services provide an effective and efficient way to share and integrate spatial information on the web. And they form an open and standard information infrastructure to implement large-scale resources discovering, accessing, sharing, and integrating (Czajkowski et al., 2001). On the other side, the OpenGIS Consortium (OGC) together with committee of ISO TC211 proposed a frame of OGC Web Services (OWS) which is an online spatial information service frame enables seamless integration of spatial information services .

Hence, the National High Technology Research and Development Program of China (863 program) proposes an innovate technical framework, i.e. Spatial information Grid (SIG), which aggregates advanced technologies such as OpenGIS specifications, Grid, Web Services, and etc. The definition of SIG is given as below (Tang et al., 2004).

Def1. Spatial Information Grid (SIG) is a spatial information infrastructure with the ability of providing services on demands, and it aims at implementing sharing, integration, organizing, and collaboration of enormous distributed spatial information.
SIG is a distributed applied environment of spatial information, which can connect, manage, access, and integrate various spatial information resources, such as spatial data, computing resource, storage equipments, processing software, user, and etc, to implement spatial information applications and services. SIG is a complex application system and it forms a new research domain. At the present time, the research on SIG is at the initial stage. So, we put research emphasis here on system architecture of SIG in order to provide technical foundation for succeeding research of SIG. Furthermore, we discuss service composition technology and introduce a workflow model which called SRN. Finally, we illustrate application patterns of SIG and an application example in geological survey based on SIG framework is presented to validate the practicability of SIG.

2. SYSTEM ARCHITECTURE OF SIG

SIG is a synthetic spatial information system and a new spatial information infrastructure. SIG may be used through whole course of spatial information applications from acquiring to applying. The spatial information resources in SIG are distributed, collaborative and intellectualized. Users of SIG are allowed to access all spatial information and resources through a single web interface.

SIG establishes a multi-layer spatial information framework that involves many components, such as tools for managing distributed enormous spatial data, analyzing software of spatial information, high-performance computing facilities, spatial information applications services, and standards for implementing interoperation of spatial information. The system constitution of SIG can be divided into three layers as Figure 1 shows.

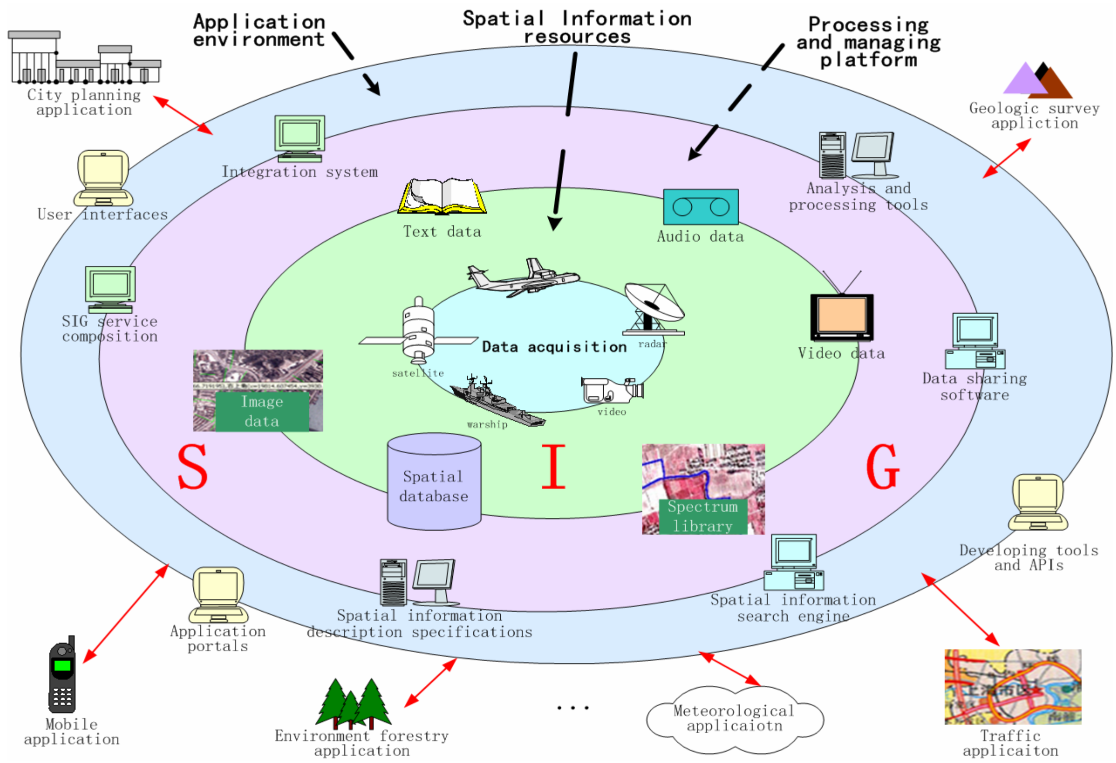

Figure 1. System constitution of SIG

(1) Spatial information resources: the foundation of SIG, including enormous data come from multiple spatial data acquiring devices, various spatial databases, computing resources, information services, and etc.

(2) Uniform processing and managing platform: provides various functions and services for managing and processing spatial information, such as data sharing software, information search engine, processing tools, service composition system, and so on.

(3) Spatial information application environment: provides trade-oriented application portal, user interfaces, and developing tools for different department applications to make SIG be applied conveniently and easily.

The system constitution gives us a holistic description of SIG from the view of components. Considering spatial application flow, e.g. user submit request-> assign task-> decompose task-> discover spatial resources-> integrate resources and services-> complete task and return results, we design an open system architecture of SIG with seven layers from applications, service integrating, analyzing and processing services, information sharing, resource organizing and storing, information transmitting to information acquiring, which is called SIGOA (SIG Open Architecture). All of the seven layers make up an up-to-down layered framework. Each layer is associated with the others, and the upper layer is able to invoke the functions and services of the lower layers (shown as Figure 2).

As shown in figure 2, we take service as one of the most important technical issues of SIG according to OWS specifications. SIG is a service-oriented innovate application framework which defines mechanisms for creating, managing, and exchanging spatial information among entities called SIG services, and enables the integration and composition of services and resources across distributed, heterogeneous, dynamic environment.

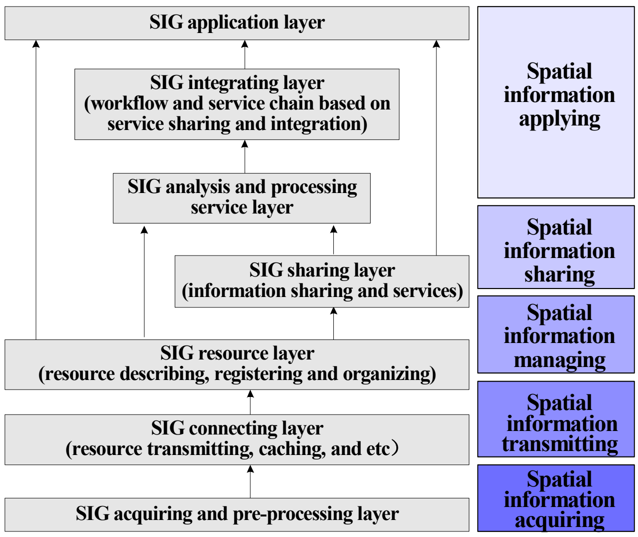

Figure 2. System architecture of SIG

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SIG service is a collection of spatial operations, accessible through an interface, which allows a user to evoke a behavior of value to the user. Based on current standards of Web services, we establish SIG service protocol framework. This framework can provide interoperation protocols for SIG services to implement integration and collaboration of SIG services in the heterogeneous web-based environment.

	Protocol	Purpose
SIG service framework	SSRL (SIG Service Request Language)	Request and get services/resources
	SSTL (SIG Service Task Language)	Integrate services and execute service chain
	Service/Resource Net (S/R-net)	Service composition process model
	UDDI (Universal Discovery, Description and Integration)	Register and discover services
	SIGonto	Express service semantics
	SSDL (SIG Service Description Language)	Describe services (based on WSDL)
	SOAP (Simple Object Access Protocol)	Transmit messages, access and invoke services
	XML (eXtensible Markup Language)	System describing, data standards, etc
	Network (HTTP, FTP, SMTP......)	Network connecting

Table 1. Service protocol framework of SIG

3. SERVICE COMPOSITION FLOW MODEL IN SIG

In actual applications, single SIG service can only support simple spatial information application, but most of current applications require wide linking and composition of multiple different SIG services to create new functionality web processes. Then we analyze and study some key technologies of SIG service composition in detail. We propose a novel workflow model for service composition based on Petri net and graph theory, i.e. Service/Resource Net (SRN).

Def 2. Service/Resource Net (SRN) is an extended Petri net, i.e. a tuple $SRN = (P, T, F, K, CLR, CLS, AC, CN, TM, W, M_0)$,

Where P is a finite set of places; T is a finite set of transitions

F is a set of flow relation; K is a places capacity function

CLR is a resource taxonomy function

CLS is a services taxonomy function

AC is a flow relation markup function

CN is a condition function on F

TM is a time function on T

W is a weight function on F

M is a marking function (M_0 is the initial marking)

SRN is a directed bipartite graph with two node types called places and transitions. The nodes are connected via directed arcs. The running of SRN is implemented by firing its transitions, and the basic transition structures of SRN are concluded into six types (Detailed description of SRN can refer to (Tang et al., 2004)).

4. SIG APPLICATION PATTERN AND EXAMPLE IN GEOLOGICAL SURVEY

National geological survey mainly aims at the basic surveying and prospecting of strategic mineral resources (solid mine, groundwater, oil gas, and etc.), and provides common information services for the society. SIG can be used widely in geological survey.

4.1 Application Pattern of SIG

SIG is a distributed application environment built on internet. Various spatial data, computing resources, processing software, users etc are connected by SIG so that spatial information can flow within different SIG nodes according to requirements. In SIG, there are lots of nodes which provide many functions such as data querying, information processing, computing collaboration, and so on. Multi-layer users can bring forward various application requirements through SIG portal and SIG will integrate many kinds of resources to implement application task. The application pattern of SIG is shown in Figure 3.

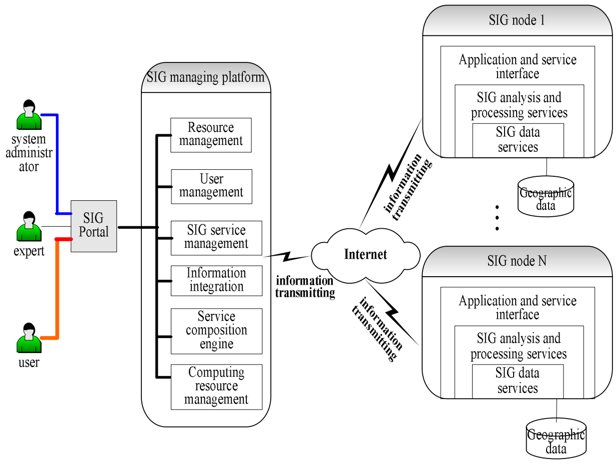

Figure 3. The application pattern of SIG

4.2 An application Example of SIG

In the following, we will illustrate SIG application in geological survey by analyzing an example of mineral resources evaluation (user request -> request parsing -> resource information service-> service chain modeling –> data services -> analyzing and processing services –> service integration –> return results).The course is shown in Figure 4.

(1) SIG users submit service request with SSRL, then SIG managing platform parses the request by using GSRL parser, and generates the corresponding service query conditions.

(2) To query resource information service (UDDI center) to find the satisfied SIG services.

(3) Condition determining: if there is not a single service that satisfies the query conditions and it requires forming sophisticated SIG analyzing and processing tasks.

If yes, to query service composition flow model repository, get (or build) a service composition flow model and invoke various

SIG data services according to spatial data request defined by service composition flow.
If not, to submit spatial data request and invoke SIG data services directly.

(4) SIG data services access and integrate distributed, multi-source geological data, and form datasets that satisfy requirements of SIG analysis and processing services (the data format may be GML).

(5) SIG analysis and processing services acquire geological data to analyze and process. In this course, distributed parallel processing can be implemented in different computers by decomposing the target datasets.

(6) According to the service composition flow model, the complex tasks may invoke various analysis and processing services and integrate them to acquire final results.

(7) Return the processed results to users.

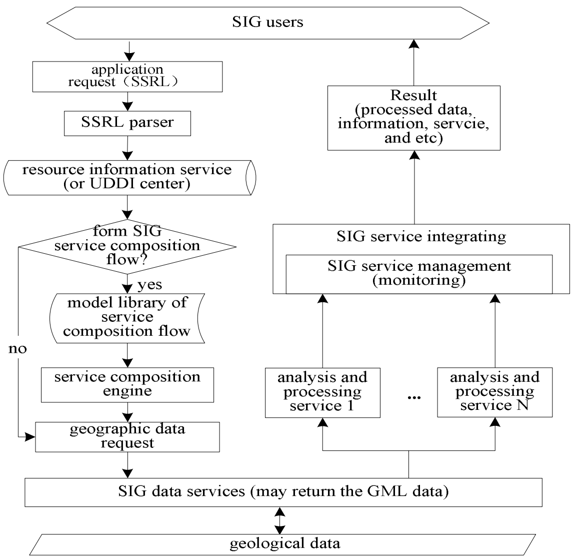

Figure 4. The application flow of SIG service

4.3 SIG Application Example

In accordance with the flow above, we have implemented an application example of geological mapping. In this example, we aggregate and processing the geological data distributed in three provinces by applying and composing multiple SIG services. In addition, many computing resources are used jointly to implement mapping. The application instance is shown in Figure 5, in which (a) denotes the course of discovering services in SIG UDDI center; (b) denotes the process of selecting geographical region by map services in SIG portal; (c) denotes the mapping result which integrated from three provinces; (d) is the detailed result of partial area; (e) is the attribute result of some geological objects.

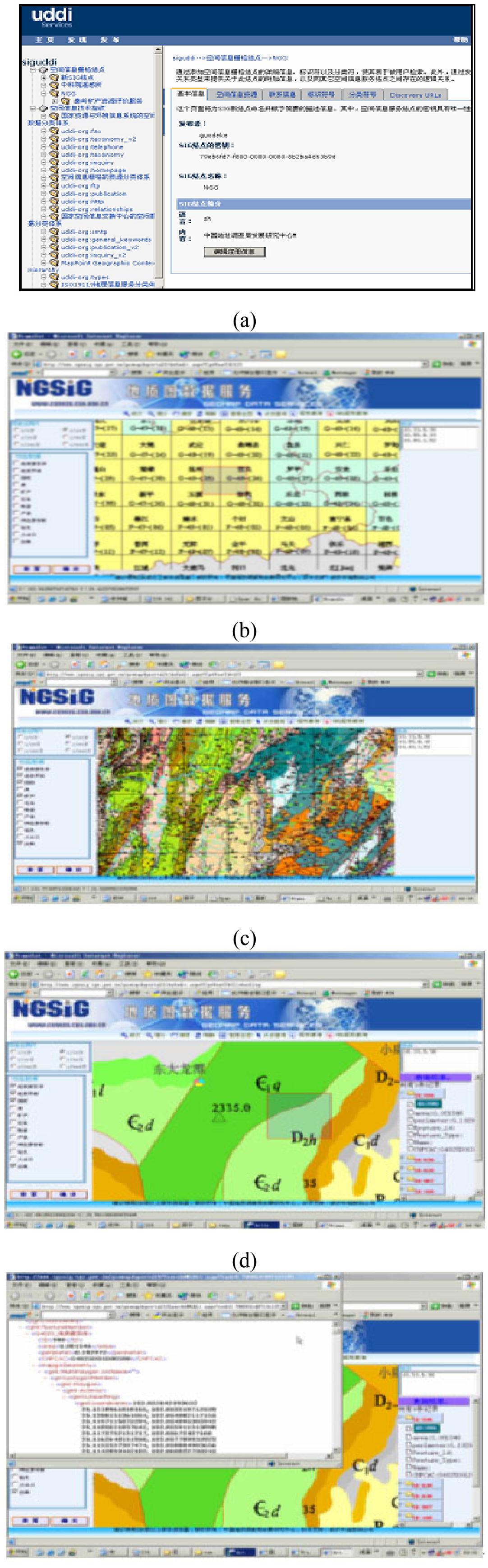

Figure 5. Application instance of geological mapping

In this example, we share and aggregate distributed spatial information from several different departments and provinces all over the country by applying SIG environment. From this instance, we can learn that SIG is capable of sharing, merging, integrating, interoperating spatial information and resources. As far as geological survey is concerned, SIG can unite a number of geological survey departments of one province or more and even the whole nation, take advantage of several related distributed spatial databases, and analyze, process the corresponding geological spatial information to form strong capability of distributed computing, high-speed spatial information acquiring, transmission, storage, sharing and interoperating in the geological survey fields.

The experiment results show that our research achievements are effective and practical. We hope that our work would provide theoretical and technical bases for succeeding research and practical applications of SIG.

5. CONCLUSIONS

SIG is a new generation spatial information infrastructure which is based on some novel technologies, such as grid, Web services, OGC specifications, and etc. It would realize not only the traditional spatial information application aim, i.e., 3W (Who, When, Where), but also a higher and more advanced aim, i.e., 4A (Anyone can get Any spatial information at Anytime in Anywhere).

The research of SIG is at the initial stage. Some key technologies will be introduced and studied in detail, such as resource management, service composition engine, spatial knowledge sharing, and etc. In accordance with application demands, we will put research emphasis on the perfecting SIG architecture and studying some key technologies in the future. We hope that our work will promote and enhance the development of information technology in environmental science and geoscience.

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