Building GIS Web Services on JXTA Network

WANG Leichun  GUAN Jihong  ZHOU Shuigeng

ABSTRACT In recent years, Web services and Peer-to-Peer (or simply P2P) appear as two of the hottest research topics in network computing. On the one hand, by adopting a decentralized, network-based style, P2P technologies can make P2P systems enhance overall reliability and fault-tolerance, increase autonomy, and enable ad-hoc communication and collaboration. On the other hand, Web services provides a good approach to integrate various heterogeneous systems and applications into a cooperative environment. This paper presents the techniques of combining Web services and P2P technologies into GIS to construct a new generation of GIS, which is more flexible and cooperative. As a case study, an ongoing project JGWS is introduced, which is an experimental GIS Web services platform built on JXTA. This paper also explores the schemes of building GIS Web services in a P2P environment.

KEYWORDS GIS(geographic information system); Web services; JXTA

CLC NUMBER P208

Introduction

Nowadays, the diversity of GIS and the availability of WWW have led to an increasing number of researches on integrating various heterogeneous and autonomous GISs into a cooperative environment for constructing a new generation of GIS featuring in open architecture, distributed computing capability, cooperativity and extensibility. For example, mobile agent technology and geographic markup language (GML) are introduced into GIS in order to build integrated distributed GIS\(^{(1)}\), an open web GIS service system which provides a spatial data transfer format based on XML and supports web GIS services as components\(^{(2)}\) is designed and implemented, a semantic Web-GIS is addressed, which can realize semantic interoperability and integration of GIS on the web by combination of domain ontol-ogy and XML\(^{(3)}\), and chaining geographic information web services is proposed\(^{(4)}\), etc.

However, current main GISs have two drawbacks: 1) since its architecture is relied heavily on centralized servers, it can cause some problems such as single point of failure, network congestion, data inconsistency, etc; 2) different GISs adopt different development languages, technologies and platforms, so it is difficult to integrate them into a cooperative environment to carry out tasks that different applications are required to communicate with each other. At the same time, GIS Web services infrastructures are mainly based on centralized approaches such as UDDI, so it is prone to introduce single points of failure, hotspots in the network and expose vulnerability to malicious attacks.

To overcome the limitations of these GISs, we suggest the techniques of building GIS Web services under a P2P\(^{(5)}\) environment by fitting...
Web services and P2P technologies into GIS. The goal is to add more flexibility and autonomy to GIS Web services systems, and alleviate to some degree the inherent limitations of these centralized systems.

In this paper, we present our ongoing project JGWS as a case study, i.e. JXTA-based GIS Web Services. JGWS is an experimental GIS Web services platform built on JXTA. We explore the schemes of combining P2P and Web services into GIS, and present the JGWS project.

1 JGWS: GIS Web Services on JXTA

1.1 JGWS in a glimpse

By fitting P2P and Web services technologies into GIS, we designed and implemented a GIS Web services system on JXTA (simply JGWS). The goal is to develop an experimental Web services and P2P based GIS platform. Typically, the JGWS system consists of two types of peers: a large number of normal peers, and a relatively fewer number of JGWS rendezvous peers (Fig. 1). A normal peer serves the system as both a GIS services provider and a GIS services consumer, not to mention a UDDI Registry. That is to say, a peer in the JGWS can both provide GIS services for other peers and obtain GIS services from other peers as well as help other peers discover and locate GIS services in the system. A rendezvous peer can process received GIS service requests and forward them to other rendezvous peers.

Fig. 1 JXTA Network

Compared with ordinary Internet-based GISs and GIS Web services systems, the JGWS system in this paper has its own features as follows.

1) The JGWS system adopts a distributed structure built on JXTA and each peer in JGWS plays three roles, i.e., a GIS services provider, a GIS services consumer and a GIS service registry.

2) Each peer in JGWS can provide GIS services for other peers and may join or depart the P2P services network at any time.

3) In addition, the JGWS system both allows applications, which adopt different development languages, technologies and platforms, to communicate with each other, and can integrate all kinds of heterogeneous and autonomous GISs into a cooperative environment.

1.2 Architecture of A JGWS Peer

As mentioned above, a peer in the JGWS system plays the roles of a GIS services provider and a GIS services consumer as well as a GIS services registry. Thus, there are no central UDDI Registries in JGWS, and all GIS services and their publishing information are distributed over the peers. Fig. 2 illustrates the structure of a JGWS peer that is essentially composed of five components integrated loosely.

Fig. 2 Structure of a JGWS peer

The first component is a JGWS Manager, also the most important component in the JGWS system. A JGWS Manager consists of two sub-components, namely, a JGWS Requester and a JGWS Provider. A JGWS Requester is responsible for completing tasks of a peer serving as a client such as discovering and locating GIS services,
sending a GIS services request to other peers, receiving and displaying the returned result, etc. A JGWS Provider can help a peer as a GIS services provider to create, deploy and publish new GIS services, and receive GIS services requests from other peers and then return the results to them. Especially, a JGWS provider can transform a JXTA message of GIS service from other peers into a Soap request of Web services and send it to the GIS services server.

The second component is a Cache Manager, which is used to cache the results of GIS service discovery and retrieval in order to reduce the response time of subsequent answers. It also determines the caching/replacement policy of a cache.

The third component is a User Interface. It includes several interface modules, corresponding to GIS services creating, deploying and publishing, and GIS services discovery and retrieval, and so on. In addition, it also provides a friendly environment for a user to submit his/her GIS services request, to maintain their sharable GIS services, and to insert/delete their GIS services and so on.

The other two components are the UDDI Registries and the Local GIS Services Repository respectively. The Local GIS Services Repository keeps the GIS services provided locally; and the UDDI Registries holds both the publication information of local GIS services and some of other peers in JGWS.

1.3 Geographic information organization

In JGWS, each peer is both a GIS services provider that can provide other peers with geographic information and a GIS services requester that can access geographic information from other peers, so geographic information is distributed over peers in JGWS. The information includes spatial meta data, spatial topology data and spatial attributes data which are stored in Spatial meta database, Spatial topology database, Spatial attributes database and Spatial data files. Geographic information in a peer is typically organized as Fig. 3.

Different from generic Web services, GIS services in JGWS are essentially to send a GIS service request to other peers of the system in order to obtain the required geographic information. Since geographic information is enormous and generally a user only needs a part, it is not necessary that all geographic information of a peer is sent to the user. Considering the speed of GIS services access and the limitation of disk space in each peer, we can divide the geographic information into two kinds of basic geographic information units, namely static geographic information unit and dynamic geographic information unit. The accessing rate of static geographic information units is generally higher, and the units have been generated and stored in the form of GML files before a GIS service request. Dynamic geographic information units are accessed less and not generated until a GIS service request comes.

1.4 UDDI registries management

Different from UDDI Registries of generic (GIS) Web services, the JGWS system adopts decentralized UDDI Registries, so each peer has its own UDDI Registries. When the GIS service needed by a user is located in remote peers, the user can not directly search and locate the GIS services in remote peers and can only retrieve the publication information of the GIS services to see whether he needs it.

The UDDI Registries in JGWS include two parts, a local UDDI Registry and a remote UDDI Registry. Local GIS services are published in a local UDDI Registry and searched firstly. Generally, its content is fixed except that a new GIS
service is generated and published. A remote UDDI Registry stores publication information of GIS services from some of remote peers and its content is changeable. It is based on two considerations. On the one hand, to improve the efficiency of search, each peer in the JGWS system should store more publication information of GIS services from other peers. On the other hand, this will hold a host of disk space and result in too much redundant information and network bandwidth. Thus, we assign an appropriate disk space for a remote UDDI Registry and adopt a LRU replacement strategy: whenever disk space is run out of, the publication information in the remote UDDI Registry is replaced that is lastly used.

1.5 A proxy: a transformer from JXTA message to soap request

There are many differences between P2P services of JXTA and Web services. For example, JXTA and Web services adopt different transport and message protocols for the communication within each realm, and the formats adopted in JXTA and Web services to describe distributed services are also different. In addition, the SOAP RPC provided by WSDL in Web services is not supported in JXTA. These makes it impossible to directly exchange service descriptions between the two platforms and further interact these services based on the service descriptions. Thus, in order to invoke GIS services distributed over JXTA peers, a proxy is needed, whose function is to transform a message of GIS services in JXTA into a Soap request of GIS services in Web services (Fig. 4).

A proxy in a peer has two interfaces modules, a JXTA Message Impl Module and a Soap Request Impl Module. The former is responsible for receiving the JXTA message of GIS service request from another peer by a JXTA input pipe, and the latter can send the transformed Soap request from the JXTA message to a GIS services server. The process can be described as follows.

Firstly, a GIS service provider generates a request message of GIS service according to the returned GIS services description and sends it to a GIS service requester through a JXTA output pipe.

Secondly, the GIS service requester receives the message and uses the proxy to transform it into a Soap request that a GIS services server can receive.

Finally, the proxy sends the Soap request to the GIS services server.

1.6 GIS services discovery

GIS services discovery is the key process of P2P services. Unlike UDDI Registries of generic GIS Web services, those in the JGWS system are distributed on peers. Here, we adopt an information retrieval (IR) based approach to search potential GIS services. For each GIS service which is created by a user, UDDI Registries maintain their publishing information including GIS services names, descriptions, keywords and URI of WSDL. Among them, GIS services names and keywords can be used to retrieve possible GIS services.

In this way, potentially relevant GIS services can be determined by use of the following GIS services matching policy.

- Consider a query \( (K) \) where \( K \) is the set of target keywords.
- \( K \) is searched against keywords for GIS services names and keywords. The result of this search process will be a list of publishing information for GIS services.
- Given a query \( Q \) of the form \( (K) \) and a GIS service \( D \), the degree in which \( D \) matches \( Q \) can be computed as follows:
Match(Q,D) = \sum_{i=1}^{w} G_{ni} \cdot w_{ni} + \sum_{i=1}^{w} G_{ki} \cdot w_{ki}

Here, \( w_{ni} \) and \( w_{ki} \) are weights assigned to reflect the importance of matching GIS services names and keywords respectively. The value \( G_{ni} \) and \( G_{ki} \) is 1 or 0; the value is 1 if and only if the targeted keywords can be found in GIS services names or keywords, otherwise, the value is 0.

Here, the sum of \( w_{ni} \) and \( \sum_{i=1}^{w} w_{ki} \) is 1. A Match(Q,D) value reflects that the query Q matches with a GIS service D.

- Set an appropriate threshold value according to some criterions in JGWS. When a Match(Q,D) value is over the threshold value, publishing information of the GIS service is chosen to return to the requester.

In GIS services discovery, since JGWS is a very big network and each peer has some GIS services, it is not realistic to search all peers and GIS services in the system. On the other hand, it is possible that we cannot find the required GIS services if we only search a few peers in the network. At the same time, a peer can receive many times of the same request forwarded by different peers. Thus, three criterions are made for the search approach:

1) A peer that submits a GIS service request can send the request to a rendezvous peer and only a fraction of its peers, selected at random. A rendezvous peer can forward the request to other rendezvous peers in JGWS. A peer, which receives the request, can forward the request to other peers only if the request is received at the first time, but it cannot forward it to a rendezvous peer.

2) Associate a TTL (i.e. Time-To-Live) value to each GIS service request to a rendezvous peer and other peers. When the request is forwarded to other peers and rendezvous peer, its TTL value will subtract 1. When the TTL value of a request is 0, the request will not be forwarded.

3) Returned publishing information of GIS services is only kept once in remote UDDI Registries.

In JGWS, once a requester submits his/her GIS service requirement, the following process will be launched.

① Search GIS services names and keywords in Local UDDI Registries of the peer. If there are GIS services matching the query, then go to ②; otherwise, go to ③.

② Browse these descriptions and see whether there are GIS services (s) he wants. If there are GIS service(s) he wants, then the process of GIS service discovery is over; otherwise, go to ③.

③ Search names and keywords of GIS services in Remote UDDI Registries of the peer. If there are GIS services (s) he wants, then the process of GIS service discovery is over; otherwise, go to ① and ⑤.

④ In a remote peer, firstly it should be known whether the request is received firstly. If so, do the same work as in local peer. Otherwise, it does not process the request. When the TTL value of the request is 0, the request will not be forwarded to other peers.

⑤ Search GIS services names and keywords in a rendezvous peer and return them to the peer. Then, forward the request to other rendezvous peers until the TTL value is 0.

1.7 GIS Services invoking

Different from generic web services, the geographic information in JGWS is generally enormous, so it cannot be returned through a soap response. Here, we use JXTA pipes to send and receive the geographic information in JGWS. In this way, the GIS service provider can receive the user’s request and send back the generated geographic information to the user by a JXTA output pipe. At the same time, a GIS services requester can receive the returned geographic information by a JXTA input pipe. In JGWS, geographic information is returned in the form of GML files by a JXTA pipe. It has two good causes: 1) GML is based on the XML standard worldwide accepted and the rapidly increasing number of tools and commercial products that generate, check, interpret and serve online XML data sets. 2) GML can integrate geographic data from different providers.

The process can be described as follows.

1) A GIS service requester creates a client in
the light of the chosen GIS service.

2) The requester creates a JXTA input pipe advertisement, and a JXTA input pipe according to the advertisement. Then, open the input pipe and wait to receive required geographic information.

3) The requester invokes the GIS service and sends the input pipe advertisement to the GIS service provider. At the same time, the GIS service provider receives the request and creates a JXTA output pipe according to the received JXTA input pipe advertisement. Then, it opens the JXTA output pipe and returns the geographic information to the requester through it.

4) The requester receives the returned geographic information by the JXTA input pipe and keeps it in local peer.

2 A prototype

In order to assess the feasibility of the JGWS system, a simplified prototype was developed. We use JXTA, J2SDK 1.4.2, Geotools 0.8.0, Oracle 9i, Tomcat 5.0, and Apache axis for implementing the prototype. Hardware includes seven PCs, in which two PCs were used as Rendezvous peers and the other five PCs were normal peers. Here, JXTA provides a P2P environment for the JGWS system; Tomcat and Apache axis serve as a container to deploy GIS services; Oracle 9i is used to store geographic information; J2SDK 1.4.2 is a Java based development platform, and Geotools 0.8.0 is a geographic development tool. Geographic information of the provinces, cities, rivers, roads, and lakes of Canada, Europe, Mexico, USA and World from ARCView GIS 3.2 are split into five parts to be stored on five JGWS peers, respectively. Fig. 5 displays the result of a GIS services request for cities, rivers and states of Canada.

3 Conclusions

In order to overcome the limitations of existing GIS systems and applications under the Internet environment, we designed and implemented the prototype of GIS Web services system on JXTA network by fitting Web services and P2P technologies into GIS. This makes it possible that various autonomous and heterogeneous systems and applications, which are developed in different languages, technologies and platforms, can communicate with each other and work cooperatively. As an experimental platform, JGWS system performs some basic functions and needs to be improved and perfected further. Our future work includes: 1) increase the interoperability between a GIS service provider and a requester in JGWS system; 2) enrich the functions of the JGWS system; 3) improve the efficiency of GIS services discovery in the JGWS system.

REFERENCES

1 Guan J H, Zhou S G, Bian F L (2002) A mobile-agent and GML based architecture for integrating distributed GIS. ISPRS (2002), Xi'an.
2 Kim D H, Kim M S (2002) Web GIS service component based on open environment. IGARSS '02, Toronto.
3 Yi S Z, Zhou L Z, Xing C X (2001) Semantic and interoperable WebGIS. The Second International Conference on Web Information Systems Engineering, Kyoto, Japan.
4 Alameh N (2003) Chaining geographic information Web services. IEEE Internet Computing, 7(5):22-29
5 Milojicic D S, Kalogerski V, Lukose R (2002) Peer-to-peer computing. Technical Reports. HP Laboratories, Palo Alto.
6 Gottschalk K, Graham S, Kreger H, et al. (2002) Introduction to Web services architecture. IBM Systems Journal, 41(2): 170-177
7 Baeza-Yates R A, Ribeiro-Neto B (1994) Modern information retrieval. Boston, MA: Addison-Wesley Longman Publishing Co., Inc.