RESEARCH ON CGeoML AND Its SPATIAL INTEROPERABILITY

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ABSTRACT
Through analyzing the status quo of national and international research on spatial interoperability, the author points out that nowadays some problems exist in it, such as import and alteration of international criterions, model descriptions and conversion standards of spatial data, and framework of application interoperability etc. Considering these, the author puts forward, based on CGeoML, which is Chinese Earth Spatial Data Format Conversion Criterion based on XML, a spatial interoperability framework, learning from OLE/COM, CORBA criterions of OGC, in this way, absorbs international criterions at high speed, meanwhile, provides a flexible and unitary interoperability solution for application GIS.

KEY WORDS: CGeoML, WMS, WFS, WCS, Interoperability

1. SPATIAL INTEROPERABILITY

1.1 Summary of Interoperability

With the popularity and deeper study in GIS application, GIS has become the primary technology of spatial information resource management, and gradually combining with IT mainstream, becomes the integration platform, supporting all kinds of spatial information processing. However, because of the diversities of spatial data contents and sources, as well as differences of spatial data models and GIS software platforms, GIS application has become a real “Black Box System”, and finally brings difficulties in sharing data and functions in GIS application. Considering that, in current GIS research, it has become the focus of great significance to study GIS interoperability technology and solve the bottleneck in GIS application interoperability.

In the field of GIS exist different understandings on interoperability. *Computer Glossary* (1997) reads that interoperability is the capacity of exchanging information and using exchanged information between two or among more than two systems, namely, means the ability of a system receiving and processing the information sent out by another software system. It reflects whether a system is easy to link fast with others, and it is a vital way to measure software quality.

ISO/TC211 (1998) deems that if two entities, X and Y, could operate mutually, then they have the same understanding on the processing request, R_i. Also, if X presents the processing request R_i, Y could make a valid response and return the result S_i to X.

OpenGIS Consortium (1998) looks on it as the capability of internal application and cooperation process controlling provided by system or system components.

From the different views listed above, we could see that interoperability focuses on integrating software systems of different data structures and data formats together to work harmoniously. In fact, GIS interoperability has different emphases under different situations. When transferring among software function modules is emphasized, we called it software interoperability; when transparent visiting among data sets is stressed, we call it data interoperability; and when we emphasize on information sharing, the interoperability under restriction of certain semantics is called semantics interoperability (Huang, 2003).

In general, GIS interoperability means different applications (including those between software and hardware) are able to transfer dynamically, and have a steady interface in different data sets.

1.2 Status Quo of National and International Spatial Interoperability Research

Ten years have past since the scholars, research institutes and GIS platform developers throughout the world devoted themselves to GIS interoperability research and implement work. On the base of research on spatial data conversion, spatial data criterions and spatial data direct reading, it took nearly ten years to make a fast progress in GIS interoperability research, not only on the theories of interoperability, but also on the establishment of interoperability criterion as well as application and production extension. Meantime, the interoperability competence was improved greatly and GIS interoperability framework was shaped by and large.

Overseas, OGC Consortium (1998) put forward, in succession, a whole set of GIS interoperability abstract criteria, which constitutes 17 abstract criteria (1998) such as geo-geometry factors, factor sets, OGIS factors, relations among factors, space reference systems, orientation geometric structure, storage functions and interpolating, covering types, earth images, covering a wide range. On the base of abstract criteria, OGC also set down 11 implement criteria, including implement criteria of simple factors based on OLE/COM, simple factors based on CORBA, simple factors based on SQL, catalog service, Grid, coordinate conversion, Web map service, GML, and service criteria of Coverage based on Web, of surface features based on Web. Besides the criteria mentioned above, still lots of implement criteria are on the way of establishment nowadays. Taking actively part in establishing OGC criteria and its standardization, the overseas mainstream GIS platform manufacturers, one after the other, append modules in their GIS products to be compatible with those criteria. For example, Corp. Intergraph not only supports to read and converse GML data, but develops WFS server as well as some software components like interoperability developing bag. In Corp. MapInfo, MapXtreme could support interoperability criteria like WFS, WMS. In the latest edition, interface functions like visiting WMS, WFS services (2003), reading GML data are also added. Similarly, Corp. ESRI developed components to support WMS, WFS criteria in the latest edition of ArcIMS (2003), in it ArcXML not only has map configuration function, but also are in charge of communicating and function answering between Client/Server. Obviously, the product of ArcIMS has an elementary framework for Web service. Additionally, these manufacturers, in order to gain profits for themselves, open the developing details of

their products reciprocally at pudding time and unite into a strategic confederation to drive the interoperability technology forward. Recently, one of the cases is that Corp. Autodesk, Intergraph, Laser-Scan and Mapinfo agreed on the interoperability framework based on database Oracle (2003). They try to share their data on each of their platforms with oracle.

National research on interoperability started later, passing through three phases. The 1st phase began when Prof. Jianbang He, Daosheng Du legislated, imported criteria and established geo-spatial data exchanging criteria. Interoperability techniques and framework research by Yuxia Huang, Shanzhen Yi declared the 2nd phase. The 863 project, "Web Spatial info-criteria and sharing application service pivotal techniques", leaded by Jianya Gong brings the 3rd phase. The implement of interoperability now primarily means spatial data conversion and reading GML data. National GIS software platforms have no normal components and interfaces.

1.3 Reconsideration Aroused by Spatial Interoperability Research

Through analyzing the status quo of national and international interoperability, especially analysis on national interoperability nowadays, we find several problems existing in the interoperability research in China.

(1) Import and Modification of international spatial interoperability criteria. OGC has established over twenty abstract and implement criteria aiming at spatial interoperability. ISO/TC211 did some work to establish and extend relative criteria according to these. Although Chinese scholars took part in the work of establishing these criteria, obviously they didn't go enough far in it. Especially, Chinese GIS platform manufacturers were inapprehensive of the interoperability during the progress. Therefore, we've lost the initiative in establishing international spatial interoperability criteria. Since international GIS manufacturers established and extended interoperability criteria, they agree on them by and large. On the base of it, we should be deliberative when building interoperability criterion, but couldn't abandon these shaped criteria to establish them solely, moreover, avoid importing them blindly. Considering the largeness and abundant contents of existing criteria system, we should pick out those more mature ones, which have gained more support from platform manufacturers, go deep into it according to national GIS application situations, modify it properly, and establish interoperability criteria system adapting to Chinese characteristics.

(2) Spatial data model expression and data conversion criterion. It is the pivotal problem in the whole spatial interoperability. If there is not a spatial data model expression criterion of consensus, interoperability is just "cloud-castle". Thinking of that, OGC established relevant simple factor model, and try to eliminate the differences in describing spatial entities among different GIS by depicting the criteria of geo-entities. According to this criterion, OGC has a more detailed description of this data model in the relative interoperability implement criterion GML. Nowadays, many GIS platform software ratify it and append relevant explaining and expressing components in their productions.

Spatial data conversion takes on the important task of sharing spatial data before

interoperability; it is also the most important pivotal technique in data interoperability. During the period of “Nine Five”, China established relevant spatial data conversion criterion, and national GIS platforms joined in supporting it in application. However, in that Chinese transversion format has only a fairly short history, it could not express the spatial data model all-sided, and lack enough power in international competition, national standardization organization and mainstream GIS platform manufacturers didn’t support it much, that also restrict the development of format itself. The perfection of GML interoperability criteria and the support from mainstream GIS manufacturers enable us to combine existing national exchanging criteria in virtue of current GML, and establish new ones according with mainstream and of independent knowledge patent.

(3) Application interoperability framework. All criteria are established to serve for application ultimately, and aim to meet the need of application and solve the problems in it; spatial interoperability criterion construction is not the exception. Many organizations throughout the world shape lots of standards and criteria in research. Take OGC as example, it has nearly thirty abstract and implement criteria of interoperability. Confronting with so many criteria, standardization organization is also endeavoring to adjust and construct elementary interoperability frameworks. While because of the immaturity of relevant criteria and complication of frameworks themselves, it’s quite difficult for application system to carry out interoperability. As the result, it should be considered in interoperability to pick out rational interoperability criterion, construct interoperability framework, and perfect it driven by application.

Considering this, it’s naturally known that the research and developing emphasis of national spatial interoperability is to learn, use and partly modify relevant international criteria, establish relevant spatial data exchanging criteria combined with national interoperability production, in this way, construct a rational framework of application interoperability, and drive the course of application GIS interoperability. In this paper, Chinese spatial data exchanging criterion CGeoML and relevant application interoperability framework are audacious attempts aiming at this target.

2. GML3 AND CGeoML

2.1 GML3

Geography Markup Language (GML) is a geo-information coding tool based on XML developed by OGC. GML has experienced in web Mapping Test Bed (WMT) plan a series of tests (1999, 9), which include exchanges among GML Mapping Clients, GML Data Servers and service providers.

Since the 1st edition GML1.0 of OGC, several comparatively large changes have taken place in GML editions. The latest edition GML3 is 8 times larger than GML2.1.1 (2003). Besides simple 2D linear factors, GML3 adds the description of geo-spatial phenomena, including complicated, non-linear, 3D factors, 2D topology factors, temporal factors, dynamic factors and layers; as well as spatial and temporal reference system, measuring units and standard information description; using reference system, units and standard information to express geo-space conception, observation value and values; visualizing factors and layers with default style. These are consistent with

ISO/TC211 1907 geo-information—Spatial Schema standards.
Considering the hugeness of GML3, not all the conceptions of GML3 could be used in general applications. OGC suggests in GML3 criteria that users may selectively use one of the subsets in GML3 to finish their application schemas. Only when using GML special criteria defined by certain GML subsets, could interoperability be enhanced, illegibility be reduced.

2.2 CGeoML

As one of the research productions of 863 research group “Web Spatial info-criteria and sharing application service pivotal techniques”, CGeoML, on the base of spatial data exchange format VCT, is a kind of spatial data exchange criterion based on XML, which extracts relative application patterns from GML3, using WFS (Web Feature Service) criterion of OGC for reference. CGeoML pattern segments are listed as follows.

```
<xsd:element name="CGeoMLFeatureMember"
type="myns:CGeoMLFeatureMemberType" substitutionGroup="gml:_Feature"/>
  <xsd:complexType name="CGeoMLFeatureMemberType">
    <xsd:complexContent>
      <xsd:extension base="gml:AbstractFeatureType">
        <xsd:sequence>
          <xsd:choice>
            <xsd:element ref="gml:Point"/>
            <xsd:element ref="gml:MultiPoint"/>
            <xsd:element ref="gml:LineString"/>
            <xsd:element ref="gml:ArcString"/>
            <xsd:element ref="gml:ArcByBulge"/>
            <xsd:element ref="gml:ArcByCenterPoint"/>
            <xsd:element ref="gml:ArcStringByBulge"/>
            <xsd:element ref="gml:BSpline"/>
            <xsd:element ref="gml:MultiLineString"/>
            <xsd:element ref="gml:MultiCurve"/>
            <xsd:element ref="gml:Polygon"/>
            <xsd:element ref="gml:MultiPolygon"/>
            <xsd:element ref="myns:CGeoMLAnno"/>
          </xsd:choice>
          <xsd:element name="PropertyValue" type="string" minOccurs="0">
            <xsd:annotation>
            <xsd:documentation>Record the attribute values in the sequence of
AttributeName in FeatureClassName, and divide values with “,”. </xsd:documentation>
            </xsd:annotation>
          </xsd:element>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
```

```
</xsd:complexType>
```

The last edition of CGeoML have characteristics and predominances as follows.

(1) Take Chinese geo-space data exchanging criterion VCT into account, able to protect national GIS software and invest on existing application data.

(2) Base on GML3 and be completely consistent with spatial data model and spatial expression in GML3 as the result. Therefore, as far as international GIS software is concerned, information loses to the least extent in data conversion process.

(3) Use WFS criteria for reference, and current CGeoML could meet the need of WFS to access spatial data.

(4) Able to verify data accurately through application schema.

(5) Able to be browsed and edited with public tools.

(6) Easy to be integrated with un-spatial data.

CGeoML integrates spatial data conversion criteria, spatial data model criteria and spatial data expression criteria; it's of great significance to drive Chinese interoperability research. It's good time to make use of and modify existing interoperability criteria, put forward spatial interoperability framework based on CGeoML.

3. SPATIAL INTEROPERABILITY FRAMEWORK BASED ON CGeoML

3.1 Hierarchy of OGC Interoperability Standards

After studying the existing spatial interoperability implement criterion of OGC, interoperability criterions of OGC based on OLE/COM, on CORBA and on Web service are the most mature ones nowadays, they're also the focus of mainstream GIS platform manufacturers throughout the world.

Interoperability criteria based on OLE/COM are interface criteria of API functions based on COM (1999). It primarily bases on 2-level structure or C/S mode, of course 3-level structure probably. By establishing unitive forms and parameters of interface functions, different GIS software could read data of each other.

Interoperability criteria based on CORBA is spatial data interoperability criteria based on CORBA or Java Bean (1998). Because Java is a web language and easy to be realized on Internet, and is easily carried out with 3-level and multi-level system structure. They are also interface criteria based on API functions, but focus on sharing and interoperability of spatial data of different structure in wide area.

Interoperability criterion based on Web service is spatial data interoperability implement criterion based on http (Web) XML (2002). It's criterion on data current, and has no relations with forms of function interface and software component interface. It obeys with sharing models of spatial data and defining criteria of spatial objects, namely, it could use XML to describe definition and concrete expression form of spatial objects. When different GIS software share and operate data, system inner spatial data are conversed into data current with public interface, other system read this data current into main system and display them.

Through analyzing these three criteria, it could be known that they present interoperability implement interface and relative mechanism respectively based on Windows Local Area Network (LAN), different structure World Wide Web (WWW)

and Internet. Based on CGeoML, and combined these three implement criteria together, it's rational to build reasonable and scientific implement interoperability framework and provide interoperability foundation and interface for application GIS.

3.2 Spatial Interoperability Framework Based on CGeoML

Spatial interoperability framework based on CGeoML (Fig.1) includes two parts, one is interface components aiming at Intranet interoperability on the base of OLE/COM and CORBA, the other is interface components aiming at Internet interoperability on the base of OGC Web services.

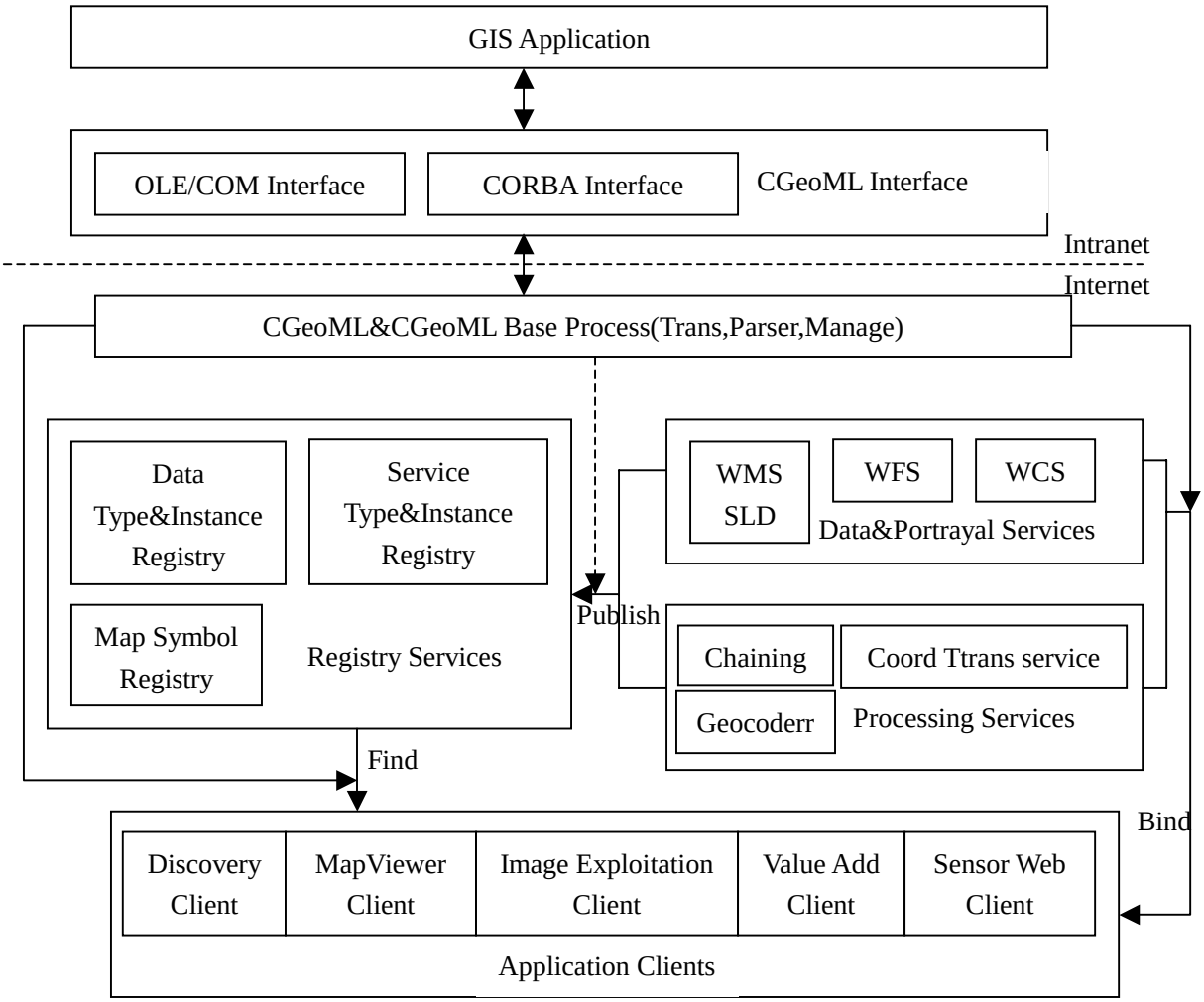

Fig.1 Spatial Interoperability Framework Based on CGeoML

(1) CGeoML & CGeoML Base Process: this part is the core of the whole framework, mainly including CGeoML criteria, CGeoML basic processing, such as CGeoML conversion(conversion with some mainstream GIS formats, E00, DXF, MIF etc), parsing and management.

(2) OLE/COM and CORBA interfaces: Because current mainstream GIS platforms support simple factor models and GML, it's feasible to realize CGeoML based on OLE/COM and CORBA firstly. This schema could achieve interoperability among Intranet GIS applications generally.

(3) Geo-data and data description service: Geo-data services mainly include Web Feature Service (WFS), Web Coverage Service (WCS). The data returned from geo-data service usually contain spatial reference system. Geo-data description service mainly contains Web Map Service (WMS), in which maps could be combined with multi-layers and described with Styled Layer Descriptor (SLD). The results returned from map service are usually vector graphics and raster images.

(4) Processing Service: provide search and index service for geo-data. Mainly include Geocoder service, Gazetteer service, Coordinate Transfer Service etc.

(5) Registry Service: provide registry services in order to be convenient for finding services. It includes registry services for data structure, data instances, service types, service instances. Registry services provide registry, update and search services for all registry items.

(6) Publish, Find, Bind: these three actions aiming at CGeoML, in fact, base on OGC Interoperability Program Service Model (IPSM). It describes a calculating model aiming at OpenGIS service. The target of the model is to explicate how to blend spatial software service in wider interoperability infrastructure to take loose coupling schema to use and extend all kinds of data and service resources.

Interoperability framework based on CGeoML could supply a flexible and unitary interoperability solution. It not only has technical foresight, at the same time, but also meets the current needs of GIS interoperability.

4. CONCLUSIONS AND PROSPECTS

Interoperability framework based on CGeoML is a completely novel system, which could meet the present needs of interoperability. It selectively learns and alters relative interoperability implement criterion of OGC, and could carry out the interoperability of applying GIS data and services on Intranet and Internet. Considering the faultiness in CGeoML criterions and quite a few new techniques in framework system, the future research on interoperability framework of CGeoML should focus on CGeoML criterion construction, relative processing in framework and development of service components. Meanwhile, validate the framework through application practice, and in this way, drive the interoperability work of CGeoML forward.

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