Use of Service Middleware Based on ECHO with CSW for Discovery and Registry of MODIS Data

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Abstract Nowadays, NASA is producing several terabytes Moderate Resolution Imaging Spectroradiometer (MODIS) data everyday; how to find the data with criteria, such as specific times, locations, and scales using an international standard becomes more and more important. In this paper, a service-oriented architecture for use of the integration Earth Observation System Clearing-House (ECHO) with the Open Geospatial Consortium (OGC) Catalogue Service—Web profile (CSW) is put forward. The architecture consists of three roles: a service requester (the user), a service provider (the ECHO metadata server), and a service broker (the GeoNetwork CSW and MODIS registry service middleware). The core component—MODIS registry service middleware includes three components: metadata fetcher, metadata transformer, and metadata register. The metadata fetcher is used to fetch metadata from ECHO metadata server; the metadata transformer is responsible for transform metadata from one form to another; the metadata register is in charge of registering ISO19139-based metadata to CSW. A prototype system is designed and implemented by using the service middleware technology and a standard interface and protocol. The feasibility and the response time of registry and retrieval of MODIS data are evaluated by means of a realistic LPDAAC_ECS MODIS data center. The implementation of this prototype system and the experiment show that the architecture and method is feasible and effective.

Keywords ECHO; GeoNetwork; ISO19139; model mapping; metadata transform; metadata register

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Introduction MODIS data is playing an increasing role in many areas, such as atmosphere, land, ocean, academic research, and government decision-making, as well as in people’s everyday lives. NASA’s Earth Observation System (EOS) provides free MODIS data with Hierarchical Data Format (HDF) files to users. On one hand, ISO19115 (Geography metadata standard)[1, 2] and ISO19139 (Geography metadata implementation specification)[3] metadata standards are used more and more in geography data management. On the other hand, the Catalogue Service for Web (CSW) implementation specification published by Open Geospatial Consortium (OGC) is developed more perfect and widespread used. Therefore, how to transform EOS metadata to ISO19139 metadata and meantime to provide a standardized CSW query interface is becoming more and more urgent. There are many geography metadata management and editing tools, such as ESRI company’s ArcCatalog, TeIDE’s ISO meta-
data CatMD Edit,[4] Ethiopian natural resources and environmental Meta-Database,[5] and INTA's ISO metadata editor (IME).[6] Wang[7] provided a construction schema for provincial spatial database of China that can manage metadata. Zhang[8] used XML schema to restrict metadata with XML form and mapped it to relational database for store. Li[9] proposed a metadata transforming method based on metadata model mapping and metadata instances transforming. Wei[10] has studied the transformation from NASA HDF-EOS metadata model to ISO19115-based metadata and tested with NASA MODIS data. Suresh[11] has studied the interoperation between NASA ECHO metadata and storage resource broker (SRB). Burnett[12] has studied the interoperation between NASA ECHO science data and services.

1 Related work

1.1 NASA ECHO and its metadata model

Earth Observation System ClearingHouse (ECHO) is a metadata clearinghouse and order broker being built by NASA's Earth Science Data and Information System (ESDIS). ECHO is an operational open system based on XML and Web Service technologies. ECHO is a middleware solution that provides a Service-Oriented Architecture (SOA) environment for the Earth observing (EO) community. Now, the services that ECHO provided are data partners service, client partners service, and service partners service. Data providers are response of building ECHO model metadata and then register them to data pools, so users can get those metadata with ECHO partners service. The ECHO science metadata model is developed based on Earth Observation system data and information core system (ECS) science data model. Data partners are responsible for generating metadata files in the XML format that comply with published ECHO data model. These metadata files are used to describe additions, removals, and changes to a provider’s data holdings. There are three metadata constructs utilized by the ECHO system: Collection, Granule, and Browse. Collection is a set of Granules, and one Granule may have some Browse images.

Collection is a grouping of science data that come from the same source, such as a modeling group or institution. Collections have information that is common across all the granules they contain a template for describing additional attributes not already part of the metadata model. The content of collection is very wide, and it has the following aspects: general, operation, process, granule, spatial, time, platform, additional online resource, and algorithm information. ECHO 10.0 collection implementation shows that the elements like DataSetId, Description, InsertTime, LastUpdate, LongName, Orderable, ShortName, VersionId, and Visible must be contained, and the elements like ArchiveCenter, OnlineAccessURLs, OnlineResources, Spatial, Temporal, and so on, are optional.

Granule is the smallest aggregation of data that can be independently managed (described, inventoried, and retrieved). Granules have their own metadata model and support values associated with the additional attributes defined by the owning collection. The elements and their relationship form “tree” document, and GranuleURMetadata are the root element. ECHO 10.0 granule implementation shows that the elements like GranlueUR, InsertTime, LastUpdate, Collection, and Orderable must be contained, and the elements like AdditionalAttributes, CloudCover, DataGranule, InputGranlue, OnlineAccessURLs, OnlineResources, Platforms, Spatial, Temporal, and so on, are optional. The content of Granule is also very wide, and it has the following aspects: general, operation, collection, DataGranule, spatial, time, orbit, measure, platform, additional, BrowseProducts, and online resources information.

Browse is an image that provides a high-level view of the associated granule or collection metadata item. Browse images are not spatially enabled but are very useful during data discovery and cross-referencing to other granules or collections. The elements of browse are ProviderBrowseId, InsertTime, LastUpdate, DeleteTime, BrowseImageFileName, and BrowseImageFileSize.

1.2 GeoNetwork and its metadata model

GeoNetwork is a standards-based decentralized spatial information management platform developed by united nations world food project and adopts CSW interfaces to access geo-referenced database, cartographic products and related metadata from a variety
of data sources. Now, GeoNetwork supports ISO19115, ISO19139 metadata standards, and CSW 2.0.1. It also embeds OGC Web Map Service (WMS) and realizes CSW distributed discovery based on Z39.50.

ISO 19115 defines the required schema for describing geographic information and services. It provides information including the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data. ISO19115 only defines the content of geography metadata but does not define the way of realization. XML is a widely used global information structure forms of expression, and it is very suited as the form of a structural data. ISO 19139 metadata implement specification defines geographic metadata XML (gmd) encoding, an XML Schema implementation derived from ISO 19115. ISO19139 contains XML schemas of ISO19115 elements, such as metadataEntity, identification, constraints, dataQuality, maintenance, spatialRepresentation, referenceSystem, content, portrayalCatalogue, distribution, metadataExtension, applicationSchema, extent, and citation.

1.3 ebRIM and CSW-ebRIM profile

Electronic business using extensible markup language (ebXML) is a modular suite of specifications that enables enterprises of any size and in any geographical location to conduct business on the Internet. ebXML Registry Information Model (ebRIM) provides a stable store where information submitted by a Submitting organization is made persistently. Such information is used to facilitate ebXML-based business (B2B) partnerships and transactions. ebRIM has several high-level classes. RegistryObject is a core class in ebRIM, and it has many attributes, such as “id,” “home,” “lid,” “objectType,” and “status.” There are many elements in RegistryObject, such as slot, name, description, versionInfo, classification, and externalIdentifier. EbRIM defines a perfect classification mechanism, and there are three main classes, i.e., ClassificationScheme, ClassificationNode, and Classification. Association class defines the relationship between RegistryObjects in ebRIM. The greatest feature of ebRIM is easily extended. OGC CSW was given ebRIM profile. There are many operations in this profile, such as GetCapabilities, DescribeRecord, GetRecords, GetRecordByld, GetDomain, Harvest, and Transaction. Some of those operations are compulsory, and some are optional.

1.4 Problems

There are differences between NASA ECHO metadata model and ISO19139 metadata model: From the point of syntax, their elements are different and the layers of the elements are also different. From the point of semantic, NASA ECHO metadata mainly focuses on the metadata of the satellite images of NASA’s, but ISO19139 metadata is the abstract of all geography metadata. The two models are different; however, there is some relation between them, for example, some of their elements have the similar or same meaning, such as the elements about spatial and time. The transforming of the two models is to find out their mapping elements, which have the similar or same meaning. How to transform the different form metadata models that have some relation from one form to another in a general automatic or semiautomatic method is a challenge. Meanwhile, CSW is only abstract interface implement, how to register ISO19139-based metadata to CSW, especially using ebRIM profile is also a challenge. This paper will give some solution to deal with those challenges.

2 Architecture and components

2.1 Architecture

According to the service-oriented, flexible, and easy extensible principle, this paper proposes an architecture shown in Fig. 1. On the role level, it contains service requester (the user), service provider (the ECHO metadata), service broker (the GeoNetwork), and service middleware. On the service component level, it contains ECHO metadata server, the middleware for fetching, transforming, and registering the metadata, the CSW, and the user client. The roles are defined as follows:

Service requester (CSW portal). Users can use CSW portal to do various find operations to CSW server and binds to the service provider in order to invoke one of its Web services.
Service broker (service middleware and CSW server). Service middleware is response to get different form metadata and register them to CSW with a standard interface. CSW server provides CSW service.

Service provider (ECHO metadata server). ECHO provider partners register metadata to ECHO metadata server, and then, this server as a service provider provides lots of earth observation data.

2.2 Components

ECHO metadata server. ECHO metadata server is provided by NASA. It provides lots of earth observation data, and users can get those data by ECHO.

Metadata fetcher. Metadata fetcher gets NASA Earth observation data. It builds a query request to meet the ECHO protocol that is the web service API and AQL provided by ECHO and gets the required Granule metadata.

Metadata transformer. Metadata transformer transforms the metadata fetched by metadata fetcher into a standard metadata. In this paper, it transforms ECHO metadata to the ISO19139-based metadata.

Metadata register. Metadata register registers the standard metadata to CSW.

CSW server. CSW server is the response to the manager, store, and distribute standard-based metadata.

Client. Users can send request to CSW server to find the metadata they want.

3 Key technologies

According to the architecture in Fig. 1, the workflow from NASA MODIS data to GeoNetwork has been implemented as follows: the fetcher obtains the MODIS metadata by the ECHO protocol, the transformer transforms it to a standardized ISO19139-based metadata, and then, the register registers the ISO19139-based metadata to the GeoNetwork. There are three key technologies in this process, which are metadata fetcher based on different protocols, metadata model mapping based on schema matching, and Metadata registration and querying based on ebRIM CSW.

3.1 Metadata fetcher based on different protocols

In reality, data providers provide metadata by a variety of application protocols. In order to effectively access metadata, we need to make use of these protocols. For example, NASA publishes MODIS metadata by ECHO application protocol. Users who want to get those metadata with this protocol must first understand it, analyze it, and then program it in the project. For example, if we want to use ECHO to get NASA MODIS, we should know something about ECHO, such as how many elements in ECHO and the relationships of them, and know how to use the Application Program Interface (APIs) of ECHO to build our services. Now, much metadata is provided in the form of web service, which can easily achieve mutual communication between heterogeneous systems and data exchange, cross-platform, cross-language, and cross-firewall communications. The development processes of web service for client are as follows: First, choose a development language and then use the WSDL of the web service to generate APIs; last, use the APIs and protocol model to develop the application program.

3.2 Metadata model mapping based on matching

The task of schema matching is to find out the semantic matching elements in two matching schemas. There are many automatic or semiautomatic schema matching systems, such as LSD, Cupid, COMA, and so on. Fig. 2 shows the flow of the implementation of schema matching. First, select two schema files that will be matched; second, select a schema matcher to match; third, reuse of used schema matcher or choose a new one to match; fourth, create a similar matrix, and finally, get the matching results and evaluate them. Schema matcher is the key of schema
metadata. Schema matcher refers to the matching algorithm that is in the form of the program. There are some schema matchers used in the above systems.

![Diagram of schema matching process](image)

**Fig. 2  Process of schema matching**

### 3.3 Metadata registration and querying based on ebRIM CSW

Registering metadata to ebRIM CSW is our aim, and the key is mapping the elements to the elements of ebRIM. We study the mapping as follows.

- Metadata maps to RegistryObject. When metadata register into the CSW, it will get an id and a UUID that is not changed anymore for this metadata. The id maps to the id of ebRIM, and the UUID maps to the lid of ebRIM. The source URL of metadata maps to the home of RegistryObject. The objectType of RegistryObject is metadata, and the status of it is submitted.

- Metadata maps to classification model. There are three classes about classification, and we should extend it. Create ISO19139 ClassificationScheme and metadata ClassificationNode by their extension.

- Metadata maps to association. We can get a new association type described by metadata. Its targetObject is related to the metadata schema, and sourceTarget is related to the metadata and web service.

After mapping all the metadata information to ebRIM elements, we can register the metadata to ebRIM CSW with the standard interfaces, and also, we can find the metadata by ebRIM CSW discovery interface.

### 4 Prototype

#### 4.1 IPV6 project description

In order to actively and steadily push forward Chinese next generation Internet business applications and industrial development, the Ministry of Education implemented the "technology upgrading and application of education and scientific research infrastructure in Internet Protocol Version 6 (IPV6) environment" project, and this project has ten subprojects. One of the subprojects is called “a sharing system of large-scale remote sensing data fusion in next generation Internet environment.” The main construction of this subproject includes the following aspects:

1. A large-scale remote sensing data-sharing system in IPV6 environment.
2. The fusion processing algorithms of large-scale and distributed remote sensing image data.
3. Integration of remote sensing data in multi-source distributed environment with online method.
4. The efficient transformation and visualization technology of large-scale remote sensing data.
5. Sharing platform of large-scale remote sensing data.
6. A demonstration and application service system of large-scale remote sensing data in IPV6 environment.

The study of this subproject will bring many benefits, such as developing Chinese remote sensing data resources, processing services resources, sharing of computing resources, as well as Earth observation data for scientific research and personnel training in
the next generation Internet environment.

4.2 Interface and functions of prototype

Metadata download and processing module is part of the subproject. The workflows of this module are as follows: First, download data and metadata from NASA’s MODIS data center through the ECHO protocol, and download data and metadata from Wuhan University’s MODIS data center through the FTP protocol. Second, transform the downloaded metadata into ISO19139-based metadata. Finally, insert those transformed metadata into CSW. Those workflows are realized by three small functional modules fetcher, transformer, and register. They respectively have interface doFetcher, doTransformer, and doRegister. For the functional modules fetcher, transformer, and register are relatively independent, so their internal and external systems interfaces are also doFetcher, doTransformer, and doRegister. Fig.3 shows the implementation of fetcher, transformer, and register in MODIS processing.

Fig. 3  ECHO MODIS processes of fetcher, transformer, and register

Fetcher generates the client API according to the WSDL provided by ECHO using AXIS2. Then, the API is used to get NASA MODIS metadata with the following steps shown in Fig. 4.

Step 1 Login the ECHO service. Using the AuthenticationService class, the username, and password to login ECHO service, and then, a token is returned.

Step 2 Build the query request. According to the data center, sensor, time range, spatial range, and so on, are used to build a request query adapting to the http://api.echo.nasa.gov/echo/dtd/IIMSAQLQueryLanguage.dtd. Fig. 4 is an example of a query request. The whole request is an XML document. <dataCenterId> is about the data center where you can get MODIS data. <dataSetId> is about dataset. There are over 100 datasets about MODIS data. <sensorName> is about the name of the sensor that you are interested in. <temporal> is used to set the range of time, and <spatial> is used to set the spatial range.

Step 3 Query and get query results. Call the catalog service class to query and get the results according to the token and query request from Steps 1 and 2. The results are XML documents, and they conform to ECHO metadata model.

Step 4 Logout ECHO service. Logout ECHO
service using the logout class and the token.

**Transformer**  The GeoNetwork provides batch-importing for “.mef” zip packages. The “.mef” consists of metadata “.xml” and “info.xml” that describes general information, group information, privilege information, public information, private information, the public folders that contain data, and the private folders that contain the thumb pictures. The main task of the transformer is to transform the metadata coming from the Fetcher to standardized ISO19139-based metadata and then zip them into “.mef” packages, which will be inserted into the GeoNetwork. The process is shown in Fig. 5: metadata transform between the NASA MODIS and ISO19139, download HDF file and jpg image, create “info.xml,” and “create.mef” zip packages.

**Step 1** Metadata transform between the NASA MODIS and ISO19139: NASA MODIS metadata is subject to the Granule specification, and the ISO19139 is subject to “its.xsd.” ISO19139 basic information model mainly contains the following schema files: metadataEntity, metadataExtension, identification, gmd, extent, citation, content, metaDataApplication, etc. The basic information model of NASA MODIS is based on schema file granule, and the key match is done between schema file metadataEntity and granule. We applied a generic match system—COMA (Do, et al., 2002) to do the matching test. In addition, choose AllContext strategy and use CONTEXTS matcher; there are 18 matchers in the repository for choosing, and the similarity cube aggregation strategy is average. Average aims at compensating between the matchers and returns the average of their predicted similarities. Apply unidirectional strategy to both, combining both directions to achieve independence from schema size. The similarity value combining strategy is average. The matching candidate selection method is multifactor. The generated mapping information is shown in Fig.5.

![Fig. 5 Mapping results](image)

After automatically matching, we modified the results and got final results. The mapping relationship between the NASA MODIS metadata and the ISO19139 can be described by a “MODIS2ISO19139.xsl.” According to the “MODIS2ISO19139.xsl” and the XSLT (eXtensible Stylesheet Language Transform), metadata from the fetcher can be transformed to standardized ISO19139-based metadata.

**Step 2** Download the HDF file. The ftp link for downloading the MODIS data can be obtained from the path “//GranuleURMetaData/OnlineAccessURLs/OnlineAccessURL/URL” in a MODIS metadata and then use the java ftp API to download the HDF file.

**Step 3** Download jpg image. The ftp link for downloading the MODIS image can be obtained from the path “//GranuleURMetaData/GranuleOnlineResources/OnlineResource/OnlineResourceURL” in a MODIS metadata and then use the java ftp API to download it.

**Step 4** Create “info.xml.” The “info.xml” is mainly used for describing the metadata that should consist of general information, classify information, privilege information, data storage information, and the thumb image storage information.

**Step 5** Create “.mef” zip packages. Parcel the “metadata.xml,” “info.xml,” “private/*.hdf,” and the “public/*.jpg” generated by the above steps to a .mef zip package using the java zip API.

Register is responsible for inserting the “.mef” zip packages from the transformer into the GeoNetwork using the GeoNetwork API. The concrete process can be described as shown in Fig.5. It scans all the files under the specified directory, and analyzes and submits the “.mef” package to GeoNetwork through a loop manner. When it analyzes the “.mef” package, it refers to the following process: analyze the “metadata.xml,” insert it into the GeoNetwork, get a re-
turned ID, and then put the HDF and jpg to the GeoNetwork storage directory. Now, all of the standardized ISO19139-based metadata have been inserted into the GeoNetwork.

5 MOIDS use case

5.1 Experiment design

In order to validate the architecture and method above, we had done some experiments. According to the service-oriented, flexible, and easy extensible principle, service-oriented architecture (SOA) experiments are designed.

Service provider (data server) is ECHO metadata server provided by NASA. All ECHO metadata is stored in an Oracle database with spatial extensions, but it is invisible to client users, and client users can only use ECHO APIs to get the metadata.

Service middleware include fetcher, transformer, and register can be deployed on any computer that can get on the Internet. This time, it is deployed on a PC (Intel(R) Core(TM)2 Duo CPU E700 @2.66GHZ, Memory of 2.00GB, PC Microsoft Windows/XP). Service broker server can also be deployed on any computer that can get on the Internet. For the architecture and method proposed in this paper that are being used in the project, we have the system of fusion and share large-scale remote sensing data based on next generation Internet; the service broker server is as follows: Intel (R) Core(TM)2 3.2GHz (2.13G) Xeon, Memory of 4GB(3GB can be extended to 8GB), and 3x73GB SCSI hard disk.

5.2 Analysis of the transform of two models

The transform between ECHO and ISO19139 model is used XSLT. Fig. 6 shows the analysis of the two models' transform. “Total” item in Fig.6 shows the whole number elements in ECHO and ISO19139 metadata. There are 59 elements in ECHO, and after the transform, they become 159 elements in ISO19139. Total number of elements is the sum of the number of direct transform elements, the number of extended transform, the number of abandoned transform, and the number of new added transform. “Direct transform” item means that there are same meaning elements in ECHO and ISO19139 metadata and that they can be directed mapping. “Extended transform” item means that the elements in ECHO metadata can find out the elements in ISO19139 to mapping, so MD_ExtendedElementInformation is used in ISO19139 to create new elements. In Fig.6, 26 elements in ECHO metadata extend into 48 elements of ISO19139 metadata. “Abandoned transform” item means that the elements cannot be abandoned or transformed. “New added transform” item means in order to meet the need add new elements to ISO19139 metadata, wherein they have no relation with ECHO metadata elements. According to Fig.6, the percentages of the direct transform of ECHO, the extended transform of ECHO, the direct transform of ISO19139, the extended transform of ISO19139, and the new added transform of ISO19139 are 55.93% (33/59), 44.07% (26/59), 20.75% (33/159), 30.19% (48/159), and 49.06% (78/159), respectively. From those percentages, we can know that the number of direct transform of ECHO is more than that of ISO19139’s, this means that most of elements of ECHO metadata can be transformed directly; the elements transformed from ECHO is about half of the elements of ISO19139 metadata elements.

5.3 Analysis of time efficiency of the function module

5.3.1 Cost time of fetcher

It will take a certain amount of time when implementing the fetcher and transformer function modules, how much time it will be taken to describe the impact of efficiency that the functional modules has played in the system, so finding out their roles and different im-
pact factors is very important. Randomly selected five datasets, time is June 1, 2009, space range (N18.16888°, N53.55374°, E73.62005°, E134.76846°), and sensor name is MODIS, and then, create a query request like Fig.4. Figs.7 and 8 give the execution time of fetcher.

Fig.7 gives the different time of fetcher query with different datasets. The largest returned results is 25 each time, that is, when a query results to not more than 25, those results will be stored in one file; while those with more than 25, each time can only return 25 results, and the remaining ones will be re-
turned in the next time. According to Figs.7 and 8, the returned results of datasets 1 and 2 are less than 10, and they cost the similar time; and datasets 3 and 4 have the same results and have similar cost time; but the cost time between dataset 2 and dataset 3 is very different because the results of dataset 3 is 5 (251/45) times of that of dataset 2. Therefore, we can see that less results means less time, similar results cost similar time, and different level results cost different time. The reason of this is less results cost less organization time and transform time.

5.3.2 Cost time of transformer

Transformer is a metadata operation to ECHO, which is composed of a number of operations. In Fig.9, we randomly selected eight instances of data for researching each operation of the spent time in the transformer.

According to Fig.9, we can see the following:

1) Cost time from more to less in transformer operation is as follows: download HDF file, download JPG, zip “a.mef” file, metadata transform, and generate configuration file.

2) Download HDF file and download JPG occupy a large space of the whole operation, and it occupies an average of 99.48%. Zip “a.mef” file, metadata transform, and generate configuration file is only 0.52%. The reason of this is that download HDF file and download JPG are operated on the Internet, so it will cost time to send requests and get the response. Meanwhile, the next three operations are done locally, so it costs less time.

3) The key of optimizing the transformer is optimizing download HDF file function and download JPG

5.4 Metadata query based on the CSW

Transforming ECHO metadata to ISO19139-based metadata is for the metadata standardizing, registering the ISO19139-based metadata to GeoNetwork is for metadata managing and CSW-based searching. GeoNetwork provides standard CSW interfaces for query, such as GetCapabilities, DescribeRecord, GetRecordById, and GetRecords. We modified the GeoNetwork CSW interfaces implementation APIs and the store structures to meet the requirements of ebRIM
CSW interfaces. We tested a query instance by using GetRecordById. The request parameters were host, port, CSW service, login information, operation method ID, and so on. The GetRecordById was set as “951aF603-F23b-495c-8F89-5F5c13dbec74”. The returned result was a CSW GetDecordByIdResponse XML document. In this way, ECHO metadata can be managed by metadata standard and be queried by ebRIM CSW standard.

6 Summary and future work

This paper proposes a service-oriented architecture of heterogeneous model mapping and transform method; this method includes three functional modules, namely, fetcher, transformer, and register. Based on this method, some experimental tests have been carried out. The experimental results show the following:

1) This method is a feasible model for heterogeneous data transform based on a service-oriented architecture.

2) This method realizes the transform from NASA MODIS metadata to ISO19139-based metadata and registers ISO19139 metadata to GeoNetwork to manage and query based on CSW. Therefore, it realizes NASA MODIS internationalization, standard management, and OCG CSW-based query.

The next step we need to do is to explore how to automatically realize the transform between heterogeneous models.

References

[1] ISO (2003) Geographic information—Metadata[S]. ISO 19115:2003
[2] ISO (2007) Geographic information—Metadata—XML schema implementation[S]. ISO 19139:2007
[3] ISO (2009) Geographic information—Metadata—Part 2: Extensions for imagery and gridded data[S]. ISO 19115:2009
[4] Sourceforge: CatMDEdit web site[OL]. http://catmedit.sourceforge.net/
[5] Uneca: enraemed web site[OL]. http://geoinfo.uneca.org/geoinfo/ethiopia/Welcome.html
[6] INTA:IME[OL]. http://www.crepad.rcanaria.es/meta data/en/index_en.htm
[7] Wang Yandong, Gong Jinya (2009) A construction schema for provincial spatial database of China[J]. Geo-spatial Information Science, 12(1): 25-32
[8] Zhang Tao, Yu Xueqin, Wei Shuangfeng (2007) Research on the geographic information metadata mode and storage mapping based on XML schema[J]. Science of Surveying and Mapping, 32(4): 113-115 (in Chinese)
[9] Li Jianhui, Wu Wei, Yan Baoping (2008) An approach for metadata model mapping and metadata instances transfer based on XML[J]. Microelectronics & Computer, 25(1): 34-38 (in Chinese)
[10] Wei Yaxing, Di Liping, Zhao Baohua, et al.(2007) Transformation of HDF-EOS metadata from the ECS model to ISO 19115-based XML[J]. Computers & Geosciences, 33(2): 238-247
[11] Suresh R, Gururaj S, Kobler B (2005) A common interoperable client for NASA ECHO and SRB[C]. Proceedings of the 2005 IEEE International Symposium on Mass Storage Systems and Technology, Sardinia, Italy
[12] Burnett M, Weinstein B, Mitchell A (2008) ECHO- Enabling interoperability with NASA earth science data and services[R]. Barcelona, Spain: Institute of Electrical and Electronics Engineers Inc.
[13] OGC (2006) OpenGIS® Web map service implementation specification (Version 1.3.0)[S]. OGC Document Number: 06-042
[14] ebXML[OL]. http://www.ebXML.org/
[15] OASIS[OL]. http://www.oasis-open.org/committees/regrep/documents/2.0/specs/ebirim.pdf
[16] OGC (2008) CSW-ebRIM Registry Service-Part 1: ebRIM profile of CSW[S]. OGC Document Number: 07-110r2
[17] OGC (2008) CSW-ebRIM Registry Service-Part 2: basic extension package[S]. OGC Document Number: 07-144r2, 40PP
[18] Doan A H, Domingos P, Halevy A (2001) Reconciling schemas of disparate data sources: a machine-learning approach[C]. ACM SIGMOD International Conference on Management of Data, Santa Barbara, California
[19] Madhavan J, Bernstein P A, Rahm E (2001) Generic schema matching with cupid[C]. Proceedings of the 27th VLDB Conference, Roma
[20] Do H H, Rahm E (2002) COMA—A system for flexible combination of match algorithms[C]. Proceedings of the 28th VLDB Conference, Hong Kong