Multisource Marine Environmental Information Grid Platform and Its Prototype System Research

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Abstract Based on the advantages of the openness, flexibility, high-efficiency, intelligence, and safety of grid, this paper focuses on the methods of marine environmental information sharing and integration in grid environment. According to the characteristics of marine information, which includes multisource, dynamic, and high-dimensional, this paper provides a framework and the technical solution for a multisource marine environmental information grid platform. As an experiment, the prototype takes the region of South China Sea as its study area and chooses three kinds of marine environmental information as the representative types for the marine information. The realization of the prototype of multisource marine environmental information grid platform shows the feasibility and practicality of the framework and the technical solution.

Keywords grid GIS; marine GIS; web service; data sharing; information integration

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Introduction

With the improvement of the resolution of marine remote sensing data and the rapid development of marine data acquisition means, digital marine simulation model, and quantitative analytical methods, the data accumulated in marine field has been exponentially increased and forms a huge “data ocean.” Although GIS is often used to manage, analyze, and visualized data in marine and ocean field,1,2 however, because of the unique features of marine environment (such as high spatiotemporal dimensional, dynamic, fuzzy, large volume multisource, etc.) and the deficiency, such as relative static (once the application is established, no other new services can be used unless for application reconstruct), lower sharing reuse (the data and function of one application cannot be easily reused by other applications), and one-way information transmission (Servers push to user) of traditional WebGIS, the data is not fully utilized, and users are often lost in the huge “data ocean.” How to make full use of the data and to use digital methods to process and represent every aspect of marine environment has...
been an urgent demand and becomes the core of digital ocean. However, as to marine information, only using traditional information sharing methods that are characterized by inflexibility, poor scalability and openness, and low degree of sharing and reusing cannot achieve comprehensive multisource heterogeneous marine environmental information sharing and integration.

The emerging grid technology, which has advantage in high openness, flexibility, security, and efficiency, has become an important solution of information sharing and integration. Especially recently, grid technology develops rapidly and has become a hot research in computer science. Grid can be simply understood as a virtual organization, which links all the resources, such as computer, database, and equipment, together and by unified management and scheduling to maximize the utilization efficiency of resources. The perspective of spatial information grid is to achieve one-stop integration and sharing of distributed, multi-source, and heterogeneous spatial data, by eliminating the heterogeneity of spatial data and its trivial details.

Although there have already been some successful grid application in the geo-spatial information world, such as Shao Zhenfeng proposed a kind of SOA-based spatial information sharing framework that worked well in digital city, either research or the application of the grid technology in marine information field is still at a blank. Therefore, in this article, we mainly focus on sharing and integrating multisource marine environmental data by using grid technology. First, we explore the key technologies, such as the dynamic and real-time integration of multisource data and models and the fast remote visualization under virtual grid environment and then elaborate the framework and implementation of a prototype system of multisource marine environmental information grid platform.

1 Architecture and key technologies of multisource marine environmental information grid platform

As the unique features of marine environmental information, it was hard to be centralized storage and unified management and can only take a road of sharing and integration under distributed, heterogeneous, and multisource web environment. First, oceanic phenomena exist in multiscale from micro to macro. They cannot be completely, accurately, and seamlessly represented in only one single application system. Instead, they should be split reasonably, distributed implemented, managed separately, and integrated organically. All those need the support of efficient interoperability framework and rapid information encapsulation and publishing mechanism. Second, the marine environmental data is complex, high dimensional, dynamic, and fuzzy, which makes it difficult to be expressed and organized in plain text or two-dimensional database table. In addition, its spatiotemporal process characteristic makes the traditional static data sharing and publishing methods unfeasible. It needs flexible data exchange technology to support the analysis, visualization, and interaction of such data that are high dimensional and dynamic changing in spatiotemporal. Therefore, a kind of common identified language that cannot only represent and store complex object but also can be efficient in data organizing and exchanging is critical. Third, marine is a real three-dimensional space, and marine environmental data is also distinctly three-dimensional. Without the help of visualization technology, they cannot be fully understood by human. The reproduction of an intuitive three-dimensional marine environment by means of three-dimensional visualization and virtual reality technologies can greatly help in phenomenon understanding and discovering of laws and mechanism. Therefore, the three-dimensional analysis and visualization of marine environmental information is a key point in this platform and is of great significance. Last, it is necessary to hide the trivial details, such as complexity, heterogeneity, and distribution of marine environmental information to form a virtual, uniform web service, and provide users with on-demand and one-stop service. All these require efficient virtual organization of service.

In summary, to achieve high degree of marine environmental data integration and efficient analysis and intuitive visualization, it should fully take into account the unique features of marine environmental
information and need to combine with the specific application requirements.

1.1 Architecture

By the integrated using of grid, web service, and virtual reality technology, we have proposed multi-layered marine environmental information grid platform architecture (see Fig.1).

In this architecture, there are five layers form bottom to top: Resource Layer, Service Layer, Management and Scheduling Layer, Application Layer, and User Layer. Service Layer encapsulates the resource and provides web service through an interoperable and uniform interface. It is the foundation of the architecture and consists of lots of web services, which are the actual sharing units. Management and Scheduling Layer is the core of the architecture. It organizes, manages, and schedules those services, and by hiding trivial details of services. It makes those service can be accurately and quickly found and accessed transparently and easily. Application Layer is the front user interface that the users interact with. Through the Management and Scheduling Layer, it integrates the services in the Service Layer to form a specified application. The application system in the Application Layer can be any customized application built in any programming language and programming IDE. In our prototype system, we only focus on application of three kinds of marine environmental data, such as Sea Currents, Sea Temperature, and Argo (just as shown in Fig.1). Users can consume service and integrate them in the customized application just like using it locally without knowing the details of the service used. By such a layered architecture, it not only makes the platform more flexible and scalable but also hides all kinds of details and makes the service easy to find and integrate. The procedure is very simple and clear: the service provider encapsulates the resource according the specified standard and specifications as a web service, and then, he registers it in the UDDI. The customer use customized application to find services by metadata-based query and dynamic binds and integrate the services he needs to the customized application and consume the services.

1.2 Key technologies

In the implementation, several key technologies have been used to ensure that the platform has the high efficiency, flexibility, and openness. These key technologies range form the design and organization in server side to the visualization and interaction in the client side.

(1) Multisource heterogeneous marine environmental data exchange based on XML

In the platform, XML plays several roles as follows:

① First, as a popular and important data format, it
can be used as the data source of the platform. KML/KMZ files or services are supported in the platform. ② Second, as the foundation for the WSDL and Soap, it is used to describe web service information (such as port, operation name, and parameter type) in the WSDL file of web service and enclose the message in Soap request and response. In our platform, we have developed an agent class whose responsibility is to parse service WSDL and according to the result parsed in the previous step (such as operation name and their input parameter types and output types) to dynamically construct the Soap request to the service and retrieve the output of Soap response from web service. With the help of such intelligent agent, it avoids the static service binding and achieves dynamic service binding and invocation. This makes the platform vigorous and enable it with capability of integration any registered web service. ③ Third, as an exchange language, it is used as the medium of information exchange between services. In grid environment, there are some cases that the data, and the function are distributed located. In these cases, at least one side of them should be migrated. In general, function needs environment of certain hardware and software and is hard to migrate, so the migration of data is always the only choice left. In our platform, we specify a standard XML schema for each type of marine environmental data source, and each data service of that type conforms to that schema and provide XML format data no matter what original format and schema it is. Therefore, function service in this grid platform can deal with those XML data uniformly and freely.

(2) Marine environmental information service encapsulation and publishing strategy

Grid is composed of services on each node, but is not just simple sum of those services. It should provide nontrivial and value-added service by organic composition of those services. To achieve efficient integration, the interface design and granularity of encapsulation of service should conform to certain specification and standard. For interface design, it can learn from thought of object-oriented and “Component Object Model (COM).” That is to “grasp the commonalities and distinguish between personality” and put similar or related function together and should explicitly describe each operation and its parameters when service publishing. Grid users can implement their concrete service according to that interface, and thus, those services can be integrated in the platform. For the granularity of encapsulation, it must gain a balance between flexibility and easy usability.

In marine environmental information field, we first classify those data source according to their thematic type (such as Argo, Sea Currents, Sea Temperature, etc.). Then, we classify the service based on the similarity and relevance among functions (such as data service, function service, visualization service, etc.). This kind of multilevel classification and categorization can reduce coupling degree among services and also improve fine-grained reuse. After that, service is implemented separately according to the specified interface. They can be simply implemented using ArcGIS Server template (MapServer, GlobeServer, GeoprocessingServer, WMS, WCS, and WFS) and can also be customized by code programming. They are platform and location independent and can be integrated and worked in collaboration together. Service of different type and granularity can be composed to form complex service or service workflow and provide advanced function. For example, as to sea current data, we implement service, such as service for retrieving the time series of sea currents, service for getting sea currents data at specified time, service of visualization of sea currents, service of sea current identifying at specified location at specified time, and service of dynamic process visualization of sea currents within a period. Through the collaboration of those sea currents services of different type and different granularity, it realizes the complex spatiotemporal analysis and visualization of sea currents.

(3) Virtual organization of marine environmental information service

The virtual organization of those services abstracts services, hides their details of the concrete service, and provides virtual service for the user. Its core component is the catalog service, which covers the function of registering, managing, finding, and subscribing service. The foundation of the catalog service is the metadata database, which is composed by three subsets. ① Metadata about the service itself.
They fall into two groups: functional information (description of operation and their parameter) and nonfunctional information (quality, security, and publisher information). These metadata are the grounds for service finding and service invocation. To achieve quick service finding, we adopt hierarchical directory-style organization of service according to its category and index the commonly used metadata field (such as name, type, geo-region served, etc.) in service discovery. Metadata about relationship between services. It mainly describes the relationship between services and is treated as knowledge database, which plays a key role in the service integration and intelligent composition. If one service is to be invoked, then its associated services are also integrated. For example, in our grid platform, a request to an Argo Query Service to find an Argo can (if it was set in the “Associated Visualization Service” item when service registering) automatically integrate its associated visualization service to locate the selected Argo and display its attributes.

Metadata about the grid. It mainly describes the current status of the grid, such as grid nodes information, user information, current user, and current requests. It is the grounds for the grid status monitoring and self-adaptive adjusting.

(4) Remote visualization

In our platform, we use two kinds of distinctive remote visualization solutions at the same time according to the actual situation. One is server-based mode: the visualization is processed at the server, the client only sends the visualization request and receives the visualization result and displays it. The other is client-based mode: the client sent the request to the server, then the server returns the data that is to be visualized to the client, and the client just can get that data and visualize it locally. The former is faster more real-time, but it is poor in interactivity and controllability for the user. The latter can avoid the frequent interaction with the server and improve the interactivity and controllability for the user. Once the client gets the data, it can work offline, and also, there exists the risk of data outdated when the data in server has been updated. In our platform, if in cases of high demand of real-time (such as statistical chart analysis) but not high demand of interactivity and three-dimensional, the server-based mode is used. If in case of high demand of interactive and three-dimensional (such as three-dimensional navigation and operation), the client-based mode is used.

2 Prototype system

With the purpose of effective integration of various types of marine information resources to achieve the sharing and exchanging of distributed multisource marine information and providing a feasible and reliable grid technologies, the Institute of Geographical Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS), and National Marine Data & Information Service Center jointly proposed the establishment of a prototype system of marine environmental information grid platform. South China Sea was chosen as the application area, three kinds of representative data (Sea surface temperature—raster field data, sea currents—vector field data and Argo-survey data) were selected as the demo data.

The prototype system was developed according to the thought of grid and was based on SOA architecture and web service technology. In the server side, ArcGIS Server was used as the GIS application server to provide powerful data service (such as Web Feature Service and Web Coverage Service), visualization services (such as Web Map Service and Web Globe Service ), and function service (such as Argo 3D Profile Analysis service) and also made use of other customized service. The client is a virtual three-dimensional marine system (VRMarine) that is developed based on ArcGIS Engine. Through the help of simple customized UDDI (Service Management and Scheduling Middleware), it could dynamically integrate the services registered in the UDDI and could achieve remote visualization of data and real-time invocation of functions.

As shown in Fig.2, the multisource of marine environmental service can be integrated and overlaid together in the unified spheroid model and form a realistic three-dimensional scene of marine environment. This kind of three-dimensional spheroid model is different with the traditional two-dimensional planar map in that it is continuous and seamless in all horizontal direction, while the planner map is artificially split in north-south and east-west. In addition,
in three-dimensional spheroid, it can be viewed at any distance and in any direction. All these make the marine environmental object and phenomenon be well represented and understood.

3 Conclusion

Through the analysis of the unique features of marine information, we carried out research on the architecture and key technologies of the marine environmental information grid platform and built a prototype system based on that architecture by using those key technologies. The successful experiment result has proved that the provided framework and the key technologies is a feasible way to achieve multi-source marine environmental information integration and interoperability. The experiment result also shows that the vital infrastructure of “Digital Ocean” and virtual three-dimensional globe is the best platform to represent the marine environment. The idea and technology solution provided by this paper can be brought into other fields (such as digital city and digital water, etc.) to achieve the sharing and integration of the distributed heterogeneous and multisource information in their scopes. Of course, there are still many technical problems, such as the parallelization of geospatial algorithm in grid environment, semantic description and semantic integration of grid service, and visual workflow modeling mechanism, that need to be resolved in the future.

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