Design & implementation of distributed spatial computing node based on WPS

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Abstract: Currently, the research work of SIG (Spatial Information Grid) technology mostly emphasizes on the spatial data sharing in grid environment, while the importance of spatial computing resources is ignored. In order to implement the sharing and cooperation of spatial computing resources in grid environment, this paper does a systematical research of the key technologies to construct Spatial Computing Node based on the WPS (Web Processing Service) specification by OGC (Open Geospatial Consortium). And a framework of Spatial Computing Node is designed according to the features of spatial computing resources. Finally, a prototype of Spatial Computing Node is implemented and the relevant verification work under the environment is completed.

Introduction

SIG(Spatial Information Grid) is the application of Grid technology in the spatial information field. Through converging and sharing mass spatial resources (including spatial data resources and spatial computing resources) and the integrated management of them, it implements a spatial infrastructure with features of service on demand and strong data supporting and computing ability[1-2].

Currently, the research of spatial information Grid technology mainly focuses on the grid sharing of multi-source heterogeneous special data, providing basic data services for SIG users[3]. However, only through processing by special computing resources, could spatial data provide useful spatial information to society[4]. By studying on how to make use of spatial computing resources in Grid, this paper introduces an integrated service process to sharing computing resources.

In SIG, spatial data and computing resources owned by organizations are referred as spatial data node and spatial computing node respectively[5]. Under the precondition that they are highly independent and autonomous, they provide data and computing service to SIG. The spatial computing resources provided by computing node for SIG contain two categories[6]:

1. The general computing resources: Include common commercial or open-source software in spatial information field, such as ENVI, ArcGIS, GDAL, GeoTools component library etc..
2. User on-demand computing resources: On account of some special application demand, spatial node permits programs developed by users to be deployed inside the node, by which users could use the high performance computing power of the node to complete certain spatial computing task.
There are some problems to implement spatial computing resources sharing and cooperating in Grid:

1. The integration of heterogeneous spatial computing resources: Spatial computing resources vary significantly in runtime platform, programming language and interactive mode. How to integrate these resources abstractly and shielding their implementing difference is the primary problem to be considered in constructing a spatial computing node.

2. The servicisation of spatial computing resources: In terms of Grid system design, Ian Foster proposed the concept of OGSA (Open Grid Services Architecture) based on “Web Services”. This architecture could well foster finding and loose coupling cooperation of resources. However, because of lacking of support for spatial metadata information and relative spatial international standard, it is can fully meet the requirements of SIG.

3. The requirements of the stateful service in Grid: The service state is always demanded in Grid. According to this, OGSA adopts Grid Services to implement it. In SIG, an analogous mechanism is also needed to implement stateful service.

On account of the problems mentioned above, this paper uses the WPS (Web Processing Service) specification by OGC (Open Geospatial Consortium) to implement the servicisation of spatial computing resources based on the virtually integration of variety heterogeneous spatial computing resources. At the same time, in order to implement stateful service, this paper expanded WPS and proposed the asynchronous WPS service mechanism based on worksheet. In the end, this paper designs a spatial computing node implementing frame based on WPS.

1. Design of spatial computing node based on WPS

The goal of spatial computing node is to provide basic computing resources to SIG as service. According to the problems on node construction mentioned in the introduction, this paper designs spatial computing node as “integration of variety heterogeneous —resources servicisation — grid adaption”

1.1. OGC and a brief introduction of WPS

OGC is a non-profit international organization[7]. OGC proposed a integrated service frame of spatial data resources and spatial computing resources. WPS is a standard to implement the interoperability of spatial computing resources. The current edition is 1.0.0 and it contains three exterior interface, responding demands for spatial computing resources from users at any time as a service[7]. The service interface provided are: GetCapabilities, DescribeProcess, and Execute. These three interfaces fix the searching and execution entrance of the meta information of computing resources.
1.2. The integration of variety heterogeneous spatial computing resources

Spatial computing resources are used to process spatial data resources such as vector data and raster data. According to the characteristic of spatial data resources, this paper designs the XML-based spatial computing resources description specification. Describing different kinds of spatial computing resources by XML could normalize the management of computing resources inside the node.

In order to process massive spatial data effectively, distributed computing architecture is used in the node. ENVI, ARCGIS, GeoTools, GDAL etc. are deployed in distributed machines to processing spatial data concurrently and effectively. In order to sharing the spatial computing resources, we use Adapter mode to design an integration framework of variety heterogeneous resources, as Figure 2 shown.

![Spatial computing resources integration inside the node](image)

Figure 2. Spatial computing resources integration inside the node

In this framework, all sorts of the software deployed in the computing service machine are assembled in the spatial computing environment and management by the XML standard mentioned above. Of course, XML is just a description mechanism. The implementation is achieved by the abstracted API interfaces and communication middleware. Communication middleware is the communication tools in the node which delivers the computing task dispatched by the node management service machine to the relevant computing service machine by LAN.

1.3. The services extention design in the node

The various, heterogeneous and multi-platform of spatial computing resources in the node are normalized by XML and Adapter mode integration method. However, these abstract spatial computing resources can only be used by grid users after being released as services\[8\].

On account of the servicisation of spatial computing resources, we use WPS by OGC to replace “Web Service” and “Grid Services” in the OGSA. The advantages of WPS are illustrated as the following three aspects:

1) WPS is a service protocol of spatial computing resources sharing, which is widely recognized in spatial information realm. It is the acquiescent standard for the sharing and cooperation of spatial computing resources\[9-10\].

2) WPS not only provides supports for complex spatial vector data and spatial raster data, but also provides supports for internet spatial data such as WMS, WFS and WCS.

3) The description of meta information as a service, the description of meta information of spatial computing resources and the execution of computing resources are provided by three standard interfaces respectively. And it is more flexible and extensible.

In order to support SIG environment, we add work order management module and spatial data management module as Figure 3 shows:
The work order management module is used to implement WPS asynchronous service communication which will be illustrated in the following part. The spatial data management module is used to deal with the spatial data. It could get and cache these data before the start of the computing task and transfer the result to spatial data service at the end of the computing task.

Considering the security issue, no matter what the communication protocol is, the node we design could adapted it through abstracting the spatial computing resources. The change of security mode in the node is only operated in the WPS level which does not have influence on the whole distributed spatial computing architecture.

1.4. The implementation of WPS in Grid

As one implementation of Web Service, WPS is also a stateless synchronous communication protocol which is not suitable for the stateful grid environment where processing mass data, monitoring the status and retrieving results are always needed. According to this, OASIS made WSRF (Web Services Resources Framework) as a stateful Web Services architecture. In SIG, a stateful service is also needed. So we have to transform WPS to meet the demand of grid environment. To large extent, WSRF is made for static resources which are not suitable for getting computing resources and supervising the execution status. So it is not a good choice to expand WPS; instead, a stateful asynchronous service mechanism is needed.[11]

In order to implement WPS asynchronous communication and make it fitful for SIG, we design an asynchronous service mechanism based on work order management module. In the expanded spatial node, all the demand of submitting computing task and obtaining of results must be complete by process module provided by work order management. They are as the following:

- GetJobID: to get a new worksheet number
- GetJob Status: to get the working status of a worksheet
- GetJobResult: to get the result of a worksheet

The process of asynchronous service is as Figure 4:
Figure 4. WPS asynchronous service
(1) The high level Grid asks the computing node for new computing task through WPS service interface GetJobID. And the node stimulates the work order management module to create and return a new worksheet number.
(2) The high level Grid provides a computing task according to the spatial computing resources on demand, then it ends the connection to the node at once and submit the task.
(3) After submitting the computing task, because of the asynchronous communication method, the high level Grid could deal with other users’ demands at the same time inside the node. At the same time the work order management module makes records of the computing status. The high level Grid can inquiry whether a computing task is finished at any time.
(4) If the computing status shows over, through GetJobResult interface, the computing result can be returned.

Through the design mentioned above, when multi-nodes work together, the high level could inquiry the task execution status at any time after submitting the task and does not need to wait all the time. In a word, this method could supervise the computing task and obtain high usage rates of the computing resources.

2. The implementing architecture of computing node base on WPS
We have solved the key problems of spatial computing node construction by the integration of heterogeneous computing resources by WPS asynchronous service. Figure 5 shows the spatial computing node architecture base on WPS.

The node management system is formed by hardware management and software management. The latter supervises the status of computing machine and provides support for dispatch of the
computing tasks in the node. WPS service modules manage the spatial computing resources and releases the abstract API as WPS services.

2.1. Middleware in the node and Adapter
The middleware is installed on the computing machine and collects current status information about CPU, RAM, etc., and sends them to management machine as basic information for dispatch scheduling. The middleware accepts the computing task from the dispatch module, then sends it to relevant computing machines, and stimulate Adapter module to complete the computing task. In order to make the middleware platform slackly coupled, we use Java Socket communication method to implement the middleware. Each Adapter should be developed according to different spatial computing platform.

2.2. Release of WPS services of the node
The basic unit of computing resources of WPS is a subset of the abstraction of spatial computing resources. Based on this abstract design, to release spatial computing resources as WPS services becomes easy and specific release process. We design and implement an automatic service release tool based on B/S architecture using “52 north WPS” container which is open source software.

2.3. The abstract spatial computing environment
The abstract spatial environment is the core part of the whole spatial computing node which assembles all the spatial computing resources in the node and described by XML. The primary function of the abstract spatial environment is to deploy the received computing demands to specific computing machine and dispatch the computing tasks.

Because of the virtual mechanism, a spatial computing software package may be deployed on multiple machines. On account of this n versus m relationship of data resources and computing resources, a dispatch mechanism is needed to get high resource usage rate. Currently, two dispatch mechanisms are designed for the Grid node: single Process dispatch and multi-Process dispatch. The dispatch procedure is as the Figure 6.

![Figure 6. Spatial computing dispatching process](image)

(1) Single Process dispatch: deploy the data to computing machines within the relevant computing resources to process. This is confined to one-step task.

(2) Multi-Process dispatch: deploy the data to multi computing machines within different computing resources and then exchange data among them. These computing procedures have to be completed by multiple computing resources and they are not confined to any order. So this strategy is much effective under this circumstance.

The whole integrated dispatch strategy implements load balancing among the computing machines which ameliorates the performance of the node.

2.4. Data transmission among the nodes
In spatial computing node, data cache among the nodes is needed to implement the cooperation among the nodes. In SIG, each computing node would release their processing result according to OGC standard about spatial data services such as WMS, WFS, WCS and so on. So, before the start of the
computing task, the node would get the data through internet and the processing result would be released as OGC data services. Then the intermediate results are delivered to the next node by URL of the result through internet dispatch module. Through this method, the cooperation among the node becomes convenient.

3. SIG spatial computing node prototype and experiment

According to the design mentioned above, we develop and deploy a spatial computing node prototype based on WPS as shown in Figure 7.

![Figure 7. Spatial computing node based on WPS](image)

This prototype implements grid servicisation of three spatial computing resources. The operating systems include Windows and Linux. The node management system based on B/S is deployed on the node management machine and it is also the entrance of WPS service.

In order to verify the validity of task submit and execution by WPS asynchronous service, we test K-means unsupervised classification algorithm of remote image based on ENVI. The first situation is to use only one computing machine and WPS service is synchronous and the second situation is to use three computing machines and WPS service is asynchronous. The data for test are images of 5000*5000 (marked by FS). The table 1 shows the experiment results.

| Experiment condition\data    | 3*FS | 6*FS | 9*FS |
|------------------------------|------|------|------|
| Single machine, synchronous WPS | 186  | 413  | 735  |
| Multi-machines, asynchronous WPS | 123  | 273  | 452  |

Firstly, this test proves that WPS is compatible to the specific features of spatial computing resources so that it could implement sharing of spatial computing resources in Grid. Secondly, with the growing of data amount, the asynchronous communication method and dispatch strategy ameliorate data processing velocity but its stability is to be enhanced. Figure 8 is the processing result.

![Figure 8. ENVI K-means unsupervised classification results based on WPS](image)
4. Conclusion
This paper designs and implements a spatial computing node based on WPS according to the specialty of spatial computing resources. In order to implement the integrity of heterogeneous spatial computing resources, this paper introduces the conception of abstract spatial computing environment and designs an integrated framework of distributed resources in computing nodes. According to the disadvantages of WPS in SIG environment, we design asynchronous WPS communication mechanism based on work order.

Because of the fact that the sharing and cooperation of spatial computing resources in Grid is complex and needs further study. Although this paper designs an integrated framework based on WPS, there are still many problems to be solved. The problems are most conspicuous in the aspect that how to transfer massive spatial data fast and perfect the abstract mechanism of spatial computing resources which limit SIG to provide spatial information in real time. In the near future, we will study how to combine the abstract spatial computing environment with the popular “cloud computing” technology and promote it to “spatial cloud computing environment”.

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