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A Research of Publishing Map Technique Based on Geoserver

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ABSTRACT
Requesting capacity of traditional WebGIS in handling the high concurrence is very limited, which is far from meeting the application demands of community nowadays. In order to minimize response time of WebGIS as well as enhance user experience, tile-mapping sever is able to realize cache middleware according to the tile-pyramid model. In this study, analyzed the tile-pyramid model and therefore present an improved quad-tree spatial index structure. To introduce the realizing process of GeoWebCache, as well as compare the response time of direct asking mapping service and GeoWebCache cache skill. Through experiments, in conclusion, the response time of GeoWebCache cache skill, which uses improved quad-tree spatial index tile-pyramid model is much lesser. It reduces the sever load and provides better user experience.

Key words: Tile-pyramid model, a quad-tree spatial index structure, GeoWebCache, WebGIS

INTRODUCTION
The world wide web geographic information system (WebGIS) (Guo, 2013; Tao, 2013; Fang *et al*., 2010; Liu and Nie, 2010) is a kind of typical geographic information system based on Internet. It uses the Internet technology to expand and improve a new technology of GIS. The core is the application of embedded GIS HTTP standard system to realize spatial information management and publish in Internet. WebGIS, which uses multi-host and multi-database distributed deployment, connects through the Internet. It is a kind of browser/server (B/S) structure. The server provides information and services so that the clients have all kinds of spatial information and application. Due to WebGIS is a distributed system, the user and the server can be distributed in different locations and different computer platforms. WebGIS is the main role in spatial data distribution, spatial query and retrieval, organizing Web resources and so on.

In recent years, the WebGIS has already become a kind of highly visited site by Internet users. The speed of web map generation, distribution, display and browse is the key determinant of WebGIS system performance. While, traditional WebGIS application system in handling the high concurrence is very limited. After traditional WebGIS clients make real-time map requests, special rendering image map is made and sent back to the clients by the sever every single time. The server will re-rendered an image every time a request is made by the client. In this way, analyze real-time performance of map but the server response time is long with low efficiency and big consumption of server resource. It causes the server to perform bottleneck. With the wide application of WebGIS, especially the launching of Google Maps and the rising popularity of the domestic various map service platforms, a large number of users' access puts forward a huge challenge to WebGIS response performance in high concurrency. Traditional WebGIS platform usually rags when dealing with the high concurrency. With the increasing number of users, each user submitting a request waits for longer periods of time, even time out, which will greatly reduce the user experience. Obviously, each request for special map image rendered has become no longer applicable in the case of highly concurrent traffic.

Now more and more map services use tiles technology (Zhang *et al.*, 2009; Xu *et al.*, 2010; Jiao *et al.*, 2014), for example, now the weather map services in our country are using the technology of map tile (Huang, 2013; Mei *et al.*, 2012; Yang *et al.*, 2005). Map tile is a raster image with no location information. However, by using relevant slicing algorithm, you can calculate the specific location of the position. Based on pyramid tiled map technology (Du *et al.*, 2011; Yin and Sun, 2010) server generates different levels of tile map in advance and stores it in the middleware. It can greatly improve the map production, distribution, displaying and browsing speed, as well as reduce the server load and network traffic load.

Therefore, in this study, based on GeoServer Open Source map service, it construct a tile-pyramid model (Hu *et al.*, 2011; Wen *et al.*, 2013), as well as improve traditional quad-tree spatial index (Niknami *et al.*, 2014; Zhou *et al.*, 2010; Sun *et al.*, 2008) in the model and apply the model to GeoWebCache caching technology to complete map distribution and display, which greatly improves the efficiency of the client and server interaction, better meeting the needs of the users.

METHODOLOGY

Geoserver map service: GeoServer is a fully functional map sever which follows the Opening Standards of OGC (the Open Geospatial Consortium) and develops WFS-T and WMS. It plays a role of providing the client with web map service. It can receive a unified, standardized WFS and WMS request and return to multiple formats of data. It creates possibilities for public map services during the process specification of WMS/WFS. GeoServer can facilitate the release of the map data, allowing users to update, delete and insert characteristic data. It can be relatively easy to quickly share geographic information between users. By using it, data can be treated as maps/images to distribute (WMS) along with releasing the actual data directly (WFS). Changing, deleting and adding (WFS-T) function are provided at the same time.

The process of GeoServer dealing OWS request is shown in Fig. 1. Detailed steps are as following:

- Parse the HTTP request parameters. Program will not directly use the HTTP parameters. They are a string key/value pair (KVP) or XML string. Program translates them into corresponding object. Type of org.geoserver.ows. Request is on behalf of the type of request parameters, which contains the transformed KVP Map. They are already changed from the original string into objects
- Match the service object, choosing proper service according to the request parameters of service and version
- Such as, http://127.0.0.1:8080/geoserver/cdc/wms? Service = WMS and version = 1.1.1 and request = GetMap and layers = CDC:China and styles = and bbox = 5781322.883446776, 600833.7781007506, 1.0633038698410608ε7, 549455.254993615 and width = 507 and height = 512 and SRS = EPSG:2309 and format = application/openlayers. This URL is WMS services of the request 1.1.1 version. Indicating the service ID and version number is needed when registration

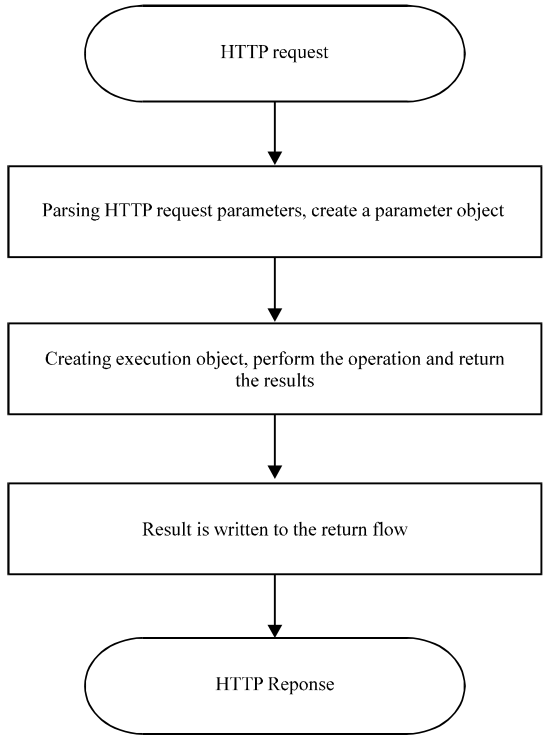

Fig. 1: Process of GeoServer dealing OWS request

- Perform operations in such a way as the main purpose is to create an object of org.geoserver. platform.Operation to execute. The object uses Java reflection principle to implement the function call, so its need to create an array of function arguments
- The results are back to the client

Tile pyramid model

Tile cutting diagram principle: Tile pyramid map model is a kind of multi-resolution hierarchical model. From the bottom to the top floor of tile pyramid, resolution becomes lower and lower. But the geographical scope is stable. The construction algorithm of tile pyramid model is as following:

- Determine number N of the zooming level provided by the map service platform. Rank the lowest scale and the biggest map images as the bottom of the pyramid, namely layer 0 and they are blocked on. Cut from the upper left of the map image, from left to right, from top to bottom. Cut into the same size (such as 256×256 pixels) of square map tiles, forming 0-floor rectangular tiles
- On the basis of layer 0 map, the method of each 2×2 pixels into one pixel generates the map image of first layer and they are blocked on. Divide the images into the square of the same size as the next layer of map tiles, forming layer 1 tiles matrix
- Use the same method to generate the layer 2 tiles matrix,... , Layer N-1 is generated by the same method. The whole tile pyramid structure is shown in Fig. 2

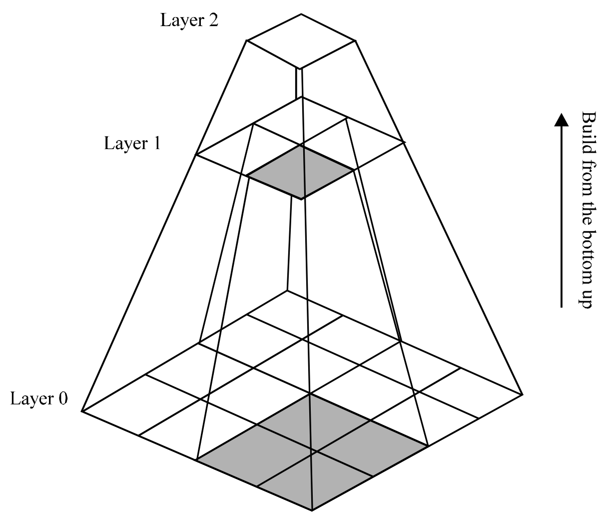

Fig. 2: Tile pyramid model

Due to tile pyramid model is a multi-resolution hierarchical model, this model provides a great convenience for application of WebGIS system of map data services. In order to show the details and levels of the terrain scene, different zoom levels require different resolution maps. Tile pyramid model can provide the multi-resolution image data directly without the need for real-time rendering. It improved the efficiency of mapping of WebGIS application system. If there is no tile pyramid model, map should be carried out on the basis of spatial geographic data real-time rendering. Due to rendering a map is very time consuming and server resources occupying, it does not support the highly concurrency visits to WebGIS site. While increasing the storage space, tile pyramid model reduces the total time the client required to complete per frame of the map. It has greatly improved the user experience. Space for time, which is a basic idea of strategy in the field of computer technology.

Quad-tree spatial index

Traditional quad-tree structure: Core idea of quad-tree index is to divide geographical space recursively into tree structure of different levels. It divides the known range of space into four equal sub-space and so on, till the level of the tree reaching to certain depth or meeting certain requirements. Quad-tree structure is rather simple. When the spatial data object is more evenly distributed, it has relatively high efficiency in spatial data inserted and queried. Thus quad-tree is one of commonly used GIS spatial index. As is shown in Fig. 3, geographical space objects are stored in the leaf nodes. Intermediate nodes and the root node do not store geographical space objects.

As to region query, the efficiency of quad-tree is higher. But if the space object distribution is uneven, the level of the quad-tree can deepen unceasingly with the insertion of geographical space object and it will form a serious of imbalanced quad-tree. So every time the depth of the query will be greatly increased, which results in the sharp decline in the query efficiency.

Improved quad-tree index structure: Quad-tree structure is a top-down gradually divided hierarchical structure of the tree shape. Traditional quad-tree index has the following disadvantages:

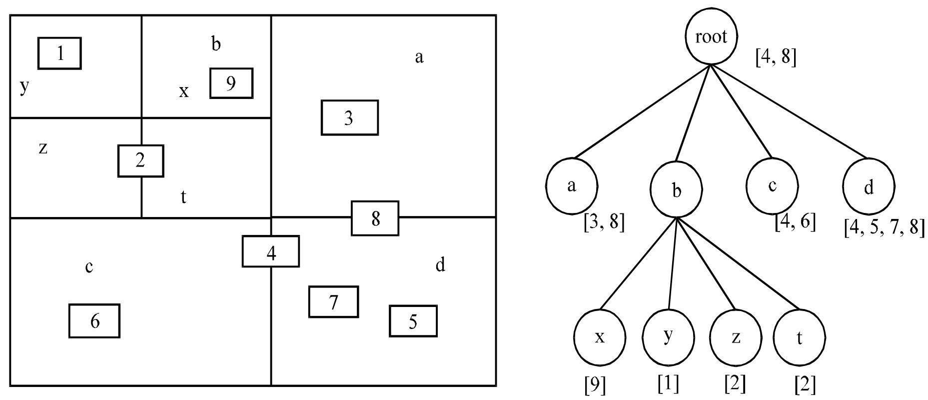

Fig. 3: Quad-tree structure

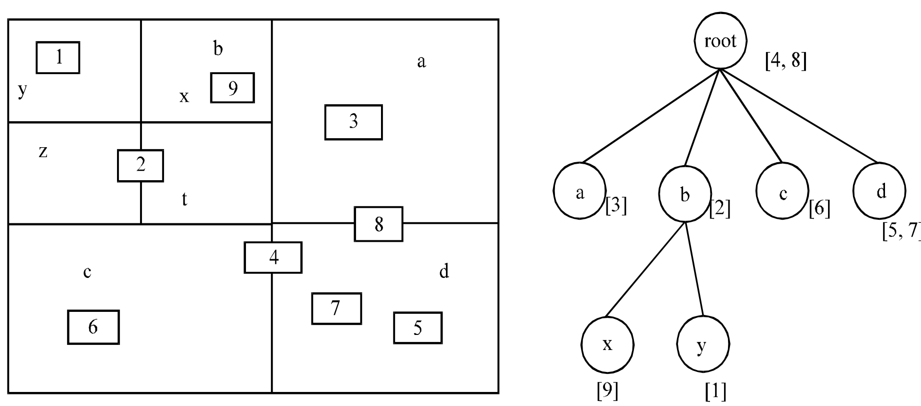

Fig. 4: Improved quad-tree structure

- Space entities can only be stored in leaf nodes. Intermediate nodes and the root node can't store space entity information. With the insertion of space object, the quad-tree becomes so deep that spatial data querying efficiency will be lower
- The same geographic entities in the process of division of quad-tree are likely to be stored in more than one node, which will lead to the waste of index storage space
- The unbalanced distribution of geographical space object can result in conventional quad-tree generating a very unbalanced tree, which leads to imbalance and wastes of storage space

Corresponding improved method is to store geographic entity information in a completely contained smallest rectangle node rather than the parent node. Each geographic entity can only be stored in a tree to avoid the waste of storage space. Firstly, generate full quad-tree to avoid reallocating memory when inserting the geographical entity. Secondly, speed up the inserting speed. Finally, release memory space of empty nodes. The improved quad-tree structure is shown in Fig. 4.

In order to keep the consistency of space index and space data stored in the file, quad-tree data structure is as following:

- The four regional identity

Define respectively four sub-region index number of the plane area, upper right for the first quadrant 0, upper left for the second quadrant 1, bottom left for the third quadrant 2, bottom right for the fourth quadrant 3.

```
type def enum
{
UR = 0, / / UR the first quadrant
UL = 1, / / UL the second quadrant
LL = 2, / / LL the third quadrant
LR = 3 / / LR the fourth quadrant
} QuadrantEnum,
```

- Space object data structure

Space object data structure is approximation of geographical object. In spatial index, a considerable part is based on MBR as an approximation.

```
type def struct SHPMBRInfo
{
int nID,/ / space object ID
MapRect Box / / space object scope of MBR coordinates
} SHPMBRInfo.
```

nID is space object identification number. Box is a minimum of the rectangular space objects outsourcing (MBR).

- The type structure of quad-tree node

Quad-tree node, which is the main component of the quad-tree structure is mainly used for the storage of space object identification number and MBR. It is also a main part of the quad-tree algorithm operation.

```
type def struct QuadNode
{
MapRect Box,/ / node represents a rectangular area
int nShpCount,/ / the number of all the spaces contained in the node
SHPMBRInfo * pShapeObj,/ / space object pointer data.
int nChildCoun,./ / the number of child nodes
QuadNode * children [4] / / point to four of children the node
} QuadNode
```

Box is on behalf of the minimum outsourcing rectangular of quad-tree corresponding area, as well as the smallest outsourcing rectangular of a layer containing a minimum outsourcing rectangular area of next layer. NShpCount represents the number of spatial objects in this node. PShapeObj represents initial address pointing to the space object storage address. The space object of the same node is consistent in memory storage. NChildCount represents data of child nodes contained by nodes. Children is an array pointing to the child nodes.

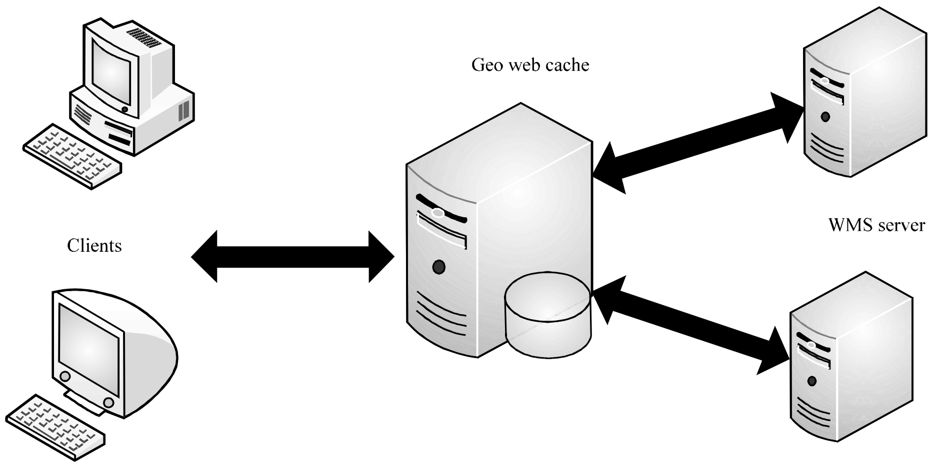

Fig. 5: GeoWebCache service framework

In a pyramid model, when the ratio of the resolution of the lower and upper map is 4:1, map tiles of tile pyramid model can be quad-tree result index storage management. Specifically from tile pyramid model layer 0, make map tiles storage paths the storage unit. Each floor tile matrix storages successively according to the sequence of line and the use of quad-tree structure establishes the storage index.

GeoWebCache service: GeoWebCache (GWC) is to use JAVA to realize WMS cache (Web Map Service) technology of tiles. Maps are often static, since the data of every request WMS (web map service) is for server to process, which may lead to unnecessary treatment and increasing the waiting time. When they request, GeoWebCache optimizes storage map tiles. GeoWebCache tile map service middleware is used as a proxy connection client (such as OpenLayers or Google map) and server (such as GeoServer or any WMS compatible server) as shown in Fig. 5. As the new map tiles are requested, GeoWebCache intercept these requests and pre-render tiles. If the request tiles have been stored in the cache, GeoWebCache will return to the client directly. Therefore, once the tiles are stored, mapping speed will increase many times to realize perfect user experience.

GeoWebCache implementation: GeoWebCache server intercepts the request of the tiles client sending with the HTTP protocol, determining whether if it is WMS request or not. If so, request is sent to the WMS service. Then WMS service parses object request parameters, packages parameters passed by the client a tile request object and turns it to the cache manager. According to the parameters' information of the request object, cache manager constructs the tiles corresponding spatial index value, then constructs the query expression and looks up in tile spatial index table. If in, the cache manager will render these cached images directly to the client, otherwise it constructs standard WMS request and submits the request to the WMS Server to provide Internet map service for actual processing. Cache manager receives the result image, cuts figure, puts tiles in the cache, renders tiles and returns tiles to the client, as is shown in Fig. 6.

RESULTS

This experiment is based on the GeoServer Open Source map service, applying for GeoWebCache cache of improved quad-tree spatial index pyramid model to test the map publishing.

Used for testing the hardware environment is as following:

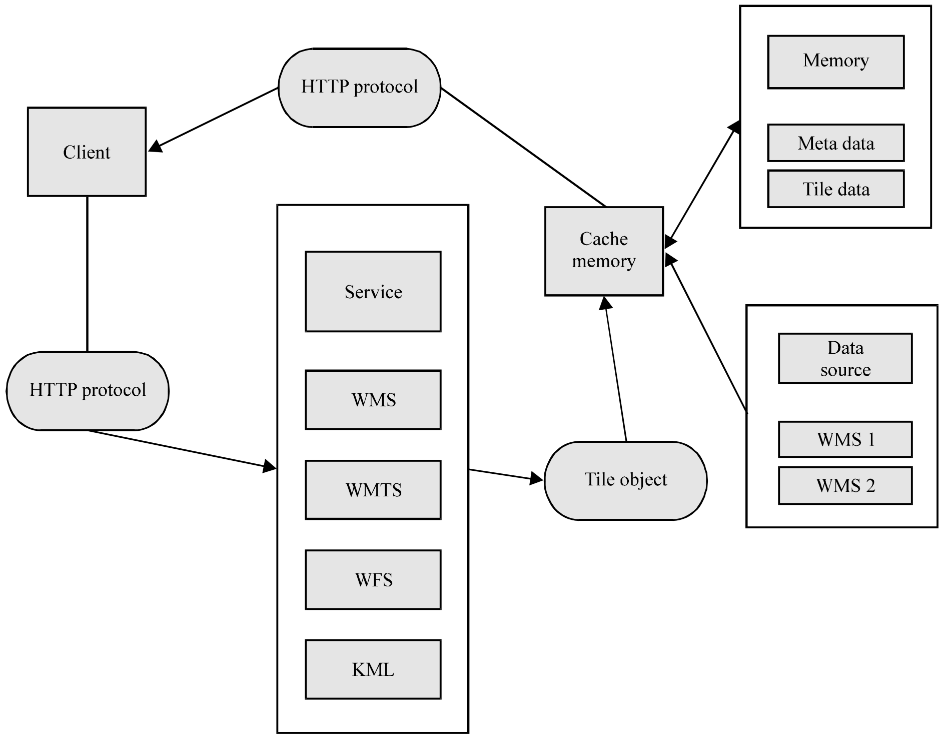

Fig. 6: Tile map request process

- Server for Intel processor (R) Core (TM) i5-3210-m @ 2.50 GHz, 8 GB of memory and 750 GB hard disk
- The client for the processor, Intel (R) Core (TM) i5-3210-m @ 2.50 GHz, 8 GB of memory and 750 GB hard disk

Used for testing the software environment is as follows:

- The Windows 7 operating system
- GeoServer source high-performance WMS server
- The experimental data using the vector map of China

Comparison of map roaming function time: Load data of the local map and roam map with three levels of province, city and country, respectively. Table 1 shows the comparisons of the average response time conducting the same experiment 20 times. The first line is the roaming time of the map of the province, the average response time 1 indicates the client gets map tiles by requesting WMS service directly. The average response time 2 indicates the client forwards requesting map through GeoWebCache. The experimental result data in the table shows that the response time of publishing map reduces significantly based on GeoWebCache caching technology. Because using GeoWebCache caching technology to request map during initialization, GeoWebCache's cache not only needs to save the data of the map tiles returned to the client but also stores the tiles surrounding the ones need to return the client. While roaming on the map, GeoWebCache can intercept the client request, parse request parameters and judge whether the

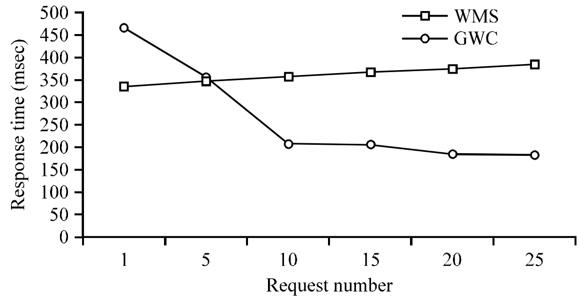

Fig. 7: Comparison of response time

Fig. 8: Response time of GeoWebCache existence of a single map tile

Table 1: Map tiles response time

	Average response time (msec)	
Request level	1 (WMS)	2 (GWC)
Province	463	122
City	153	43
Country	45	3

request tiles are in GeoWebCache's cache or not. If in, just need to forward some requests to the WMS services. Compared with the direct request, response time decreases significantly. The method of requesting of map tiles of the second and the third lines is the same as the first line. The only difference is the range of requesting map. The effect is the same as the first line.

Comparison of time of multiple threads requesting the same area simultaneously: The ratio of the map layer is 1:34 M, a group of clients request the same area of the map. As is shown in Fig. 7, the horizontal axis shows the number of clients request and the vertical axis indicates the average response time of map service. At the beginning using GeoWebCache caching technology, the response time of requesting WMS is more than requesting WMS service directly. Because at that time there is no corresponding tiles in the cache. GeoWebCache caching management forwards request to WMS services and WMS parses parameter object, then return the corresponding map tiles. Before returned, map tiles are put in GeoWebCache cache. With the increasing number of requests, GeoWebCache cache stores all requesting map tiles. So the client requests and GeoWebCache cache returns the tiles to the client directly. The response time decreases significantly as shown in Fig. 8 and the final response time is in a stable value. But with the increasing number of requests, the response time of requesting WMS service directly is almost unchanged. Experimental result shows that using GeoWebCache caching technology reduces the response time significantly when the map server returns to the client. Especially when the requesting map tiles are all in the GeoWebCache cache, the response time changes more evident and it reduces the load on the server at the same time.

DISCUSSION

Comparison of response time's experimental data of map roaming function and multiple threads requesting the same area simultaneously draws a conclusion. When using the GeoWebCache caching technique of pyramid model based on quad-tree spatial index, according to the parameters' information of the request object, GeoWebCache manager constructed of the tiles corresponding spatial index value, then constructs the query expression and looks up in tile spatial index table. If in, the cache manager renders these cached images directly to the client and the response time reduces significantly, otherwise it constructs standard WMS request and submits the request to the WMS Server to provide Internet map service for actual processing. So the response time and the load on the server reduces significantly by using the GeoWebCache caching technique of pyramid model based on quad-tree spatial index. The present research of technology of instantaneously generated map tiles leads to that the server response time is long, with low efficiency and big consumption of server resource. It causes the server to perform bottleneck. However, according to experimental results, using the GeoWebCache caching technique of pyramid model based on quad-tree spatial index not only improves the efficiency of the map tiles to return but also reduce the server overhead and improve the user experience greatly. But due to the limitations of the experimental data, further demonstration of the reliability and stability of the experimental results under high concurrency need to be discussed in the future.

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