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Improvement of Spatial Data Service's Performance with Access Control for Business System by using Web Caching

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ABSTRACT

The research on implementing the access control of the spatial data in the integrated architecture based on Web GIS and improving the rendering performance by using Web caching has been widely performed. Recently Web GIS has been widely applied in various fields of social life and the integrated service architecture based on Web GIS has been implemented to help solve the problems arising in practice. In this paper, we propose an integrated service architecture that realizes the integration of different thematic Web GIS by using single map server based on a service-oriented spatial data infrastructure(SDI). We extend the multi-granularity spatial-temporal data access control (MSTAC) model to propose an access control model of spatial data according to business systems. We also propose and implement a web caching model to enhance the performance of spatial data service. The experimental results show that our method can reduce the request-response time of spatial data service and preserve the rendering of map at a constant rate.

Keywords **- Web GIS, MSTAC, SDI, Access control, web caching**

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1. INTRODUCTION

Many studies have been performed to build an integrated service architecture that integrates different fields of Web GIS based on the service-oriented spatial data infrastructure(SDI) [1,2,3].

In such integrated service architectures, there have been extensive studies on access control of GIS spatial data [4,5,6,7].

And Damiani [8] has performed the research on realizing access control to spatial-temporal resources of both spatial and non-spatial data by using GEO-RBAC model.

Ai-juan ZHANG et al. [9] proposed the multi-granularity spatial-temporal data access control (MSTAC) model by extending the RBAC model, and performed the research on realizing access control of spatial data of GIS for business system users with a constrained role on time, space, map layer, feature and feature view.

The MSTAC model proposed in the above paper is as follows:

$$MSTAC = \{User, Role, Permission, Operation, SpatialObject, URA, PRA, RH\}$$

where User = (identifier, location, role) consists of a role attributes representing the user's identity, location attribute, and permission set, Role = (name, permissions) is the unit of permission assignment, Permission = (operations, spatial objects) is the set of assignments to roles according to certain rules associated with objects and operations, operation is the public method of a spatial class, and Spatial Object is the spatial data set representing map objects, layer objects, feature objects, and feature view objects. URA refers to the roles assigned to the user at a period time, while PRA refers to the constraints on the roles set at a period time. RH represents the ordering relation in the role set.

In an integrated Web GIS, the access constraints of authenticated users must be different according to which

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business system receives spatial information services.

As modern web applications are complex systems with a wide range of features and access too many data sources, improving the request-response rate is a challenging task. A caching system helps in reducing the query response time.

Web caching is a well-known technique for reducing access latency and bandwidth consumption.

The research on reducing the server loads, the client request latency and network traffic by using web caching has been performed [10].

And a built-in memory data network with high performance has been designed by storing information in memory[11,12]. The built-in memory data network reduces the response time of data access by saving the information built-in memory and by sharing the information in the user object format and across multiple servers.

In this paper we first propose a Web GIS-based integrated service architecture to realize the integration of business GIS based on a single map service center.

Secondly, we extend the MSTAC model to propose a spatial data service model for business systems.

Finally, we propose a web caching model to enhance the performance of business systems and user-specific spatial data services, and implement the GIS-based integrated service architecture in SDI and evaluate its effectiveness.

2. SPATIAL DATA ACCESS CONTROL MODEL FOR BUSINESS SYSTEM

The spatial data service and the access to spatial data of Web GIS are different depending on the system's purpose, and the problem of controlling the user's access according to the system must be solved.

To solve the problem, we propose a spatial data access control model for business systems (Fig. 1).

This model implements access control on spatial data based on user-role assignment (UBR) by each business system.

By further elaborating the constraints by business systems, multiple granularity and spatial resource control in individual Web GIS-based business systems are achieved.

The control model with multi-granularity spatial-temporal data access control (MSTAC) by business system is called the spatial data access control model by business system and is denoted as BS_MSTAC.

$$BS\_MSTAC = \{BS, User, Role, Permission, Operation, SpatialObject, UBR, BPR\}$$

The elements of the BS_MSTAC model are defined as follows:

$BS = \{bs_i \mid i = \overline{0, n}\}$: A set of business systems.

bs_i is a business system identifier and means a business system assigned access control.

$User = (id, location, sBS, role)$: A set of users.

Here, the id attribute is the user's identifier, the $location$ attribute represents the user's location, the business system sBS attribute represents the business systems used by user, and the $role$ attribute represents the user's permission set.

$Role = (name, bs_i, permissions)$: The permission to be assigned by the business system.

The permissions assigned to each business system are limited, and when a session is held, the roles of the user are activated with the set of permissions that are restricted to the business system.

$Permission = (operations, spatialObjects)$: Authorization

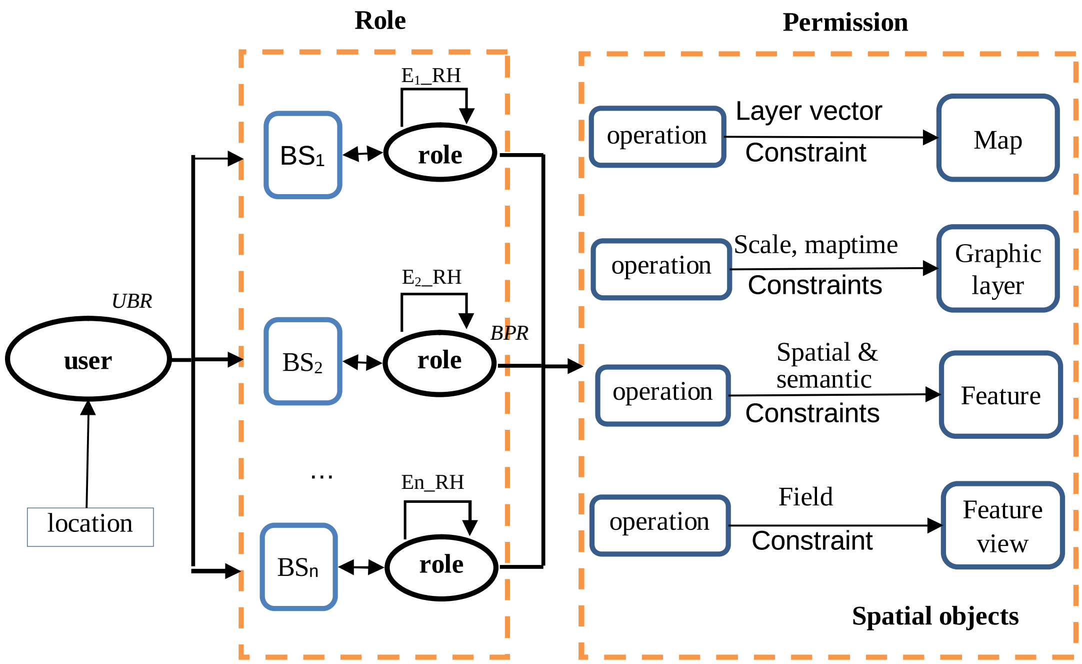

Fig. 1 *BS_MSTAC* model

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They are associated with access and operations to spatial data are assigned to roles.

$Operation$: Public methods of space classes.

$SpatialObject$: Spatial objects.

They are spatial datasets for map, graphical layer, feature layer, and feature view objects.

$UBR \subseteq (User \times BS \times time \times Role\,)_{C_1}$,

$C_1 \in \{\,time\ constraint, duty\ constraint\}$:

Relationship between business system, user and role.

In a certain period, the user is assigned roles according to the business system.

$BPR \subseteq (BS \times Permission \times Role\,)_{C_2}, C_3 \subseteq C_{map} \cup C_{lay} \cup C_F \cup C_V$: Relationship between business system, role and permission.

C_{map} denotes the layer vector constraint, C_{lay} denotes the scale and map time constraint, C_F denotes the spatial and semantic constraint, and $C_V \subseteq C_F \cup \{field\ constarint\}$.

$E_i\_RH \subseteq (\,BS \times Role \times Role\,)_C, i = \overline{0,n}$: The ordering relation among the role set of each business system. It represents the permission relation between two roles.

We assigned the permissions with the spatial data constraints according to the themes by using spatial data access control model for business system, and designed our system so that users can get the spatial data service based on the assigned roles in business systems.

3. WEB CACHING FOR IMPROVING THE PERFORMANCE OF SPATIAL DATA SERVICE

3.1. WEB CACHING ARCHITECTURE OF SPATIAL DATA SERVICE

In this paper, we propose a web caching architecture to enhance the processing performance of spatial data services with access control on a web map server (Fig. 2).

As shown in the Fig. 2, if User 1 sends a request (Request 1) to the Map Server through the Business System, the Map Server restructures the filter through the access constraint module and then passes the process to the core processing module of spatial data service.

The core processing module of spatial data service obtains the response data (Response 1) corresponding to the request from the database, stores the caching data by the caching server and sends it to User 1.

When User 2 sends a Request 2 with the same parameters to the map server, it sends the caching data to User 2 and does not send the request back to the database, since the data already requested by User 1 is stored in the caching server inside the map server.

When a request is arrived to the caching server, if there is no data, it sends the request data to the core processing module of spatial data service.

The core processing module of spatial data service then sends a request to the database, stores the response data from it in the caching server, and then sends the response data to the business system.

3.2 WEB CACHING MODEL OF SPATIAL DATA SERVICE

Web caching model M of spatial data service is as follows:

$$M = \{Q, U, P, C', R'\}$$

The meanings of the elements are as follows.

$Q = \{Q_\alpha |\, \alpha = \overline{1,\ m}\}$: A request set of spatial data services, where Q_α is the set of the same requests for spatial data services, and m is the number of different requests.

$U = \{U_\alpha | \alpha = \overline{1.\ l}\}$: Client set, where U_α is the client's identifier and l is the number of clients.

$P = \{(\varepsilon, \tau, \upsilon, \rho, \lambda, \xi) | \varepsilon \in \mathrm{E}, \tau \in \mathrm{T}, \upsilon \in \Upsilon, \rho \in \Pi, \lambda \in \Lambda, \xi \in \Xi\}$: A set of spatial data constraints.

Here E represents the set of service constraints, T represents the set of time constraints, ϒ represents the set of

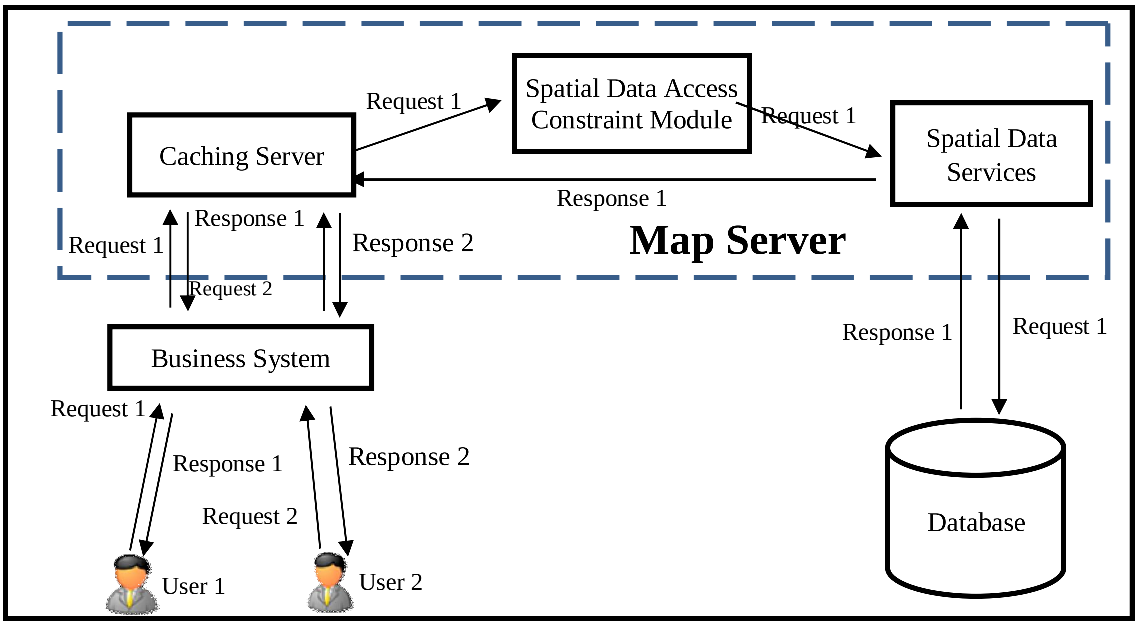


Fig. 2 Web caching architecture of spatial data service

domain constraints, Π represents the set of data constraints, Λ represents the set of attribute type constraints and Ξ represents the set of attribute view constraints.

C': Web caching dataset of spatial data services.

$$C' = \bigcup_{\alpha} C'_{\alpha}$$

$\Theta_{\alpha} \subset Q_{\alpha}$: A set of requests for clients with the same spatial constraint among the same requests.

$\Gamma_{\psi} \subset U,\ \psi \in P$: A set of clients with common spatial constraints.

$O[\Gamma_{\psi}]$: The number of clients in Γ_{ψ}.

$Z_{\psi} \subset \Gamma_{\psi} \subset U$: A set of clients with the same spatial constraint, whose requests are the same.

$\Delta_{\alpha\psi} = \{\delta_{\alpha\psi}\}$: A set of request information (client and request) with the same request and spatial constraint.

where $\delta_{\alpha\psi} = (\theta_{\alpha}, \zeta_{\psi}), \theta_{\alpha} \in \Theta_{\alpha}, \zeta_{\psi} \in Z_{\psi}$.

$O[\Delta_{\alpha\psi}]$: The number of elements in the set of requests with the same request information.

Then, the web caching dataset can be expressed as follows:

$C' = \cup_{\alpha,\psi}\{\delta_{\alpha\psi} | \Theta_{\alpha} \subset Q_{\alpha}, Z_{\psi} \subset U\} \cup (Q_{\alpha} \setminus \cup_{\Theta_{\alpha} \subset Q_{\alpha}} \Delta_{\alpha\psi})$

R': The set of relations between elements.

We designed and implemented the system to reduce the response time of spatial data service by storing the called spatial data in the caching server by using the above caching model of spatial data service.

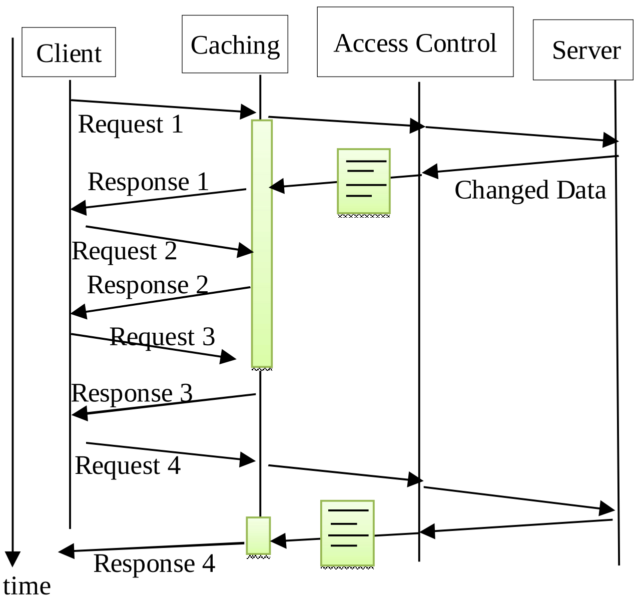


Fig. 3 Request-response processing flow

3.3. REQUEST-RESPONSE PROCESSING FLOW OF SPATIAL DATA SERVICES USING WEB CACHING

When the user returns to the previously visited page, the browser matches the original web server to determine whether the page has changed since the last time it was seen.

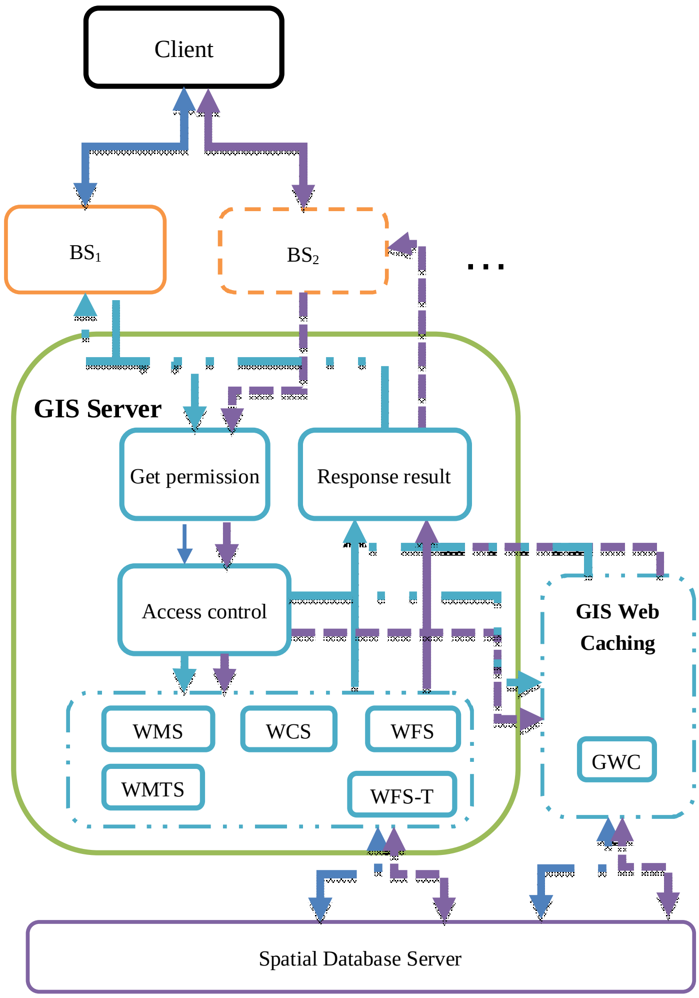


Fig. 4 The integrated service architecture based on Web GIS

The flow of request-response processing of spatial data services using web caching is shown in the Fig. 3. When a client sends a request to a server, it will proceed through caching and access constraints. When the client sends Request 1 to the server, the server sends a corresponding Response 1 to the client. When the client sends Request 2 again, it sends the corresponding Response 2 in the caching server because the request parameters are the same.

Thus, the caching server will be placed between the client and the server to shorten the request-response latency.

4. IMPLEMENT OF INTEGRATED SERVICE ARCHITECTURE BASED ON WEB GIS

The integration of business systems based on a single map server requires access control for business systems.

The map server provides access control and spatial data services for incoming requests through the business system.

The integrated service architecture model ($GISISA$) of GIS infrastructure is denoted as follows:

$$GISISA = \{BS, GeoServer, SPATIALDS, Reo, Reg\}$$

The elements of this model are as follows:

BS: Business system set.

$GeoServer$: Map server.

$SPATIALDS$: Spatial data storehouse.

Reo: Relationship between elements in a spatial data access control model for business system

Reg: Relationship between business systems and map server.

$$Reg \subseteq (BS \times GeoServer)_{C_{bs}}$$

$$C_{bs} \subseteq (C_{req} \cup C_{resp} \cup C_{ges})$$

$$C_{req} \subseteq Req, Req = \{GeoServices\ to\ GeoServer\}$$

$$C_{resp} \subseteq Resp, Resp = \{Image, GeoData, NULL\}$$

C_{bs} refers to spatial data service requests and responses that user sends to the map server by business system.

C_{ges} refers to the access control constraint for business system in GIS.

The integrated service architecture of business systems based on a map server is shown in Fig. 4.

We have implemented the Web GIS-based integrated service architecture under the following conditions:

BS_1 is a business system developed as the Springboot-based JSP project, BS_2 is a business system developed as the Node.JS-based project, and both business systems interact with the map server.

The Map Server uses GeoServer and services on port 8080.

GeoWeb caching function as map browsing buffers, map attribute browsing buffers, feature view buffers, and feature type description view buffers. When requests and responses to spatial services, including the most frequently used services, WMS:GetMap, WMS:GetFeatureInfo, WFS:GetFeature, and WFS:DescribeFeatureType, request-response information and access constraint information are stored in memory. If the server receives a request with access constraint information such as the same parameter information, it directly finds the response information in memory without calling the spatial service.

The resulting screens of access constrained spatial information services for business systems are shown in Fig. 5. The screen of restricted map service response about a user signing in BS_1 is shown in Fig. 5 a). And about a user signing in BS_2 the resulting screen is shown in Fig. 5 b).

As shown in Fig. 5, although users access to the same map, the spatial data serviced from map server differ according to the business systems that users signed in.

The average request-response time with and without using web caching is shown in Fig. 6.

In general when the number of requests increases, the response time increases.

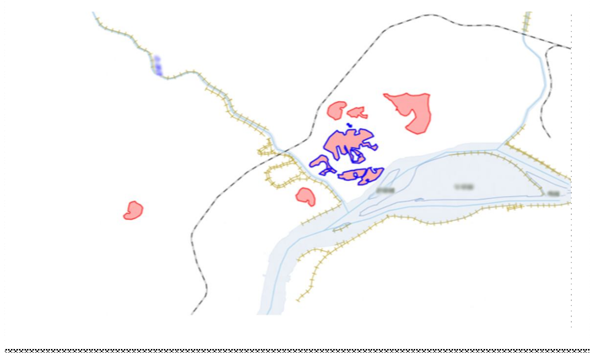
As shown in the Fig. 6, it can be seen that increasing the number of clients does not significantly increase the response time to spatial data.

As known, using the web caching can reduce the load of map server and the request-response time of spatial data service, and preserve the rendering of map at a constant rate.

5. CONCLUSION

We proposed and implemented a model of the integrated service architecture based on Web GIS. We have built an integrated service architecture that integrates several business systems based on a single map server. Spatial data access control models for business systems was designed by expanding MSTAC model, and the spatial data access control according to business systems was implemented.

a) Result screen in BS_1



b) Result screen in BS_2

Fig. 5 Example of access control result screen in business system BS_1 and BS_2

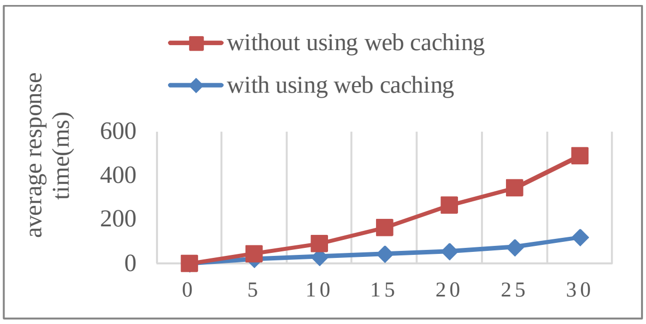


Fig. 6 The average response time with and without using Web caching

And we improved the processing performance of spatial data services in map server by using web caching about the spatial data services with access constraints.

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