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A Component-based Management Platform for Multi-source Spatial Data

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Abstract: This study introduces a component-based management platform for multi-source spatial data. The four-layer architecture and the main functions designed for the management platform are addressed in details. The main components, including the integration component for multi-source spatial data, the role-based security management component for spatial data, the user-friendly mapping component and the sharing component for spatial data are presented, respectively. Finally, as a typical application case, the platform has been used to manage the county-range agricultural spatial data in China.

Key words: Integration component, sharing component, spatial data management, web service

INTRODUCTION

With the development of the distributed computing and the network technology, it is possible to make access the spatial data and other applications remotely. By now, the paradigm of Geographic Information Systems (GIS) is shifting (Preston *et al*., 2003; Tsou and Buttenfield, 2002) and distributed GIS becomes practical and acceptable widely. Traditional GIS plays an extremely valuable role in the applications by providing a wide variety of tools to handle geo-referenced data. However, the traditional GIS cannot be applied directly in the distributed and heterogeneous computing environments due to its closed and centralized architectures. To hide the heterogeneity and to accommodate the distributed environments, open and component-based GIS is replacing the traditional monolithic GIS (Coddington *et al*., 1998; Goddard *et al*., 2003; Jacobsen and Voisard, 1998). Under the open and component-based architectures, the distributed data and functions can be integrated and cooperate with each other well. Lots of component-based technologies, such as CORBA (Common Object Request Broker Architecture), DCOM (Distributed Component Object Model) and RMI (Java Remote Method Invocation RMI), are playing major roles in the construction for open and component-based architectures. While many component-based GISs have been developed, there are many requirements to develop a component-based GIS based on the existing codes rather than to develop it from start. For instance, the approach for constructing systems from GIS commercial off-the-shelf (COTS) products has been proposed (Tu *et al*., 2002). There are many advantages to develop a new system based on the previously-existing codes, such as tested reliability, approved features and an opportunity for expanding system capabilities (Tu *et al*., 2002). Thus, to build a component-based GIS from the existing traditional GIS is one of the main research problems addressed in recent years. This study proposes a component-based four-layer management platform for multi-source spatial data.

Spatial data are associated with the locations on the Earth and they are the dominant form of data in terms of data volume. It is estimated that more than 80% of data collected by human beings so far are the geospatial data. Spatial data are widely used in many aspects of socio-economic activities, ranging from the environmental management to the military operations. However, most of the geospatial data are obscure from those names which are named by different people. Therefore, it is inconvenience for the users to apply those spatial data. A user-friendly mapping component is designed in the study to solve such problems.

With the utilization of the Web-based GIS technology, the spatial data from GIS sites can be accessed from any node in World Wide Web (WWW). However, the applications of GIS have also been extended from one institution to the worldwide range. As a result, the integration and share of the data among different

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institutions require a standard to exchange the data and to invoke the operations. Unfortunately, the traditional solutions to the Web-based GIS, for example, Common Object Request Broker Architecture (CORBA) solution presented by Jacobsen Voisard (1998) are incapable to implement the standard data exchanging and communication in the heterogeneous environments. Fortunately, a set of web service based solution was proposed to facilitate the integration and share of spatial data produced by Ma *et al*. (2005). The solutions including utilizing GML (Geography Markup Language) to encapsulate spatial information, using WSDL (Web Service Description Language) to describe XML WMS (Web Map Service) and the approach for service publication and registry were introduced by Ma *et al*. (2005). Therefore, a Web service base sharing component and an integration component for the multi-source spatial data are designed and implemented in this study, respectively.

FOUR-LAYER ARCHITECTURE OF THE COMPONENT-BASED MANAGEMENT PLATFORM

The four-layer component-based architecture of the management platform for the spatial data is presented in Fig. 1, which includes data layer, component layer, application layer and user layer.

Data layer: The main purpose of the data layer is to provide spatial data resources for the component layer and to receive the implementation results to store the appointment location. SIR (Spatial Information Resources) and VSDE (Virtual Spatial Data Engine) are two main modules in this layer. SIR is the main resource that the system processes and has variety data formats. Different data formats lead to different data storages. Therefore, the VSDE is applied o resolve the different data formats. A VSDE can be a sub-system or a component.

Component layer: The main purpose of the component layer is to obtain the user's requirements from the application layer, to access the data layer to obtain the source data and to process the data by the component and to return the processing results to the data layer and the application layer. The components include the common GIS components and the components defined by users. The common components are mainly used for the data input, data processing, spatial querying and analysis, the data feedback and output. The user-defined components are developed based on the GIS components.

Application layer: The main function of this layer is information management and user's requirement processing. The application layer is not only an interactive agent between the user layer and component layer, but also provides user's information, the RBAC (Role-Base Access Control) and the management of the metadata.

User layer: The main function of the user layer is to display the results from the component layer and to provide the interface between the users and systems.

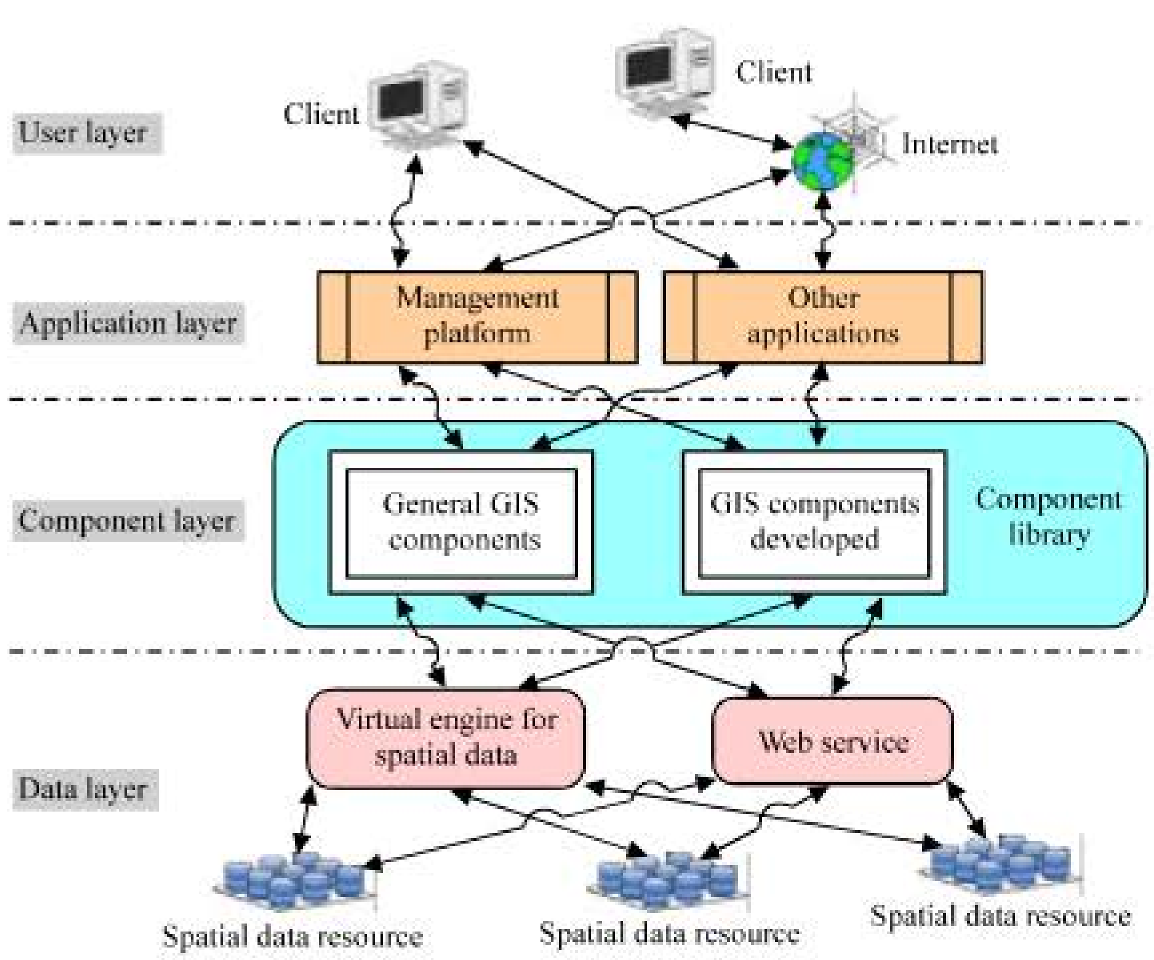

Fig. 1: The architecture of the component-based management platform

MAIN FUNCTIONS DESIGNED FOR THE COMPONENT-BASED MANAGEMENT PLATFORM

The study presents the platform from the function perspective. The component-based management platform for the multi-source spatial data is composed by a B/S (Browser Server) system and a C/S (Client Server) system. In the management platform, the browser corresponds to the common users with requirements and the client corresponds to administrator who has the authority to manage the data. The following gives the main functions of the B/S system and the C/S system, respectively.

Main functions of the B/S system: Figure 2 shows the main functions of the B/S system which include the common operations of map, spatial data management, spatial data query, spatial analysis, buffer analysis, thematic map management and meta-data management, data mapping management and sharing of spatial data.

Main functions of the C/S system: The main functions of the C/S system contain: spatial data management, spatial data analysis and map operations, thematic map management, users management, Personal Information Management (PIM) and data mapping management. Figure 3 shows the main functions of the C/S system.

MAIN COMPONENTS

Here, the four main components contained in the component-based management platform for spatial information are addressed. They are the integration

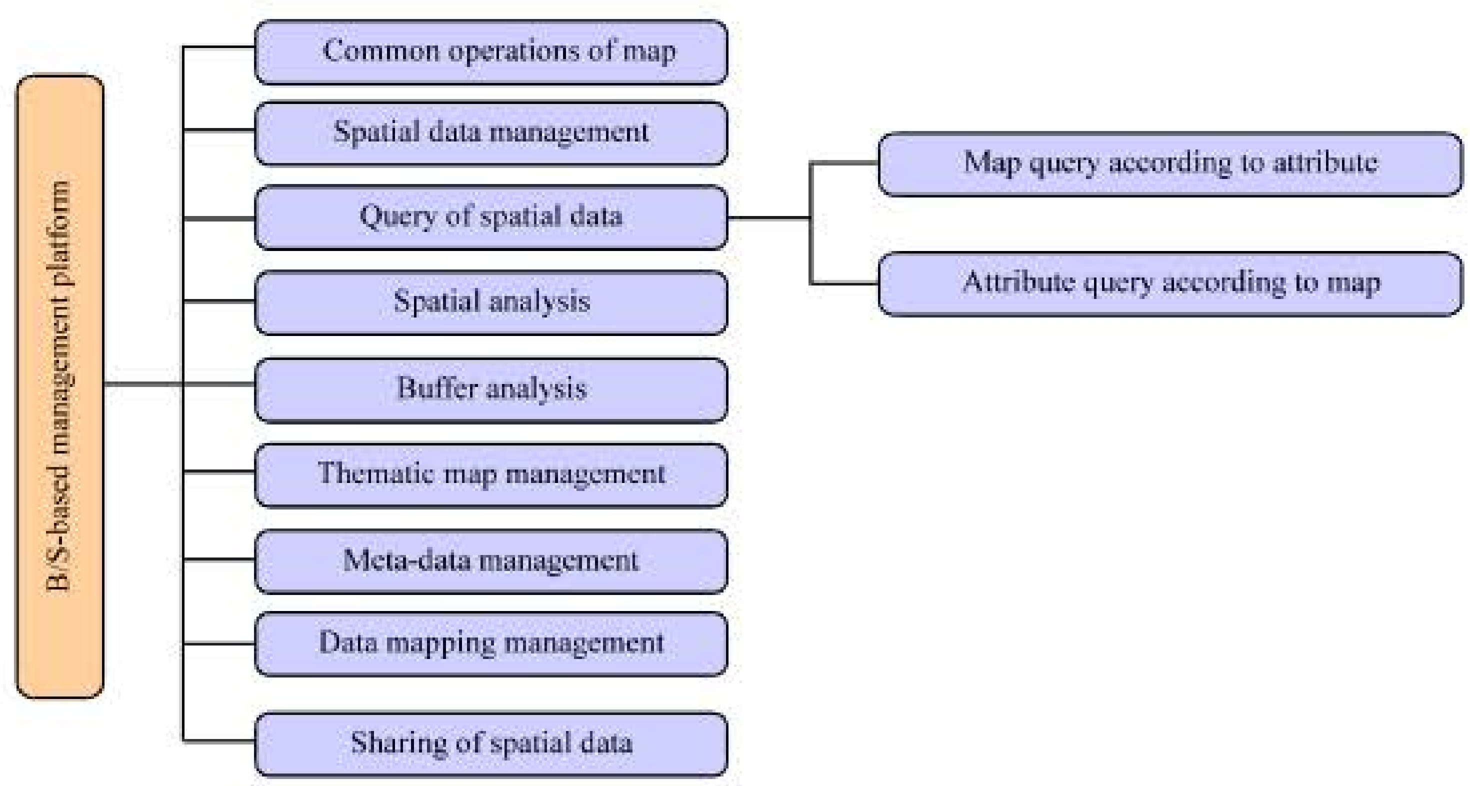

Fig. 2: Main functions of the B/S system

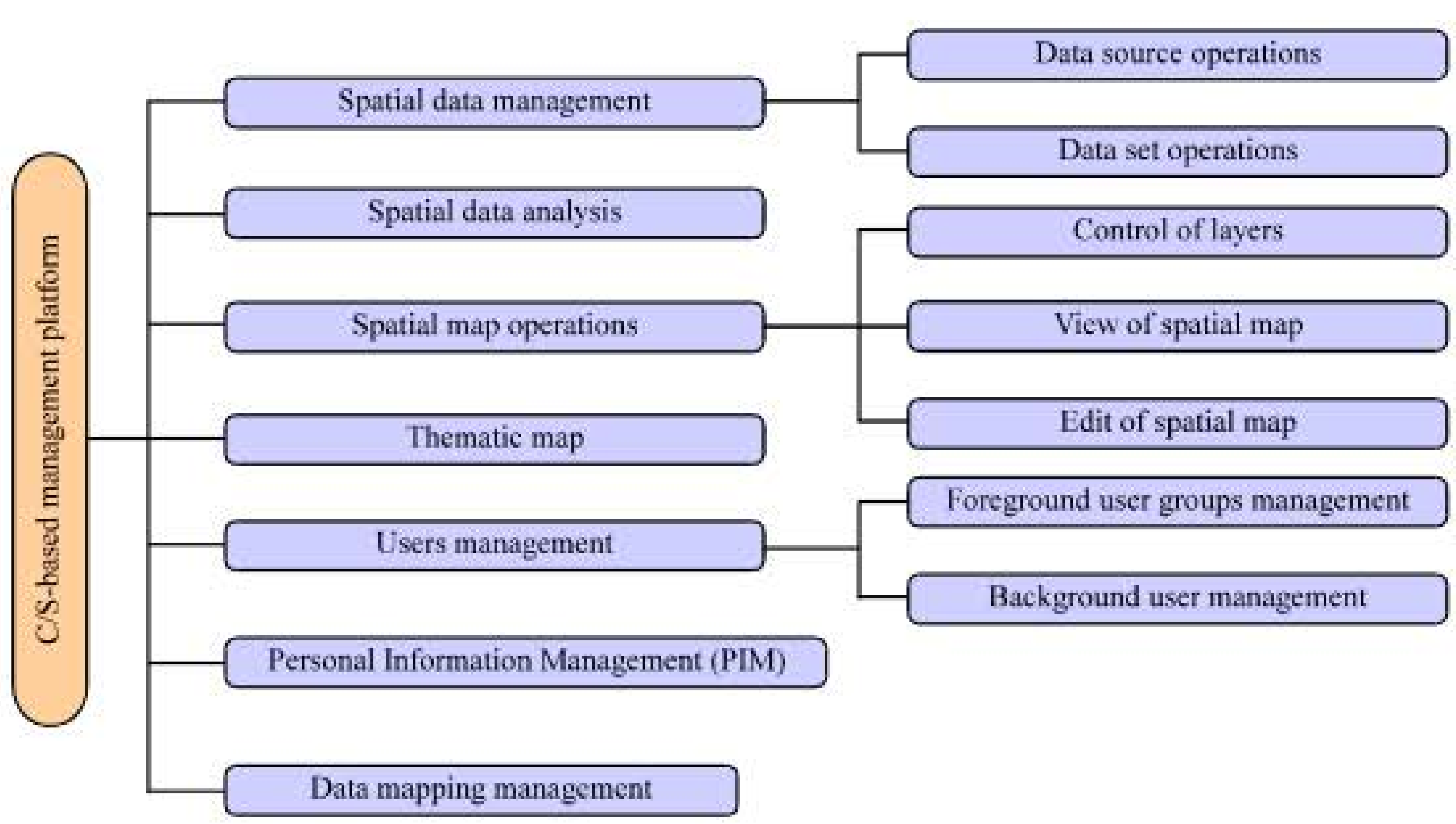

Fig. 3: Main functions of the C/S system

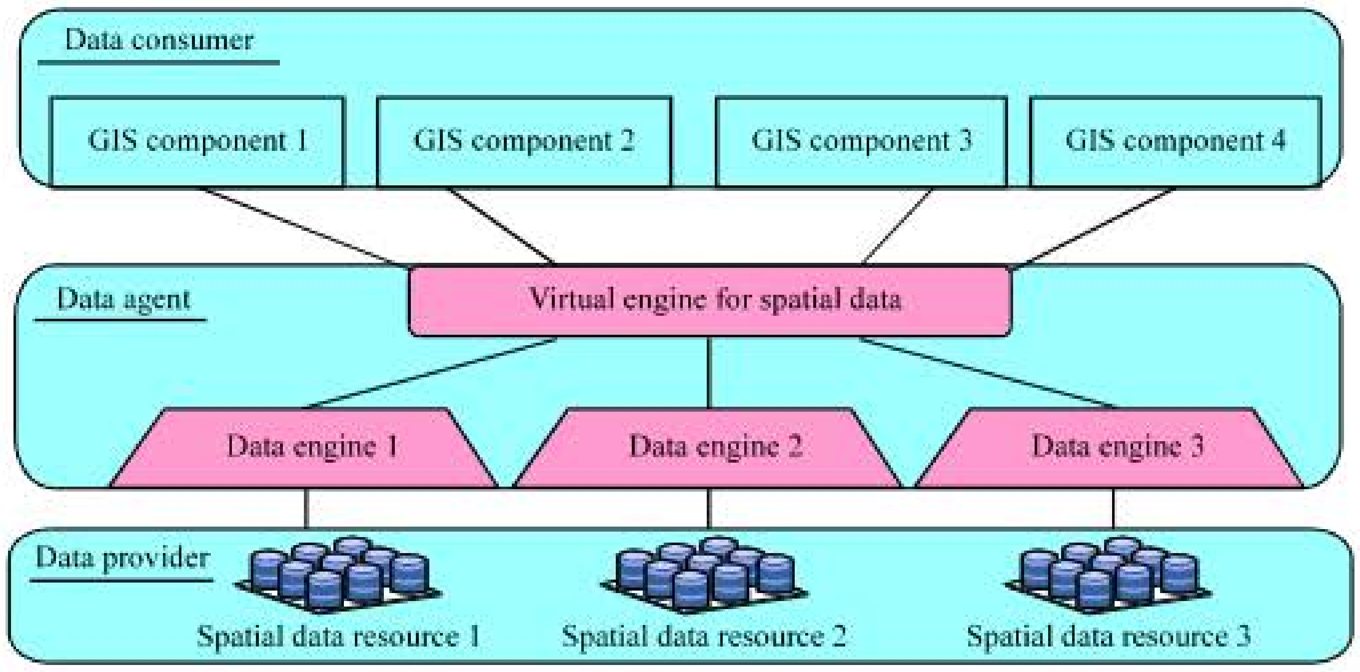

Fig. 4: The technical architecture of SIMS

component for the multi-source spatial data and the role-based security management component, user-friendly mapping component and the sharing component for spatial data.

Integration component for multi-source spatial data: The management system is based on SIMS (Seamless Integration of Multi-source Spatial-data). The architecture of the SIMS is shown in Fig. 4. SIMS is a model to access data directly which is built in the software of the GIS. There are no data transformations and it can be accessed directly in the multi-source by the virtual spatial data engine. It integrates three layers including data consumers, the agents and the providers. In the architecture of the SIMS, different layers play different roles. Data consumer contains many GIS function-components that are used for spatial data processing. The data agents are used to transmit the spatial data information as a bridge between the data consumer and the data provider. The data provider can access all the modules of the data sources which make up of a group of engine directly and each engine accesses one data format.

There are many kinds of data engines provided by the system, for example: SDB, MDB, SQL Server, Oracle and SDE. Moreover, Arc/Info Coverage, MicroStation DGN, ArcView Shape and AutoCAD DWG provided by the system can be accessed by other GIS/CAD directly.

Role-based security management component for spatial data: There are three kinds of roles in the system, which are administrator, registered users and unregistered users in the system. Administrator has all kinds of the authorities, but the unregistered users only have authority to access data which have been published. Those two kinds of roles are not difficult to control and to be realized. However, as a kind of registered users, the authority is not easy to control by the same way. The registered users may come from different departments and should have different access authorities. One user may have two or more authorities; however, one authority may belong to many users which form different departments. Therefore, the role-based access control (RBAC: Role-based access control) is introduced to realize resources be accessed legally.

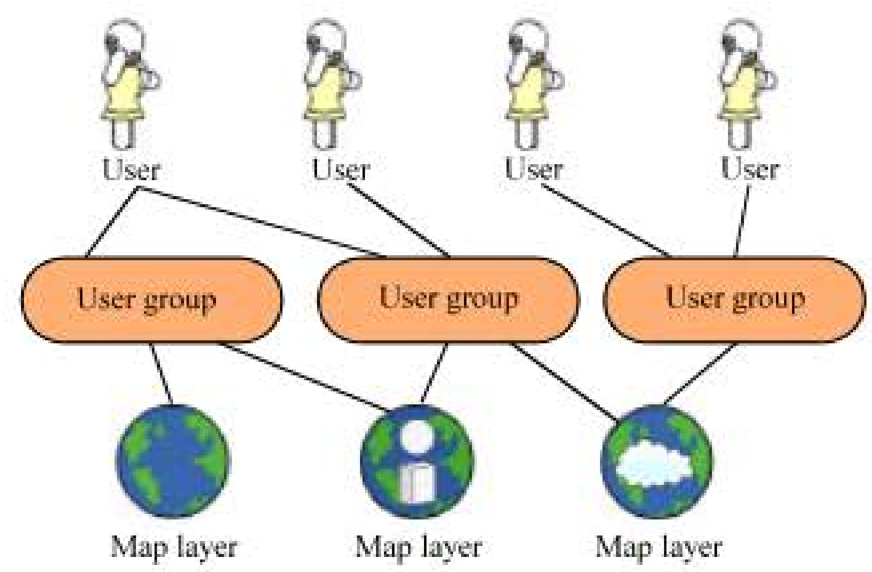

Fig. 5: The relation of users, roles, resources

The role relations are defined between the users and the resources. One user can contact with one or more roles and one role has relationships with one or more recourses. Moreover, the role can be created and deleted according the actual requirements and the relationships between users, roles and recourses can also be changed according the actual requirements. In the component-based system, the registered users are grouped by their departments. All the users which are from the same department are grouped into one group. One role is defined for every group in RBAC. The relations between users, roles (groups) and resources are shown in Fig. 5.

To realize RBAC in the system, one user information table is designed to store each user's information and another table is designed to store the information of the user-groups and the layer information is stored into the resource table. Moreover, there are three necessary tables in this system: the relation table between users and user's groups (User_Role), the relation table between user's groups and layers (Role_Layer) and the role description table (Right_Def). The User_Role table contains the information about which group each user belongs to. The Role_Layer table stores the information about which layers each user group has. And, the Right_Def table stores what kinds of roles that have been defined in the system.

User-friendly mapping component for spatial data: A geographic information work space is the basic unit for the published maps in the SuperMap IS.NET. The work space contains the index information about the data sources. Moreover, every data source has many data sets and there are a set of maps which are produced by the data sets in the work space. All of the objects are named freely without any standard. For example, traditionally, the layers are named by the codes or abbreviation of English name. It is inconvenient for users to understand the meaning of the map, the layer and the field. Therefore, the data mapping mechanisms are introduced in the component-based management system to build the user-friendly interface for the system.

Before data mappings are defined, three tables are created to store the mapping information about the map names, the layer names and the field names, respectively. The mapping relations are built semi-automatically. While the maps are released, the tables about the map names, the layer names and the field names are built automatically by the GIS server. Therefore, the true names of the mapped maps, layers and fields are replaced by their alias. According to the requirements, the administrator can modify those with user-friendly aliases through the API of the component. Using the user-friendly aliases users can complete the operations on the spatial information.

Sharing component for spatial data: Another important component in the component-based management platform is the sharing component that can provide the spatial information sharing developed based on Web service. The registration center is the core of the sharing component. The main functions of the registration centers are shown in Fig. 6 which include publishing the metadata, inquiring the metadata and management of the child nodes.

The sharing component is mainly composed by three Web services which are management of GIS-WS (Geographic Information Systems-Web Services), the transformation of GIS-WS and the publication for GIS-WS. The sharing component is realized by the data interchanged between those three Web services. The Web service for management of GIS-WS is just like an administrator to manage all users who want to share the spatial information. The application of the spatial data sharing can invoke the API of this Web service API to obtain the license. The Web service for publication of GIS-WS is the API for data providers. The data providers can use this API to publish their spatial information. The Web service for transformation of the GIS-WS can resolve the problem of data heterogeneity that can convert one format of spatial data into another format. The application architecture of the component for spatial data sharing is shown in Fig. 7.

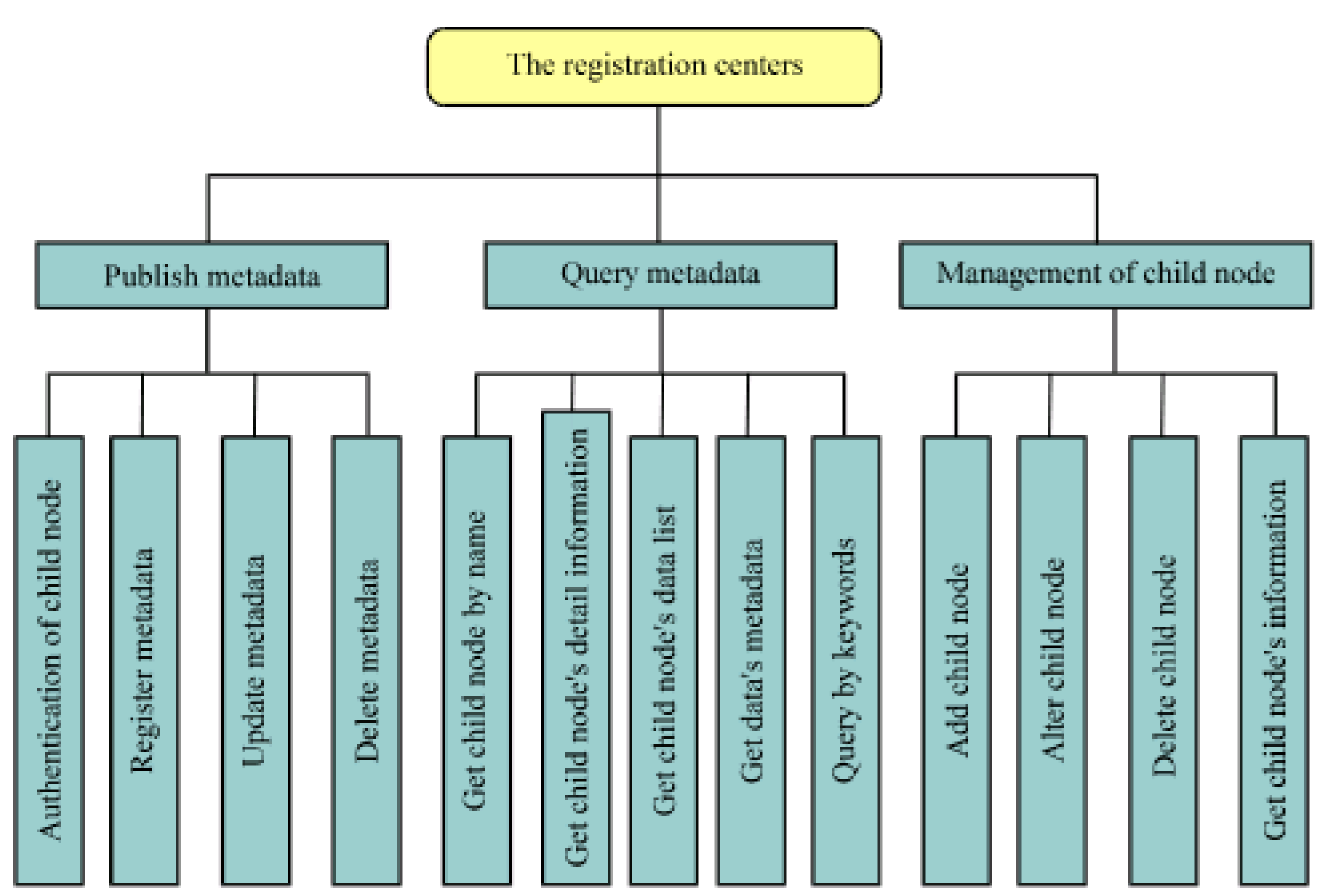

Fig. 6: The main functions of the registration centers

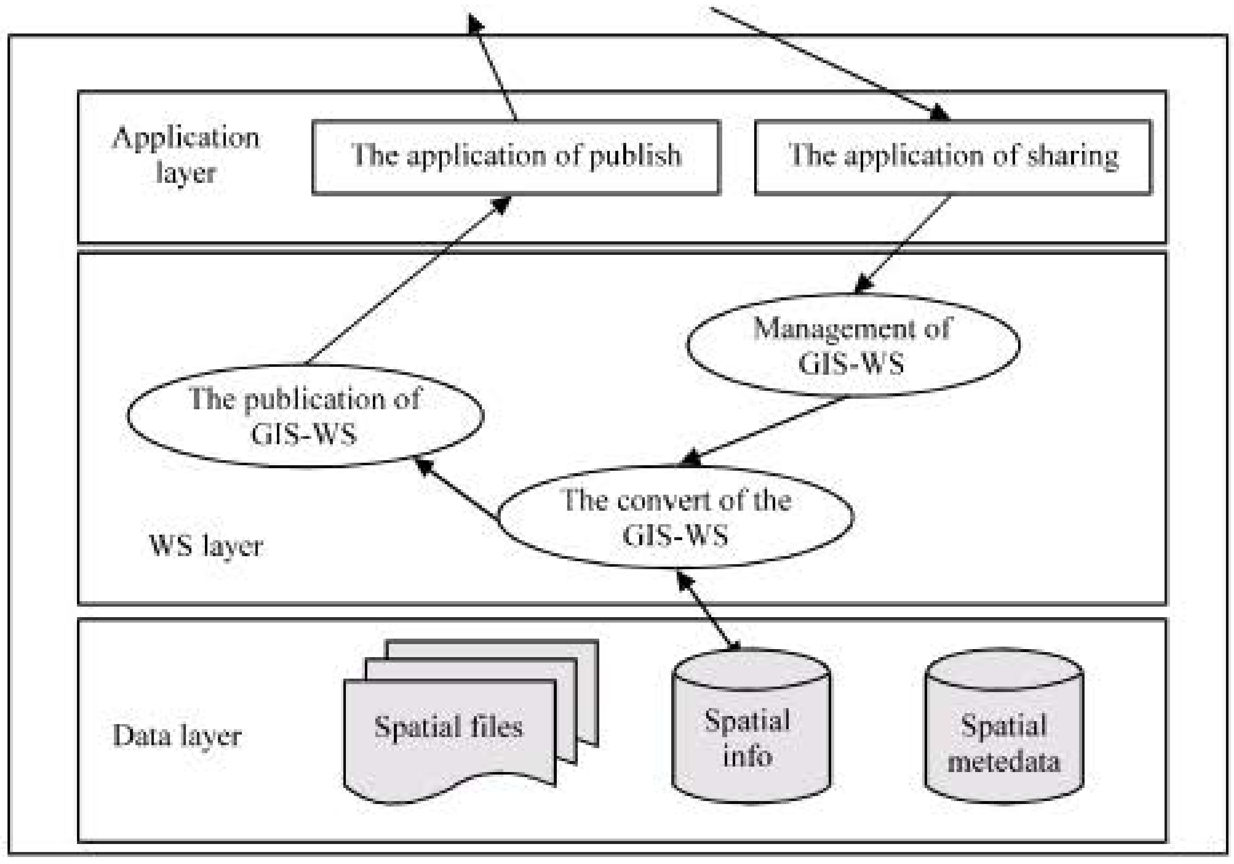

Fig. 7: The application of the sharing component

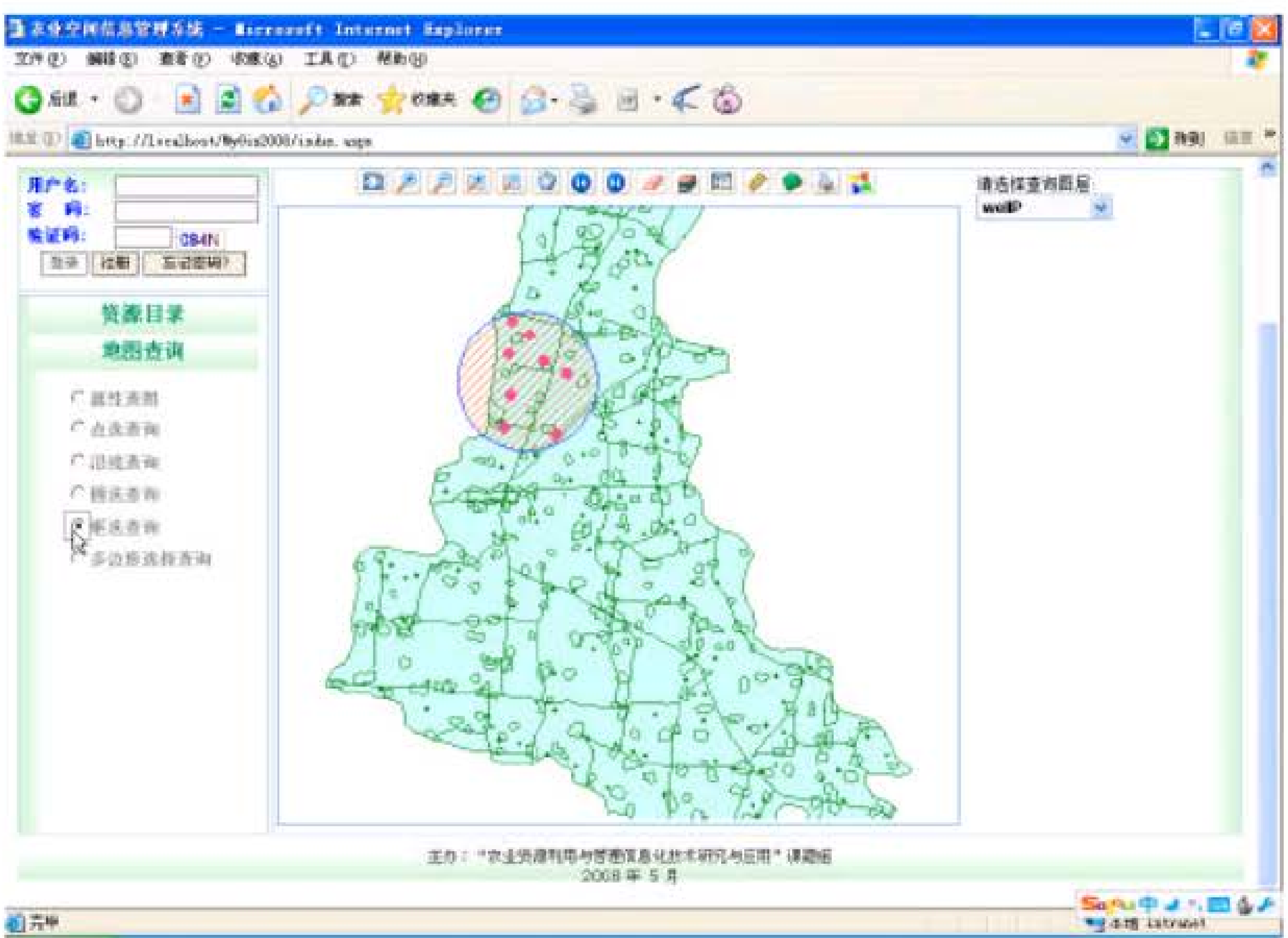

Fig. 8: Map query according to attribute

APPLICATION CASE

To evaluate the component-based management platform for the multi-source spatial data, the platform has been applied to manage the county-range agricultural spatial data in China. In QUZHOU, one county of HEBEI Province of China, the platform has been used for the agricultural spatial data management. Figure 8 shows the screenshot for the map query according to attribute with experimental data at QUZHOU China.

Figure 9 shows the results for spatial analysis on the agricultural spatial map of QUZHOU in China, where all

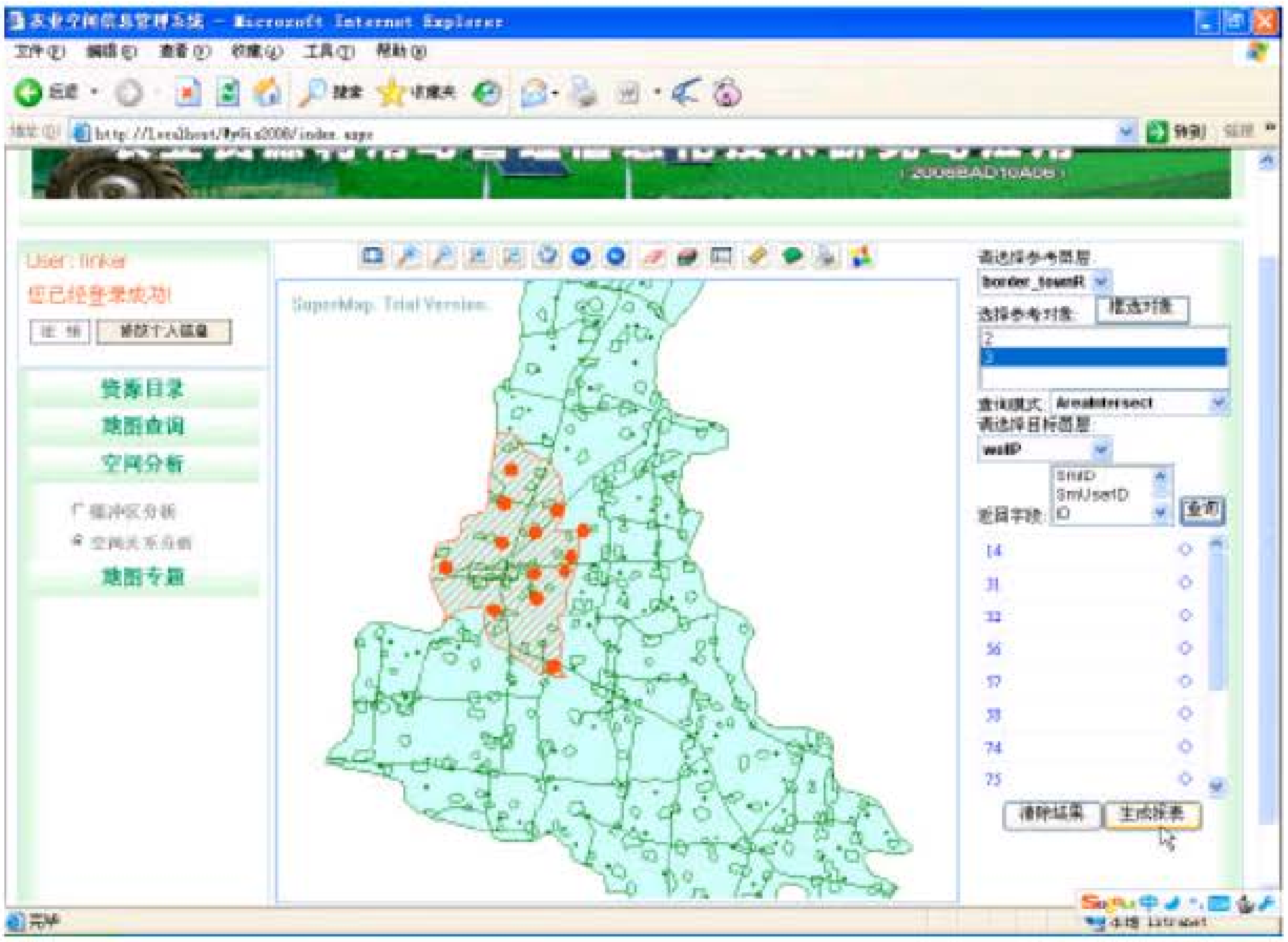

Fig. 9: Spatial analysis in QuZhou map

the villages in one of the zones in QUZHOU are displayed. The detail information about all the villages displayed is shown on the right of the system.

CONCLUSION

In order to integrate and share the heterogeneous, distributed and autonomous spatial data from the distributed sources, a component-based management platform for the multi-source spatial data has been designed and implemented. The architecture and the main functions designed for the component-based management platform are addressed in this study. Four main components, including the integration component for the multi-source spatial data, the role-based security management component for the spatial data, the user-friendly mapping component and the sharing component for the spatial data, are presented in details. Finally, as an application case, the platform has been applied to manage the county-range agricultural spatial data in China to verify the performance of the management platform.

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