# Spatial Decision Support System for Precision Farming Based on GIS Web Service

Chen Tian-en, Chen Li-ping, Gao Yunbin, Wang Yanji
*National Engineering Research Center for Information Technology in Agriculture, Beijing, 100097*
*chente@nercita.org.cn*

## Abstract

*As the next generation GIS technology, GIS web service is able to effectively cope with several problems of traditional GIS applications, such as hard to update old systems, lacking of good interoperability and hard to integrate with other systems, etc. This paper studied how to construct a spatial decision support system (SDSS) for precision Farming based on GIS web service. Main components of the system and the decision workflows were discussed in the paper. As examples, Precision fertilization and precision irrigation were used to explain key technologies of the SDSS construction based on GIS web service. The research result shows that GIS web service is suitable for developing spatial decision support system for precision farming, and GIS web service based applications has obvious advantages in dealing with problems such as sharing spatial data, software reuse and reducing the cost of system integration.*

***Keywords:*** *GIS web service, spatial decision-making support system, precision agriculture*

## 1. Introduction

As one of the important parts of precision farming (PF) technical architecture, spatial decision support system (SDSS) for PF is a kind of software which can be used to meet the needs of quantitative analysis and intelligent decision-making support in precision farming production. Through farmland-related spatial information analysis, the SDSS for PF is able to provide decision-making services for agricultural production, and support intelligent farm machinery in practice. The research of SDSS for PF is very meaningful for popularizing and applying technologies of precision farming.

Most of the current spatial decision support systems for PF are desktop based or website based soft wares [1], which would be difficult to maintain and update because the data and system functions are closely coupled. It is also hard to share information and achieve interoperability among these soft wares because they were established into isolated islands of information. The problems above have already lead the extraordinary waste of resource, and because of these problems, the current spatial decision support system for PF are not capable of responding the changes from the market based agricultural production. In short, the current SDSS for PA have restricted the development of PF because of their inherent shortcomings, it is urgently necessary to develop next generation SDSS for PF, which would be on-demand, much more open, and easy to maintain and update.

In recent years, the rises of web service technology promote the development of software architecture from traditional mode (Host, Client/Server, Browser/Server style) to network interactive mode [2]. This web service based software architecture mode can cope with the inherent shortcomings of traditional systems, so it is possible to design and establish an open, loosely coupled SDSS for PF by using the architecture. The paper studied the suitable spatial analysis and decision-making methods for precision fertilization and irrigation. On this basis, the paper analyzed the possibility of the system construction, and provided blueprint and implementation solution of the SDSS for PF. The blueprint of web service components collection, which would be used to implement the analysis and decision-making functions of SDSS for PF were also been studied in the paper. At the end of the paper, several key technologies of the system construction were discussed.

## 2. GIS web service & its application

As a new kind of software architecture, web service is composed of 3 participators and 3 basic operations. Three participators are: service provider; service requester and service agent, and three operations are publishing; finding and binding. The basic architecture of typical web service can be described as follows: a service were published onto a service agent menu by its provider, when service requester wants to call the service, it will firstly search this service from the menu provided by the service agent, so as to get the information of how to call the service, finally, the requester can call the service published by the provider through the service description information. It should be figured out that the service provider and the requester will communicate directly after the requester gets the service information from agent.

Web service implements related functions by using a series of criterions and protocols. For a example: it uses WSDL (web service description language) to describe service, uses UDDI (universal description，discovery，

978-0-7695-3600-2/09 $25.00 © 2009 IEEE
DOI 10.1109/IFITA.2009.550

integration) to publish and find service, and uses SOAP(simple object access protocol) to call service. Messages in XML format are transferred among web service components and component internal, because message in XML format is easy to read and understand, and it is accepted by most of the platforms, such as Microsoft windows, UNIX, Linux, etc.

GIS web service is a combination of web service and GIS technology [3]. It is designed specially for managing, analyzing and publishing geospatial information. Comparing to traditional GIS, GIS web service own characteristics of cross-platform, scalable, good maintainability, and high degree of standardization, it has obvious advantages in dealing with problems such as spatial data sharing, software reuse and reducing the cost of system integration. For example, through its standard interface, geospatial data web service helps user search and obtain geospatial data published by different providers from internet, so as to realize geospatial data sharing. Through reconstructing current GIS, building service components and providing regular interfaces, GIS web service can call each other to realize software reuse. While GIS web service provides new technique of system integration. Comparing to the object-oriented or message based system integration techniques; it can be much more efficiently in coping with the integration problems of heterogeneous systems.

Many GIS web service applications have already appeared recently. ESRI, a leader of GIS companies, established "Arc Web Services" as a GIS web service architecture to provide a series of spatial information related services; further more, most of the services had been registered to the UDDI registration center. "ArcGIS Server", as the first GIS web service product brought by ESRI, provides tools for users to customize and publish GIS web service, such as raster calculation, etc. "Map Point", which was brought by Microsoft also provides several GIS web services, including location service, route selection service, etc. Besides, web service architecture recommended by OGC (Open Geospatial Consortium) has already been successfully applied in the geospatial information infrastructure construction of Germany and Canadian in 2002, and the famous geospatial information gateway: www.geodata.gov is also a successful application of web service.

Most of farmland-related information, such as soil, crop and weather information, has spatial relativity. Precision farming, including precision fertilization and irrigation, focuses on farmland-related information and its collecting, processing and analysis. While, agricultural production in different area is tremendous difference, so establishing region-suitable precision agriculture services based on GIS web service, and integrate into a loosely coupled application to share data and reuse function is an ideal solution to meet the needs of precision farming in different area.

## 3. GIS web service based SDSS of PF

Through analyzing kinds of decision-making workflows of agricultural production and effectively using GIS web service to build decision-making services based on the demands of precision farming production. SDSS for PF was constructed based on the integration of decision-making services and farmland-related spatial information. System analysis of the SDSS, including system roles, system architecture, and workflows, were discussed as follows.

### 3.1 System roles of the SDSS

System roles mainly include users, equipments, and soft wares. According to the difference of authorization, system roles were divided into 4 classes: junior role, senior role, data provider, and service provider. Junior role was authorized to download specific analysis and decision-making results to process corresponding practice, senior role was authorized to find decision-making service, spatial analysis service and spatial data based on the needs of specific job, then complete the workflow of modeling, deploying, and executing so as to get the result. Service provider was authorized to develop and publish kinds of web services of spatial decision-making for precision farming. Data provider was authorized to produce and publish spatial data in different area.

### 3.2 Architecture of the SDSS

Web service-driven service-oriented architecture (SOA) was selected to establish the SDSS for PF in this paper. According to the regulations of service description, registration, finding and interoperability, the SDSS for PF separated service provider and service requester. Based on technologies of enterprise service business (ESB), including communication, message processing and security control, the SDSS for PF designed a series of tiers, including client tier, application tier, service tier, and data tier of the architecture. Interactive mechanism among tiers and security management was also been established, the whole architecture of SDSS for PF was shown in figure 1.

Client tier is the entrance for junior role and senior role. Senior role are supported to operate the SDSS based on specific job and get the decision-making results. Junior role, which including intelligent farm machinery, client software, and outside web service, were supported to download the decision-making results for further processing, or directly apply to the agricultural production.

Application tier provides tools for finding, matching, integrated modeling, and combination of services & data.

According to the specific decision-making demand of precision fertilization or irrigation, application tier provides high efficiency service finding and matching tool based on service description. Visualized environment was also provided by application tier to complete service validation and integrated modeling. Besides, environment of service execution was built to call service and create service instance, and control the activation, hanging up, resuming, and termination of service instances.

Service tier provides 4 web service collections: basic services collection, spatial analysis service collection, decision-making service collection, and assistant service collection, these services can call each other, and be called by application tier through ESB. Service tier is also the entrance for service provider to publish and manage services, service register center and a series of service manage tools are deployed in the service tier to help service provider complete the tasks of service registering, publishing and monitoring.

Data tier stores all kinds of data which can be called by application tier. Besides, metadata management center, an environment for data providers to publish and manage all kinds of data of SDSS, was been deployed at data tier.

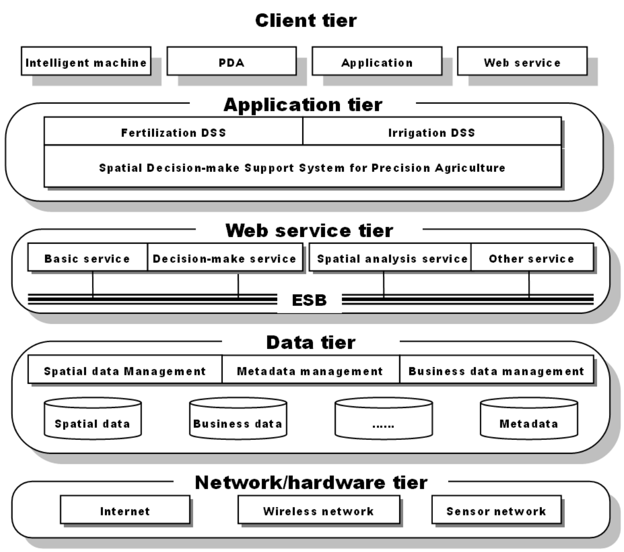


Figure1. Architecture of SDSS for PF

## 3.3 Workflows of the SDSS

SDSS for PF would respond and analyze the request of specific decision-making task of agricultural production, and then it would select a prepared workflow template which is suitable for the specific decision-making task. Based on the template, SDSS would establish a new workflow for the specific task using services combination modeling tool (SCMT). According to the workflow, corresponding GIS web services and spatial data would be found, and describing documents would be generated. The services combination execution tool (SCET) would startup the service execution engine. After receiving the task, the service execution engine would call corresponding web services and spatial data to execute the workflow according to the document. During the executing course, it would return status messages to monitoring tools, and give the result to user when the execution is complete. The whole workflow of SDSS for PF was shown in figure 2.

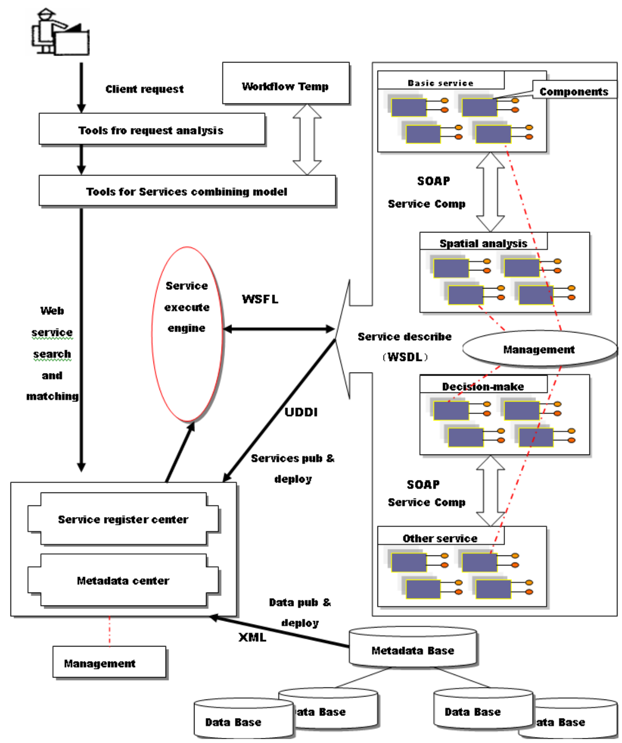


Figure2. Workflow of the PF SDSS

# 4. Key technologies of constructing the PF SDSS

There are several key technologies in constructing SDSS for PF, which including multi-source geospatial data based decision-making model creating, GIS web services implementation, and SOA based system designing, etc.

## 4.1 Geospatial decision-making models

Spatial decision-making models can make decision on spatial related problems based on multi-source geospatial data and its analysis result. Through research on spatial analysis demand in precision agricultural decision-making process, spatial decision-making models of precision farming can be established based on the geospatial analysis methods, such as interpolation, buffer, and raster re-class, overlay, etc.

Under the help of remote sense image, sampling data and high precision farm/field map, spatial decision-making models of agriculture is able to cope with problems of agricultural production analysis, simulation, explanation, and forecasting. For example, spatial decision-making models of precision fertilization are able to complete the diversity analysis of farm soil, dynamic requirement analysis of fertilizer and the analysis of balanced fertilization. Spatial decision-making models of precision irrigation are able to complete the diversity analysis of soil moisture, regionalization analysis of irrigation and balanced irrigation analysis which based on specific crop water-production model.

### 4.2 Coarse-grained business service modeling

SOMA (Service Oriented Modeling Architecture) was used as a main tool of coarse-grained service modeling in the research to build models during 3 stages of service identification, specification, and realization [4]. Domain decomposing, goal-service modeling and services allocation to components were used to identify and realize services from a spatial decision-making request. While, service and message operation and corresponding operation object, regulation and events were built to help complete modeling and optimize analysis of decision-making workflow [5]. The modeling flow of SDSS for PA was shown in figure 3.

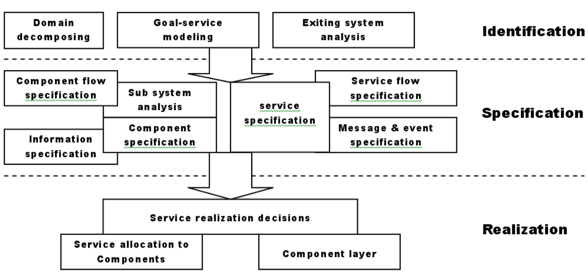


**Figure3. Web services modeling**

### 4.3 Implementation of spatial decision-making web service

No matter how the service modeling works, services should be allocated to soft components ultimately. A common solution of service allocation is reflecting the operation scope directly to the service component or component collection, so as to realize the consistency between services and components [6].

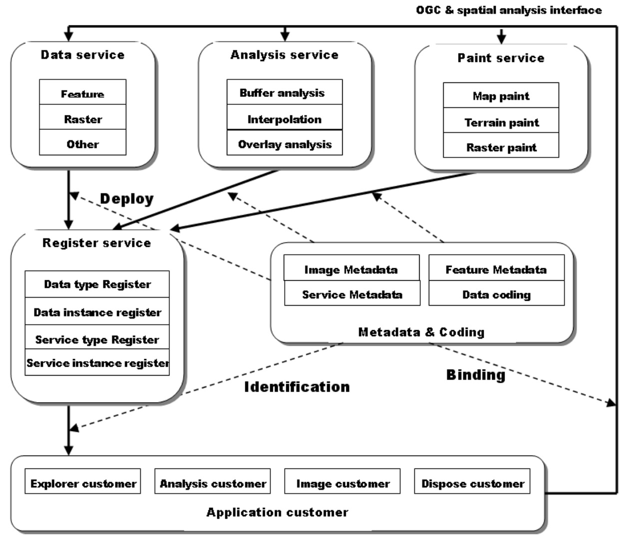


**Figure 4. GIS web service & its' workflow in SDSS for PF**

According to the decision-making requirements of precision fertilization and irrigation, we designed corresponding service components, and also established the interface criterion and accessing protocol for service components, which was shown in figure 4. On this basis, 4 service components collection: basic information services, spatial analysis services, intelligent decision-making services and assistant services were developed on Microsoft .net 2.0 platform.

## 5. An instances of the PF SDSS

As an instance of the PF SDSS, wheat remote diagnoses and decision-making system was shown as Figure 5. It is a web browser based application. The construction of this application was based on the methodology of component, which including component based analysis, design, development and deployment.

According to the component design method of "Top-to-Down", Wheat remote diagnoses and decision-making system was buildup by three levels from top to down, which include application system level, business composite level, and function component level.

According to the component development and deployment method, Selecting existed function components and developing new components according to the system requirement was the first step of the system development, the second step was components arrangement and combination, so as to create business composites, these composites would be deployed onto the ESB. While complete the job of business composites construction, the following step was selecting suitable customized template and completing the job of user interface customization. After all these steps down, wheat remote diagnoses and decision-making system was created. It can help farmers make decision though internet in precision fertilization and irrigation.

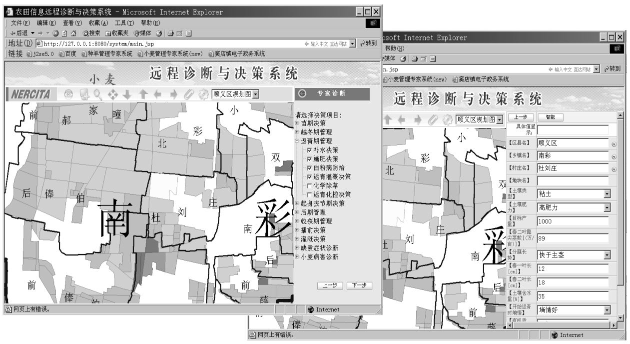


**Figure 5. An instances of the PF SDSS**

## 6. Conclusion

GIS web service is able to effectively cope with the traditional GIS applications' problems such as difficult to maintain, lacking of good interoperability and hard to integrate with other systems, etc. The paper gave the solution on how to establish a spatial decision-making support system for precision farming based on GIS web service, main components of the system and the spatial decision-making workflows were discussed in the paper. Precision fertilization and precision irrigation, as examples, were used to describe key technologies of GIS web service based SDSS for PF. The research result shows that GIS web service is suitable for developing Spatial decision-making Support System for PF, and GIS web service based applications has obvious advantages in dealing with problems such as sharing spatial data, software reuse and reducing the cost of system integration.


## Acknowledgment

This work was supported by a grant from the National High Technology Research and Development Program of China (863 Program, No. 2006AA10A306 & No. 2006AA10Z271）.


## References


[1] Martin D., Cheyer A., Moran D., "OWL-S: Semantic Markup for Web Services", *http://www.dam1.org/services/ow1-s/*, 2004.

[2] Open GIS Consortium, "Web Services Choreography Description Language (WS-CDL) Version 1.0, W3C Working Draft 17", *http://www.w3.org/TR/ws-cdl-10/*, 2004.

[3] Peter Vretanos, "Open GIS Specifications: Web Feature Service Implementation Specification Document", *http://www.opengeospatial.org/standards*, 2008.

[4] Cottenier T., Elrad T, Prunicki A., "Contextual Aspect-Sensitive Services", *the 4th International conference on Aspect-Oriented Software Development (AOSD'05)*, pp 84-92, Chicago, USA, 2005.

[5] Jones Smith, "Business Process Execution Language for Web Services, BEA Systems, IBM, Microsoft, SAP AG and Siebel Systems", *http://www.28.ibm.com/developerworks/library/ws-bpel*, 2003.

[6] Joshua Lieberman, "Open GIS Discussion Papers: Open GIS Web Services Architecture", *http://www.opengeospatial.org/standards/is*, 2003.