Turning remote sensing to cloud services: Technical research and experiment

REN Fuhu[1,2], **WANG Jinnian**[1,2]

1. *Institute of Remote Sensing Applications*, *Chinese Academy of Sciences*, *Beijing* 100101, *China*;
2. *Cloud Computing Industrial Technology Innovation and Incubation Center*, *Chinese Academy of Sciences*, *Dongguan* 523000, *China*

Abstract: Remote sensing cloud services are the remote sensing application services provided through a network as a way of on-demand sharing of integrated remote sensing information and technological resources based-on cloud computing. Up on the analysis of service models and technical requirements, the author highlights the key technologies of remote sensing cloud services, including remote sensing data cloud storage, processing, application and security. We propose an architecture and functional design of the remote sensing cloud service platform and introduce a prototype developed by our R&D team. This remote sensing cloud service prototype allows users to choose required remote sensing data and software, and automatically deploys them to a virtual computer that users can access through Internet to perform their remote sensing data processing and application. Experiments show that the remote sensing cloud service platform can gather remote sensing information, software and computing resources from different providers, and provides them for sharing on user's demand. Such a remote sensing service platform can significantly promote remote sensing to public users and a healthy development of the remote sensing industry.

Key words: remote sensing cloud services, remote sensing services, service platform, cloud computing, cloud services

CLC number: TP701 **Document code:** A

Citation format: Ren F H and Wang J N. 2012. Turning remote sensing to cloud services: Technical research and experiment. Journal of Remote Sensing, 16(6): 1331–1346

1 INTRODUCTION

During the Twelfth Five-year Plan, China plans to launch several remote sensing satellites to form satellites series and combined constellation for the observation of meteorology, land, ocean, and environment. These satellites will provide a tremendous amount of multi-resolution, multi-type, wide-coverage multi-source remote sensing data, which will provide the data foundation of applications and popularization of remote sensing and industrialization service.

Remote sensing has the characteristics of quick repeating, multi-resolution, information rich, multi-type and strong monitoring capability, so it has a great potential for broad industrialization. However, due to the difficulties of getting and updating data, as well as a high technical requirement, high cost, and long deployment cycle, the application of remote sensing is still restricted to only professional users. The industrialization of remote sensing in public market is still limited.

The production technology and overall service level of the remote sensing information product does not follow the quick development pace of remote sensing data collection platforms. It does not satisfy the requirements of the commercial operation of industrialization market and actual business demands from public users. It is also not adapted to the development of remote sensing data collection technology and the rapid increase of public requirements of the remote sensing service. The main problems are as below.

(1) Lack of standardized information products to meet public requirements

As of now, producing remote sensing information relies mainly on experts' manual operation, and there are no standardized information products and streamlining production technology, which are necessary for the industrialization of the information service. Therefore, it is difficult to provide practical, long-term, routine services to public.

(2) Lack of one-stop remote sensing information and application service platform for public users

The remote sensing information extraction and application technology is dispersed in separate specialized libraries and through research projects. There are only scattered "isolated islands" of technical resources but lack of integrated systems and platforms for knowledge accumulation. This situation causes replicated research and development, raises the cost of remote sensing service and restrains the technical innovation and sustaining development of the industry. Furthermore, public users cannot enjoy the prompt

Received: 2011-07-05; **Accepted:** 2012-05-14

Foundation: National High Technology Research and Development Program of China (863 Program)(No.2012AA12A311)

First author biography: REN Fuhu (1962—), male, Ph.D. from Peking University in Economic Geography, is currently engaged in research, software development and applications of Remote Sensing and Geographic Information Systems, and has published six books and 77 research papers. E-mail: renfh@rsclouds.com

services of the integrated industry chain, which adds to the difficulties of meeting the public users' various demands of remote sensing information.

(3) Lack of commercial service model

Current remote sensing application services are mainly conducted through projects, so it needs initiate a particular project and apply the project funds. This procedure may take a long time and have a high construction cost. Users also need to build their own technical platforms and acquire special equipments before using. Data updates, system maintenance and technique upgrades are not guaranteed (Ren, et al., 2010). This model is not suitable for applying remote sensing information in public users' daily operations and does not support long-term development of the remote sensing industry. It is necessary to follow the market's needs through building a large-scaled, routine and sustainable service model, reduce the cost, increase user scope and realize a positive industry circulation.

Cloud computing is the third revolution of information technology (IT) after the inventions of Personal Computers (PC) and Internet. The PC age is coming to the end; we are entering the Cloud age. The cloud computing technology provides new solutions to the challenges in the twenty-first century: data intensity, computing intensity, concurrent access intensity and spatiotemporal intensity (Yang, et al., 2011). The development of cloud computing also provides new opportunities for the popularization of remote sensing and business development.

The concept and the technical system of remote sensing cloud computing and a new model of remote sensing services integrating cloud computing and remote sensing technology are discussed in this paper.

2 THE CONCEPT OF CLOUD COMPUTING

Cloud computing includes a new computing model and a new service model.

Cloud computing utilizes a new computing model based on a shared resources pool that is composed of mass storage devices, networks, computing equipments and softwares, from which the storage space and computing power required can be obtained according to the needs of the processing tasks. This way of sharing computing resources will allow each user to receive maximum computing capability. Cloud computing guarantees the scalability and high availability of distributed computing by large-scale low-cost server clusters, collaborative development of application and underlying services, and server redundancy (Chen & Zheng, 2009).

The essence of cloud computing is resource sharing, which unbinds the applications to resources; shares computing or information resources as services between different tasks or different users, and decreases the idle time to reduce cost.

Therefore, the most important aspect of cloud computing is the resource sharing service model, called cloud computing services or cloud services, which supports business applications via the Internet based on cloud computing resources. In support of cloud computing, computation resources (computing, storage, network, data, and software) are formed into a unified cloud resource pool and packaged into measurable services similar to public facilities (like water, electricity, etc.). Finally, the services are scheduled on demand and distributed through the network, so that different users and applications can access the storage spaces, computing capabilities, network bandwidths, and information resources according to their actual needs.

Grid computing is also a computing resource pool technology (Yang & Xu, 2006), but differs from cloud computing in various aspects such as the business model, architecture, resource management, programming model, application model, and security model (Foster, et al., 2008). The major distinction between cloud computing and grid computing lies in the resource dispatching model. Cloud computing data is distributive and the computing tasks are dispatched to data storage nodes, while grid computing delivers data to computing nodes because computing and storage resources are distributed in different nodes on the Internet. Hence, it usually takes a longer time to transmit data, and how to alleviate network transmission is an important issue for the design of earth data grid computing system architecture (Shelestov, et al., 2008).

Cloud computing and grid computing is essentially different in that cloud computing supports distributed applications using centralized resources, while grid computing supports centralized applications using distributed resources; cloud computing is to share resources between different users and tasks, while grid computing is to complete large-scale computing tasks through integrating dispersed computing resources. The grid computing technology can be used to integrate distributed computing resources to provide cloud computing services.

3 THE DEVELOPMENT OF SPATIAL CLOUD COMPUTING

In April 2011, Google released a map platform for enterprise users, Google Earth Builder, based-on Google cloud technology. Users can upload internal maps, browse and manage their own map using Google Earth and Maps.

ESRI provides online maps and data through ArcGIS Online services, supplies MapIt services in cooperation with Microsoft, and offers statistical reports and mapping functions by Business Analyst Online to share its software. However, these are not yet built on a real cloud computing platform. In 2010, ESRI adopted the technology of deploying a Geographic information system on Amazon Elastic Compute Cloud (EC2), which allows ArcGIS 10 to be directly deployed on a cloud computing platform.

There are other Geospatial softwares, such as Spatial Cloud, APOLLO on the Cloud of ERDAS, EarthWhere of the GeoEye, and Sensor Service Grid (SSG), which support deployment on EC2. In universities, researches focus on studying the parallel processing of remote sensing data using cloud computing to improve the processing efficiency (Golpayegani & Halem, 2009).

In China, Redhat and Supermap jointly developed a GIS platform solution, SGS, based on open source cloud computing architecture. Unistrong is making a great effort to promote the position cloud services. Wuhan University and other institutes are actively studying remote sensing data processing technology based on cloud computing (Liu, et al., 2009; Wu, et al., 2010).

4 REMOTE SENSING CLOUD SERVICE TECHNOLOGY

4.1 Concept of remote sensing cloud services

Remote sensing cloud services are the application services provided through a network as a way of on-demand sharing of integrated remote sensing information and technological resources based on cloud computing. Remote sensing cloud services should reflect the advantages of cloud computing in two aspects. One is to improve the efficiency of storage and processing of remote sensing data; the other is to share remote sensing resources through an on-demand service model. The technical characteristics of remote sensing cloud services are as below.

(1) Remote sensing data, processing software, development environment, and computing equipment shall be acquired on demand through the network at any time without purchasing in advance.

(2) On-demand and pay-as-you-use services can avoid unnecessary labor and costs caused by idle resources and duplicated technical support, system installation, upgrading, and maintenance.

(3) Remote sensing data distributed storage and parallel processing capabilities are more powerful, more reliable, and more efficient, as required in emergency or peak needs of the storage and computing.

(4) Remote sensing cloud services can provide users with more choices and combinations of various remote sensing data, processing software and application environments according to their actual needs.

4.2 Remote sensing cloud service models

Following the basic service models of cloud computing, remote sensing cloud services should support four typical service models as listed:

(1) Remote sensing data as a service (RSDaaS): RDaaS provides data browsing and on-demand use services. Users can use the remote sensing data and information products without purchasing the original remote sensing data.

(2) Remote sensing software as a service (RSSaaS): RSaaS provides online remote sensing software services. Users can use remote sensing data processing and business applications software online without purchasing and installing.

(3) Remote sensing platform as a service (RSPaaS): RSPaaS provides remote sensing data processing and application development platform. Clients can uses SDK and API to develop and deploy remote sensing applications, and invoke powerful computing power in the background for remote sensing data processing, information production and business applications.

(4) Remote sensing infrastructure as a service (RSIaaS): Virtualization is the most important feature of cloud computing (Wang & Liu, 2008). Remote sensing data, remote sensing software, business application systems, computer hardware and software environment, and storage network all can be virtualized and managed integrally in the cloud computing platform and provided as services. Users do not need to build remote sensing application system in a traditional way, but can build virtual remote sensing application environments on the cloud computing platform at anytime, anywhere to use remote sensing data , software, computer and network environment for conducting business applications or providing their own services.

4.3 Characteristics of remote sensing cloud computing

Due to the particularity of remote sensing technology, remote sensing cloud services are different from other cloud services in the following aspects.

(1) Remote sensing data, information, software and required computing resources provide an integrated, one-stop service. Data is the basis of remote sensing applications and is the most time-consuming and costly part. Remote sensing software and computing devices are prerequisite but not fully occupied infrastructure for remote sensing applications. The integrated service of data, information, and infrastructure are the basic requirements to apply remote sensing cloud services to the actual business.

(2) Built on a unified basic spatial database and visualization frame, remote sensing cloud service platform shall support data sharing and collaborative work. It will not only allow users to use spatial data and software freely, but will also avoid the loss of the property rights of the data and software. Meanwhile, real-time multi-source data integration and interoperability can meet a wide range of needs in spatial data sharing.

(3) Professional and standardized remote sensing information products online service is available in combination with remote sensing data processing and thematic information production systems. Users can produce and publish standardized remote sensing thematic information regularly on the cloud services platform, and directly access the thematic information required for business applications to reduce the cost of technology and applications by avoiding organizing data processing processes.

(4) The open access and dynamic dispatch of remote sensing service elements (data acquisition, processing, algorithm, and application models) includes the combination of data, information and technical resources, as well as the procedure organization for service providers, to realize the collaborative service of the information chain, technology chain and industrial chain through remote sensing cloud services.

4.4 Technical architecture of remote sensing cloud services

4.4.1 Remote sensing data cloud storage technology

Cloud storage organizes a large variety of storage devices in a storage resources pool to provide unified dynamic scaling storage service. By means of large file chunks, distributed storage, and multiple copies, the cloud storage can automatically schedule required data and storage resources on the user's demand and ensure the reliability of data and the efficiency of access by redundant storage. As the amount of remote sensing data is huge and is still being increased rapidly with the operation of remote sensing satellites and service platforms, cloud storage with unparalleled scalability and devices reuse can meet scalability requirements of data growing, and reduce investment for new equipment.

Remote sensing data cloud storage shall solve the following key issues.

(1) Currently, distributed file system on cloud computing platform is on data bytes. However, the remote sensing cloud

storage needs multi-level subdivision and a storage strategy for remote sensing image tiles to optimize the efficiency of updating and accessing of remote sensing data, according to the format of remote sensing image data and the characteristics of spatial data access.

(2) At present, there is no spatial database management system on distributive file system and bigtable database technology. Remote sensing cloud storage needs to develop a spatial database and the corresponding data storage architecture on the cloud distributed storage platform in order to present and index the remote sensing data more effectively.

4.4.2 Remote sensing data cloud processing technology

Remote sensing data cloud processing technology utilizes high performance, high scalability, and high availability cloud computing technology to realize the high-speed processing of massive remote sensing data and the mass production of remote sensing information products based on distributed storage and parallel computing model. Because remote sensing data processing consumes a lot of computing resources and it is apt to split remote sensing image into blocks in different scales, and thus the parallel cloud computing technology is very suitable.

The difference of data processing between cloud computing and conventional parallel processing is that in cloud computing the computing resources are dynamically allocated and shared in the resource pool and does not bound to tasks. In this way, the powerful computing resources of the entire cloud computing systems can be fully used if needed.

Remote sensing data cloud processing shall solve the following key issues.

(1) It is necessary to develop remote sensing image parallel processing technologies based on cloud computing parallel processing architecture, such as MapReduce, especially the efficient parallel processing technologies that are suitable for remote sensing data cloud storage.

(2) It is essential to develop open service elements container technology and remote sensing cloud processing platform, through which computing facilities, data resources, the algorithm module library and business applications are independent and linked on the cloud platform. Users can easily access all sorts of data processing resources, and dynamically build the remote sensing data processing procedure to complete application tasks.

4.4.3 Remote sensing applications cloud service technology

Remote sensing applications cloud services join a variety of remote sensing and computing resources together and provide integrated services of remote sensing data, information products, data processing, application software, and computing environments, so that users can get services through network terminals anywhere, anytime on demand in pay-as-you-use model.

Remote sensing applications cloud services shall solve the following key issues.

(1) Stand-alone or web-based remote sensing software should be transformed into cloud services software, supporting network service transformation, performance customization, resource allocation, multi-tenant sharing management and software update technology on cloud platform.

(2) It is important to dynamically create virtual machines, deploy and update of remote sensing data and software, realize use work point reservations, data sharing and collaboration of different users.

(3) Utility computing and accounting services of remote sensing applications should be developed. The costs of remote sensing cloud services may include data fees, remote sensing information products fees, software license fees, space usage fees, processing charges, platform charges, virtual machine renting charges, mapping fees, mobile service fees and so on. The system may monitor the usage of all resources, convert the usages into users' fees and distribute benefits according to the contribution of service providers.

(4) It is important to develop portable terminal equipment by which users can access and manipulate the remote sensing cloud service platform anywhere, anytime - the same as using their personal computers to process and utilize remote sensing data, software and computer environment.

4.4.4 Remote sensing data cloud security technology

Information security is one of the key problems affecting wide adoption of cloud computing technology (Feng, et al., 2011), and this problem determines whether users are willing to store their own data on the remote sensing cloud service platform. High-precision remote sensing data, business information products, and business information are highly confidential. Ensuring information security is crucial to the practical application of remote sensing cloud service platform and the remote sensing cloud services model.

Remote sensing cloud services shall implement the following safety strategies.

(1) Full-life-cycle encryption technology of remote sensing data and information products: Data and products are encrypted throughout the whole process of production, storage, transmission and application. The data can only be displayed on the users' terminal, even if the system administrator cannot decrypt data.

(2) Delicacy management of access and authorization of remote sensing data and information: Data and information is authorized up to data sets, users and access type. Permissions of release, modification, and application are delicately managed for different data and different users to meet the security requirements.

(3) Flexible distributed storage strategy: The users shall be able to store high confidential data to private machines and use the data on cloud platform. Data and information can be managed separately on departmental servers and be unified when processed on the cloud.

(4) Asymmetric distributed data security storage technology: Commonly used data encryption methods are actually password-based transformations. As long as the information is completed, it may be decrypted. Remote sensing cloud services can apply asymmetric distributed storage technology by dividing data and information in bit-level due to the black-box features of cloud storage. As a result, each data block does not contain complete information, which guarantees the high security of data and information.

5 THE TECHNICAL DESIGN OF THE REMOTE SENSING CLOUD SERVICE PLATFORM

5.1 Development goal

With the remote sensing data service as the core, technology and value-added product services as revenue mechanism, the remote sensing cloud service platform for sharing industrial resources can be established by integrating remote sensing data, thematic information products, analysis software, computing and storage facilities, business application system, and mobile terminals. All resources of the remote sensing industry such as data acquisition, data processing, information production, software R & D, application development, system integration, equipment manufacturing, and consulting support, can be integrated dynamically on the remote sensing cloud service platform. A new business model based on the remote sensing cloud services, which integrates services of industrial chain, supports on-demand and shared usages, and divides benefits among providers, would be created. The development of remote sensing cloud service platform will promote wider application of remote sensing and better growth of the industry.

5.2 Overall architecture

The remote sensing cloud platform has a four-tier framework (Fig. 1). The resource tier is the foundation and integrated resources of the system, the function tier implements the basic functions of the system, the service tier realizes remote sensing service model combining the system function following business logic, and the application tier establishes business application procedures.

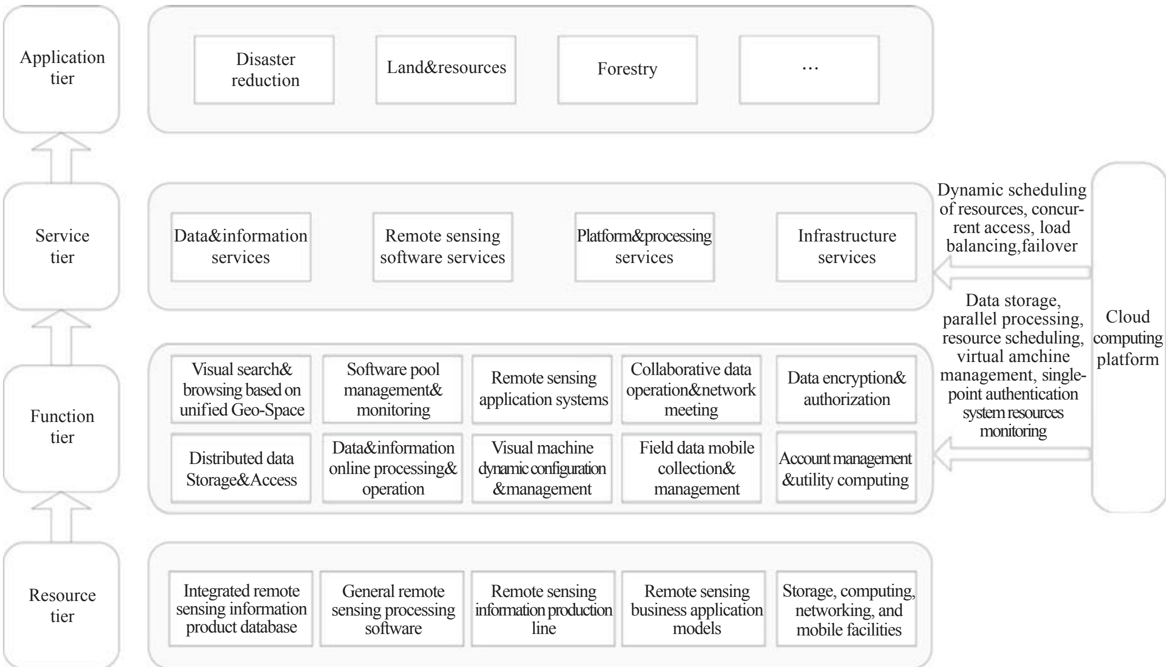

Fig. 1 The framework of remote sensing cloud service platform

The function tier and service tier are set up on the cloud computing platform, and utilize the basic function of the cloud computing system including the data distributed storage; high-speed parallel data processing; resources pool; dynamical scheduling and management; virtual machine building and multi-tenant management; user management and single-point authentication; data encryption; concurrent access from large numbers of users; load balance; and failure transfer. The interface of the cloud computing platform system is shown in Fig. 2.

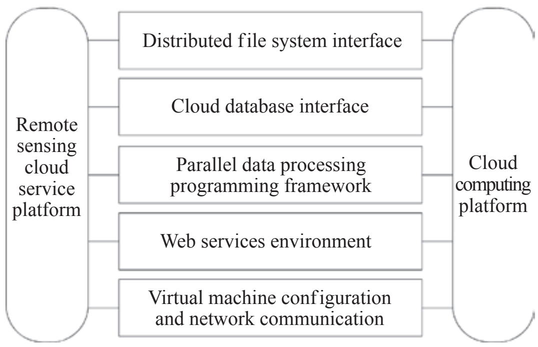

Fig. 2 The interface between remote sensing cloud service platform and cloud computing platform

5.3 Function modules

The basic functions of the system are as follows.

(1) Visual searching and browsing based on unified geo-space: LOD pyramid technology and cloud computing distributed storage system are used to establish visualized basal in regional space. Supporting fast data drowsing, spatial base is provided for data retrieval, while the remote sensing data and information products can be visualized and searched on the map.

(2) Distributed data storage and access: The cloud storage and index mechanisms of the remote sensing database, information products, and related business data are realized through the distributed data storage and database services of the cloud computing platform. With cloud storage, the remote sensing data, information products and related business can be extracted rapidly and compressed on-line dynamically. The efficient concurrent accesses are supported while data can be automatically deployed to user's virtual machines depending on the needs of application.

(3) Software pool management and monitoring: Submission, registration, testing, release, user authorization, on-line operation, monitoring and lifecycle management of the common software and business applications are supported. Users can use the software on-line without installing. The function also allows software be deployed on virtual machines on demand and updated automatically.

(4) Data and information online processing and operation: Through integrating general software tools of the remote sensing processing, data and information on-line processing and operations are supported according to application needs. Remote sensing production service system is integrated to provide information production services by orders. The cloud computing parallel processing programming model is utilized to process the remote sensing data rapidly.

(5) Remote sensing application systems: Application systems are developed on the cloud service platform based on business application models. Users can utilize remote sensing data, information products, online processing functions, business processing interfaces on web platform as well as use stand along application software in the environment of the virtual machines.

(6) Virtual machine dynamic configuration and management: Taking the advantage of virtual machine function on cloud platform, virtual environments can be established for users according to application needs. Data, software, computers for application can be deployed dynamically to the virtual machines. This infrastructure service allows users to directly utilize all the resources of cloud platform at any time without purchasing and installing first.

(7) Collaborative data operation and network meeting: Geo-conferences system is configured and deployed automatically through communication mechanism between virtual machines, unified spatial foundation, remote sensing data and information services. The collaborative work and sharing of remote sensing data and information is supported through the network conference, such as jointly interpretation and tagging on remote sensing images.

(8) Field data mobile collection and management: With the support of the cloud platform to various mobile equipment (such as smart mobile phone, PDA, and panel computer), field data can be collected and uploaded to cloud platform. At the meanwhile, fieldwork data can be located, processed, and operated by accessing cloud computing platform with mobile equipment based on unified spatial foundation and remote sensing data, so that users can flexibly survey, operate and apply the remote sensing data in field without copying the data to mobile terminals.

(9) Data encryption and authorization: Data encryption and authorization are implemented through whole-process encryption mechanism and distributive storage of cloud computing platform.

(10) Account management and utility computing: User logging system and on-demand usage measurement can be established using the functions of cloud computing system, such as the user management, unified authentication and resource monitoring.

6 A PROTOTYPE OF REMOTE SENSING CLOUD SERVICE PLATFORM

Guang Dong ChinaRS Geoinformatics Co., Ltd., i.e. the Remote Sensing Cloud Services Research Center of the Cloud Computing Industrial Technology Innovation and Incubation Center of Chinese Academy of Sciences, has developed a prototype of remote sensing cloud service platform based-on G-Cloud cloud computing operating system from the Guangdong Electronics Industry Institute. Integrated cloud services of remote sensing data, processing software and computing facilities are achieved through this prototype.

Fig. 3 shows a simplified application flow including the following three steps.

(1) The user accesses the remote sensing cloud service platform through the web to browse remote sensing data, selects areas of interest, and chooses needed remote sensing data processing software (Fig. 4).

(2) The remote sensing cloud service platform loads virtual machine with pre-installed software, and automatically imports the remote sensing data chosen by user to the virtual machine (Fig. 5).

(3) User logs into the virtual machine directly through the web interface, processes the remote sensing data with the pre-installed software selected by user, and gets the results (Fig. 6).

In the operation, the remote sensing data and application software are published to the cloud service platform from different service providers, and users use the remote sensing data and software on demand. The services are charged according to usage of

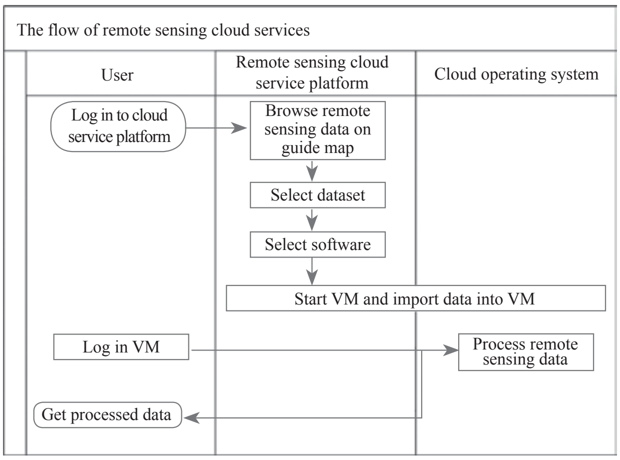

Fig. 3 The flow chart of remote sensing application service through virtual machine technology

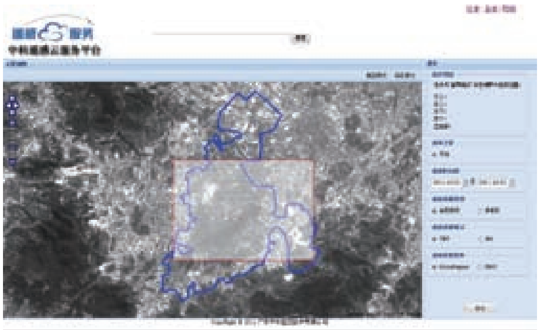

Fig. 4 The user interface for selecting remote sensing data and processing software

Fig. 5 The user interface to import remote sensing data to virtual machine

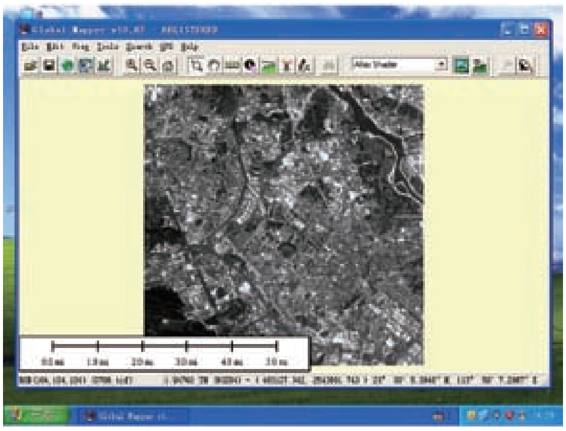

Fig. 6 The user interface to process remote sensing data with pre-installed processing software

contents and lasting time; the platform operating agency assigns payments from user to related service providers according to resource usage records.

A key problem of spatial data sharing is how to allow users to use the shared data freely in this way while preventing other users from owning or transferring the shared data. The owner may lose control of the data if other users are allowed to download. In the other hand, data sharing services can hardly satisfy application needs if only data access interfaces are provided. This problem has long been the constraints for promotion of spatial data sharing and applications. The remote sensing data and software service model presented by this prototype highlights a new technical solution to this problem based on the cloud computing platform. On a cloud computing platform users can use and process the data freely like with their own equipment, but data transfer to local machine is prohibited. Meanwhile, the data and software used on cloud computing platform can be monitored all the time, so the benefits of service providers can be protected. This mechanism innovation has great significance for promoting spatial data sharing.

7 CONCLUSIONS

By upgrading the technologies of data storage and processing services, cloud computing will bring significant opportunities for the popularization, application and industrialization of remote sensing. With cloud computing, remote sensing data, and information products, processing technology and computing resources can be packed into measureable public facilities (similar to water and electricity services). The services are provided to users through a network or mobile terminal whenever and wherever possible, so that the application bottleneck in data, technology, equipment, cost and personnel can be removed and the popularization and application of remote sensing information technology in the daily businesses of government and the public will be realized.

Remote sensing cloud services have the following important roles of the remote sensing industry:

(1) Remote sensing cloud services are the best way to improve popularization and application of remote sensing business. Providing large-scale, socialized and professional services can make obtaining remote sensing information more convenient and more economic, lower the threshold of technology and costs for applying remote sensing, and accelerate the society to enter the era of universally use of remote sensing services.

(2) Remote sensing cloud services are an effective solution to the problem of spatial data and software sharing. With the integrated cloud services of spatial data, application software, computing facilities, the user can use shared data and software just like on their own computer, but the owner can avoid losing their data and software. The conflict of supporting personalized usage and the ownership of shared data can be effectively solved which can significantly promote the development of spatial data and software sharing.

(3) Remote sensing cloud services are a new engine to promote the development of the industry. The remote sensing cloud service platform supports the accumulation of technical resources and the remote sensing data acquisition, information production, platform services and business applications to be connected as an industrial chain. Users can access the required resources and services on demand without focusing on specific technology providers. This business service model containing on-demand services, pay-as-you-use model, and benefits distributing among service providers according to contribution can promote the formation of industry chain, modernization of remote sensing services, and the rapid development of the whole industry.

(4) Remote sensing cloud service is an efficient platform for technological innovation. Through remote sensing cloud service platform, remote sensing information and technology service pro-

viders can focus on their own business without having to construct and maintain their own infrastructures. This can help to reduce cost and shorten commercialization cycle, so the innovation of technology, product and application can be promoted (Wang, 2010).

As one of information technology frontiers, remote sensing applications technology shall timely track the trend of technology and industry, develop service model and application technology for remote sensing information extraction based on cloud computing technology. This is not only the requirement of the coming cloud era, but the remote sensing industry and public users can also enjoy the benefits brought by new technology development and service model innovation.

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遥感云服务平台技术研究与实验

任伏虎[1,2]，王晋年[1,2]

1. 中国科学院 遥感应用研究所，北京 100101；
2. 中国科学院 云计算产业技术创新与育成中心，广东 东莞 523000

摘　要：遥感云服务是基于云计算技术，整合各种遥感信息和技术资源，通过互联网以按需共享的方式提供的遥感应用服务。本文在分析遥感云服务的基本模式和技术特点的基础上，阐述了遥感云服务的技术体系及关键技术，包括遥感数据云存储、遥感数据云处理、遥感应用云服务以及遥感数据云安全技术等，设计了遥感云服务平台总体架构和功能模块，并介绍了作者团队基于云计算技术研发的遥感云服务平台原型系统。该系统支持用户根据业务选择遥感数据和应用软件，在云服务平台自动部署的虚拟机上进行在线使用。实验表明，遥感云服务平台可以汇聚来自不同服务商的遥感信息、应用软件和计算资源，为用户提供一体化的按需应用服务，对于遥感技术的普及应用和产业化发展具有重要意义。

关键词：遥感云服务，遥感服务, 服务平台，云计算，云服务

中图分类号：TP701　　**文献标志码**：A

引用格式：任伏虎，王晋年．2012．遥感云服务平台技术研究与实验．遥感学报，16(6): 1331–1346

Ren F H and Wang J N. 2012. Turning remote sensing to cloud services: Technical research and experiment. Journal of Remote Sensing, 16(6): 1331–1346

1 引　言

“十二五”期间，中国计划发射多颗遥感卫星，包括气象、陆地、海洋和环境等成系列的、行业性的卫星体系和组合星座，将形成多分辨率、多类型，高覆盖度的海量多源遥感数据，为遥感应用与产业化服务提供了数据基础。

遥感具有采集更新快、多分辨率、信息丰富、数据类型多、监测能力强等特点，具有广泛的产业化应用前景。但由于遥感数据获取困难、技术难度大、建设成本高、开发周期长和动态更新不及时等问题，制约了遥感信息的普及应用和产业的发展。

与遥感数据采集平台的快速发展相比，遥感信息产品生产技术和服务总体水平还不高，难以满足产业化市场商业运作和公众用户实际业务的要求，无法适应遥感数据采集技术的发展和满足社会对遥感服务的需求迅速增长的需要。主要问题如下：

(1)缺乏满足公众需求的标准化信息产品

目前遥感信息产品的产生以专家人工方式为主，缺少产业化信息服务所需的标准化信息产品和流程化的生产技术，不利于面向公众的产品化、长期化、日常化的服务。

(2)缺乏公众可直接使用的一站式遥感信息和应用服务平台

遥感业务信息提取与应用的技术分散在各专门领域的实验室和应用项目中，造成了零散的技术资源“孤岛”，没有形成完整的体系，缺乏技术积累平台。一方面造成研发工作重复，遥感信息服务成本高，行业的技术创新与持续发展受到制约；另一方面公众用户也无法快捷地获取一体化的产业链服务，难以直接满足公众用户对与遥感信息的全面需求。

(3)缺乏商业化、规模化的服务模式

目前遥感业务应用服务以项目方式为主，往往需

收稿日期：2011-07-05；**修订日期**：2012-05-14

基金项目：国家高技术研究发展计划(863计划)(编号: 2012AA12A311)

第一作者简介：任伏虎(1962—　)，男，博士，研究员，现从事遥感与地理信息系统开发与应用研究, 已发表专著6部、论文77篇。E-mail: renfh@rsclouds.com。

要专门立项并申请项目经费，不但立项周期长、建设费用高，而且用户需要自行建立技术平台和专门设备才能进行应用，后续数据更新、系统维护和技术升级也无法得到保障(任伏虎 等，2010)。这种商业模式不利于公众用户在日常业务中应用遥感信息，也不利于遥感产业的长远发展。需要按照市场规律，建立规模化、常态化和持久化的服务模式，降低成本，服务广泛的用户，实现良性产业循环。

云计算是继个人电脑、互联网之后电子信息技术领域又一次重大变革, PC时代即将结束，世界将进入云端时代。一方面，云计算技术为解决空间数据的海量存储、复杂处理计算、服务时效性和时空特性等问题提供了新的解决方案(Yang 等，2011)，另一方面，云计算技术的发展也为遥感技术的普及应用与商业模式的建立带来了新的机遇。

本文基于云计算与遥感技术的结合，提出遥感云服务的概念与技术体系，探索遥感服务的新模式。

2 云计算的基本概念

云计算包括两个方面的涵义，即新型计算模型和新型服务模式。

云计算采用一种新型的基于资源共享池的计算模型，利用大量存储设备、网络、计算资源和软件等构成资源池，再根据计算任务的要求从资源池中获取所需的存储空间和计算能力，完成计算任务。通过这种方式实现计算机资源共享，使每个用户可调用系统强大的计算能力。云计算通过大规模廉价服务器集群、应用程序与底层服务协作开发和服务器之间的冗余，实现分布式计算的可扩展性和高可用性(陈康和郑纬民，2009)。

云计算的本质是“资源共享”，即解除应用与资源的绑定，将计算或信息资源以服务的方式，在不同的任务或不同的用户之间进行共享，减少资源闲置和浪费，降低使用成本。

所以云计算更重要的方面，是基于云计算资源通过因特网提供业务应用的“资源共享”服务模式，称为云计算服务或云服务，即在云计算技术支持下，将计算机资源(计算、存储、网络、数据和软件等)形成统一的存储、计算、网络和信息资源池，再根据不同用户的需要打包成类似公共设施(如自来水和电力等)的可计量的服务，按需(On-Demand)调度资源通过网络提供给用户使用，使不同用户和各种应用系统能够根据需要获取存储空间、计算能力、网络带宽和信息资源。

网格计算也是一种计算资源池技术(杨铁利和许惠平，2006)，但与云计算在商业模式、系统架构、资源管理、编程模型、应用模式和安全模式等方面有很大不同(Foster 等，2008)。云计算和网格计算的一个重要区别在于资源调度模式，云计算对数据采用分布式存储管理，运算时以数据为中心，调度计算任务到数据存储节点运行。而网格计算则以计算为中心，计算资源和存储资源分布在因特网上的不同节点，运算时需要将数据传送到计算资源所在的节点上，因此数据传输时间开销通常比较大，如何减轻网络传输是地球数据网格计算系统架构设计的重要课题 (Shelestov 等，2008)。

云计算与网格计算本质的不同在于，云计算是集中资源支持分散应用，而网格计算是分散资源支持集中应用；云计算是为了将资源在不同用户和任务中共享应用，而网格计算是为了完成大型任务而集成使用分散计算资源。网格计算技术可以用来集成分布式计算资源提供云计算服务。

3 空间信息云计算发展现状

Google 2011年4月推出基于Google云技术的面向企业用户的地图平台Google Earth Builder，用户可以上传内部地图数据，并利用Google Earth和Maps浏览和管理用户自有的地图数据。

ESRI通过ArcGIS Online服务提供了在线的地图和数据，与微软合作提供MapIt服务，提供Business Analyst Online共享软件的统计报表和制图功能，但这些都不是真正建立在云计算平台上的。2010年ESRI实现了基于亚马逊弹性计算云EC2快速部署自定义的地理信息系统，用户可以将ArcGIS 10直接部署在云计算平台上。

其他将自己的产品部署在亚马逊弹性计算云EC2上的还有Spatial Cloud、ERDAS的APOLLO on the Cloud、GeoEye的 EarthWhere以及移动服务平台Sensor Service Grid (SSG)等。而一些大学的研究人员则研究利用云计算进行遥感数据的并行处理以提高处理效率(Golpayegani 和 Halem，2009)。

中国的红帽与超图软件公司合作发布基于开源云

计算架构的GIS平台解决方案SuperMap SGS，合众思壮在全力推动“位置云”服务，武汉大学等单位在积极研究基于云计算的遥感数据处理技术等(刘异 等，2009；武云龙 等，2010)。

4 遥感云服务技术

4.1 遥感云服务的基本概念

遥感云服务是基于云计算技术，整合各种遥感信息和技术资源，通过互联网以按需共享的方式提供的遥感应用服务。遥感云服务应体现云计算两个方面的优势，一是通过云计算技术提高遥感数据存储与处理的效率，二是实现资源共享、按需使用的服务模式。具体地说，遥感云服务应具有以下特点：

(1)无需事先购买，可以随时通过网络使用所需的遥感数据、处理软件、开发环境和计算设备。

(2)按需使用、即用即付，只需支付实际使用遥感数据、软件和计算资源所产生的费用，避免不必要的资源闲置和技术支持、系统安装、升级维护等所产生的人力和费用。

(3)获得更强大、更可靠、更高效的遥感数据分布式存储与并行处理能力，并可满足应急或高峰期的存储和计算需求。

(4)可以从众多的遥感数据和遥感软件中选择或组合应用，也可以根据需要使用多种不同的业务应用环境。

4.2 遥感云服务的基本模式

基于云计算的基本服务模式，遥感云服务主要有4种典型服务模式：

(1)遥感数据作为服务RSDaaS：提供数据浏览和按需使用服务，用户无需购买遥感数据，即可使用遥感数据并获得遥感业务信息。

(2)遥感软件作为服务RSSaaS：提供在线遥感软件服务，用户无需购买和安装，即可使用遥感处理和业务应用软件。

(3)遥感平台作为服务RSPaaS：提供后台遥感数据处理与应用开发平台，用户可以通过系统开发工具包和程序接口开发和部署遥感应用软件，调用强大的后台计算能力进行遥感数据处理、信息产品生产和业务应用。

(4)遥感应用系统设施作为服务RSIaaS：虚拟化是云计算最主要的特点(王昊鹏和刘旺盛，2008)，可以把遥感数据、各种遥感软件、业务应用系统、计算机软硬件环境和存储网络等要素都进行虚拟化，放在云计算平台中统一管理并提供服务。用户无需通过传统方式构建遥感应用系统，可随时随地即时地在云计算平台上建立虚拟遥感应用系统环境，使用遥感数据、软件、计算机和网络环境进行业务应用或提供服务。

4.3 遥感云服务的技术特点

由于遥感技术的行业特点，遥感云服务与其他云服务有所不同。它的主要技术特征包括：

(1)提供遥感数据、信息、软件与所需计算资源的一体化、一站式服务。数据是遥感应用的基础，也是遥感应用费用和时间开销的重要环节，遥感软件和计算设备是遥感应用必需但又非全时占用的基础设施。数据、信息和软硬件设施一体化服务是遥感云服务可应用于实际业务的基本要求。

(2)基于统一的基础空间数据库和可视化基底，支持数据共享与协同工作。遥感云服务平台可以通过云平台支持用户既可以自由使用空间数据和软件，又可以避免数据和软件的流失，同时还可以实时进行多源数据融合与协同操作，满足多方面的空间数据共享需求。

(3)与遥感数据处理及专题信息产品生产系统相结合，提供业务化、标准化的遥感信息产品在线服务。通过云服务平台，可以定期生产和发布标准化的遥感专题信息产品，使用户无需自行组织数据处理就可以直接获得业务应用所需的专题信息，降低技术和应用成本。

(4)通过对遥感服务元素(数据获取、加工处理、处理算法、应用模型等)的开放性接入和动态化调度，既包括对数据、信息和技术资源的组合使用，也包括对服务提供方的流程化组织，实现信息链、技术链和产业链的协同化服务。

4.4 遥感云服务技术体系

4.4.1 遥感数据云存储技术

云存储是将网络中大量各种不同类型的存储设备作为存储资源池，提供统一的可动态扩展的存储服务。云存储采用大文件分块、分布式存储和多份拷贝的技术架构，可以根据需要自动调度数据和所需的存储资源， 通过冗余存储保证数据的可靠性和访问处

理的高效性。遥感数据量巨大，并随着卫星和服务平台的运营迅速增加，采用云存储具有其他技术无可比拟的可扩展性和设备复用性，满足数据量不断增长的按需扩展要求，同时可以降低设备成本。分布式数据冗余存储，可以提高遥感数据的可靠性和访问效率。

遥感数据云存储需要解决以下关键问题：

(1)目前云计算平台上的分布式文件系统是基于文件数据流的，遥感云存储需要根据遥感影像数据格式和空间区域访问的特性，设计针对遥感影像空间区块划分的分布式数据多层次剖分与存储策略，优化遥感数据更新与访问的效率。

(2)目前尚没有基于云分布式文件系统及大表数据库技术的空间数据库管理系统，遥感云存储需要研发建立在云分布存储平台上的空间数据库和相应的数据存储架构，以便更有效地对遥感空间数据进行时空表达和索引管理。

4.4.2 遥感数据云处理技术

遥感数据云处理是利用高性能、高可扩展性、高可用性的云计算技术，通过分布式存储和并行计算模型，实现海量遥感数据的高速处理和遥感信息产品的批量生产。遥感数据处理需要耗费大量的计算资源，同时遥感影像有具有易于在不同尺度进行分割的特性，特别适合于应用并行云计算技术。

基于云计算平台的数据处理与通常的并行处理的重要不同是，云处理所用到的计算资源与任务是非绑定的，可以通过资源池进行动态分配和共享，既可减少设备闲置，又可保证在需要时最大限度地利用整个云计算系统的强大计算资源。

实现遥感数据云处理需要解决以下关键问题：

(1)开发基于云计算并行处理架构(如MapReduce)的遥感图像并行处理技术，特别是适合遥感数据分块云存储的高效并行处理技术。

(2)开发开放式服务元素容器技术和遥感云处理平台，使计算设施、数据资源、算法模块库和业务应用相互独立，通过遥感云处理服务平台进行对接，用户可以方便地获取数据处理所需的各种资源，动态构建遥感数据处理流程，完成业务所需的遥感数据处理任务。

4.4.3 遥感应用云服务技术

遥感应用云服务是通过云计算平台，将各种遥感与计算资源连接在一起，提供遥感数据、信息产品、数据处理、应用软件和计算环境的一体化服务，是用户可以随时随地通过各种终端设备按需使用，按使用付费。

实现遥感应用云服务需要解决以下关键问题：

(1)将通常的单机版或网络版遥感软件转化为云服务软件，包括网络服务化改造、性能定制与资源配置、多租户共享管理以及云平台软件更新技术等。

(2)实现针对不同用户的遥感应用虚拟机动态构建、遥感数据与软件动态部署与更新、场景保留、数据共享与协同等。

(3)开发针对遥感应用云服务的效用计算与计费技术。用户使用遥感云服务的费用可包括以下几个部分：数据使用费、遥感信息产品使用费、软件使用费、空间使用费、计算处理费、平台使用费、虚拟机租用费、制图服务费和移动服务费等，需要对各资源的使用进行精细地监测，换算成用户费用，并根据各服务提供商的资源贡献分配收益。

(4)开发遥感云服务平台便携式专用终端设备，方便用户随时随地接入和使用遥感云服务平台，像使用个人计算机一样使用遥感数据、软件和计算机环境，进行遥感数据的处理与应用。

4.4.4 遥感数据云安全技术

信息安全是云计算技术普及的核心难题之一(冯登国 等，2011)，也是用户是否愿意将自己的数据存储于遥感云服务平台的关键问题。高精度遥感数据、平台生产的业务信息产品、以及应用所需的业务信息都具有高度的保密要求，如何保证在平台上存储和应用过程中的信息安全，是遥感云服务平台是否能够被实际应用的关键，也是决定遥感云服务模式成败的重要课题。

遥感云服务可以采用以下安全策略：

(1)遥感数据及信息产品的全生命周期的加密技术：数据和产品在生产、存储、传输和应用过程中全程加密，只在用户的终端上才能被显示和理解，即使是系统管理员也无法解密。

(2)遥感数据及信息的访问授权精细管理：对数据和信息按照数据集、用户和访问类型逐一授权，针对不同数据和用户，对发布、修改和应用权限进行精细管理，以满足安全保密的要求。

(3)灵活的分布存储策略：根据需要，用户可以将密级较高的数据和信息自行保存在终端上或部门的服务器上，进行单独管理；在应用时与平台密级较低的数据和信息之间执行分隔管理的安全策略。

(4)非对称分布式数据安全存储技术：通常的数据加密实际上是一种基于密码的变换，只要信息是完整的，就有可能被解密。遥感云服务可采用非对称分布式存储技术，利用云存储的暗箱特性，将数据和信息进行比特级划分，使每个分布式存储的数据块均不包含局部的完整信息，独立信息的不完整性可保证无法被解密。

5　遥感云服务平台技术设计

5.1　建设目标

以遥感数据服务为核心，以技术和产品增值服务为收益机制，建立集遥感数据、专题信息产品、分析处理软件、存储计算设施、业务应用系统、移动终端一体化、共享式的产业化遥感云服务平台，动态汇聚遥感服务行业的遥感数据采集、数据处理、产品生产、软件研制、应用开发、系统集成、设备制造、技术支持等技术资源，形成产业链服务集成、用户按需共享使用、服务商分享收益的新型遥感云服务商业模式，促进遥感的普及应用和产业化发展。

5.2　总体架构

遥感云服务平台可以采用4层架构实现(图1)：资源层是系统的基础和集成资源，功能层实现系统服务所需的基本功能，服务层是对系统功能进行业务逻辑组合建立的遥感云服务模式，应用层是针对业务应用建立的操作流程。

图1　云服务平台总体架构图

功能层和服务层建立在云计算平台之上，利用云计算操作系统的数据分布式存储、数据高速并行处理、资源池管理与动态调度、虚拟机建立与多租户管理、用户管理与统一认证、数据安全加密、大量用户并发访问、负载均衡与失败转移等基本功能。系统与云计算平台的接口如图2所示。

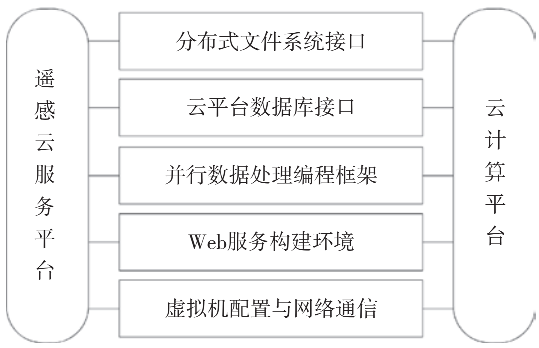

图2　遥感云服务平台与云计算平台接口关系图

5.3 功能模块

系统的基本功能包括：

(1)统一空间基底可视化查询浏览：利用LOD金字塔技术和云计算分布式存储体系，建立区域空间可视化基底，支持快速浏览，为数据检索提供空间基础，同时可以将遥感数据和信息产品在统一的基底上进行浏览显示。

(2)遥感数据分布式存储访问：利用云计算平台的分布式数据存储与数据库服务，实现遥感数据库、信息产品和相关业务数据的云存储与索引机制。在云存储的基础上，实现遥感、信息产品和相关业务数据快速提取与动态在线压缩，支持大量用户的高效并发访问，同时也可以根据应用需要自动将数据部署到虚拟机上。

(3)遥感软件池管理与监控：支持遥感通用软件和业务应用软件的提交、注册、测试、发布、用户授权、在线运行、监控与生命周期管理等，使用户无需安装，即可在线使用遥感软件。本功能也负责将软件根据需要部署到虚拟机上，并进行自动升级维护。

(4)遥感空间信息在线处理与操作：集成遥感处理通用软件工具，支持用户根据应用的需要，对平台提供的遥感数据和空间信息进行在线处理与操作；与遥感信息产品生产服务系统集成，提供订单式信息产品生产服务；利用云计算并行处理编程模型(如MapReduce)实现遥感数据的高速并行处理。

(5)遥感业务应用系统：基于遥感业务应用模型，将业务应用系统在云服务平台上实现，支持用户通过在Web平台直接使用平台提供的遥感数据、信息产品、在线处理功能、以及业务流程界面进行业务应用，同时提供可在虚拟机环境下使用的业务应用软件系统。

(6)虚拟环境动态配置管理：利用云计算平台的虚拟机功能，根据应用需要，动态建立针对用户的虚拟机遥感应用环境，动态部署应用所需的数据、软件和计算机环境，提供基础设施服务，使用户无需购买和安装数据、软件和计算机设备，即可随时随地使用平台资源完成业务应用。

(7)数据协同操作与网络会商：通过云计算平台上的虚拟机通讯机制、空间可视化基底和遥感与信息产品数据服务，建立可自动配置和部署的网络协同会商会议系统，支持在共用的遥感影像和空间信息基础上的协同工作(如联合图像解译、标注等)和网络会议。

(8)移动外业采集与数据管理：利用云计算平台对于多种移动平台(智能手机、PDA和平板电脑等)的支持，实现野外数据采集(照片、表格等)的采集与上传。同时利用移动设备访问云计算虚拟机，在统一空间基底和遥感数据基础上对外业信息进行定位、处理与管理，使用户无需实现将遥感和空间数据拷贝到移动终端上，即可对灵活地开展外业调查和管理应用。

(9)数据加密与授权管理：利用云计算平台的数据全程加密和分布式存储方式，实现数据安全加密和用户授权管理。

(10)用户管理与效用计算：利用云计算平台的用户管理与统一认证和资源监控功能，建立用户使用履历跟踪和按需使用计量系统。

6 遥感云服务平台原型实现

中国科学院云计算产业技术创新与育成中心遥感云服务研究中心暨广东中科遥感技术有限公司，基于广东电子工业研究院自主研发的云计算操作系统G-Cloud，开发了一个遥感云服务平台原型，初步实现了遥感数据、处理软件和计算机设施一体化云服务。

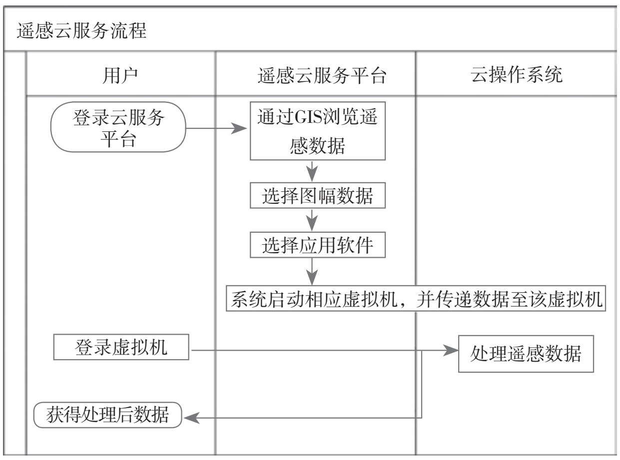

图3 遥感应用虚拟机服务技术流程图

图3是原型系统实现的一个简化应用流程，包括以下3个使用步骤：

(1)用户通过Web界面登录遥感云服务平台，浏览遥感数据，选择数据区域并选择需要使用的遥感数据处理软件(图4)；

(2)遥感云服务平台启动预装了用户选择的软件的虚拟机，并把用户选择的遥感数据自动导入到该虚拟机中(图5)；

(3)用户通过Web直接进入虚拟机，使用选择的软件对导入的遥感数据进行相应操作，得到处理结果(图6)。

在实际运营中，遥感数据和应用软件可以由不同的遥感服务商注册到云服务平台，用户可以按需选择遥感数据和软件在虚拟机上进行处理和应用，按使用内容和时间付费；平台运营商根据资源被使用的记录，从用户付费中分配给各服务商相应的收益。

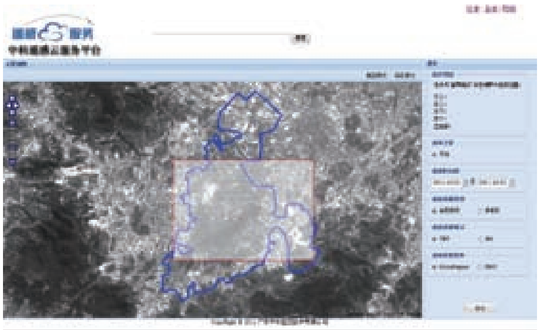

图4 遥感数据与处理软件选择用户界面

图5 遥感数据导入虚拟机用户界面

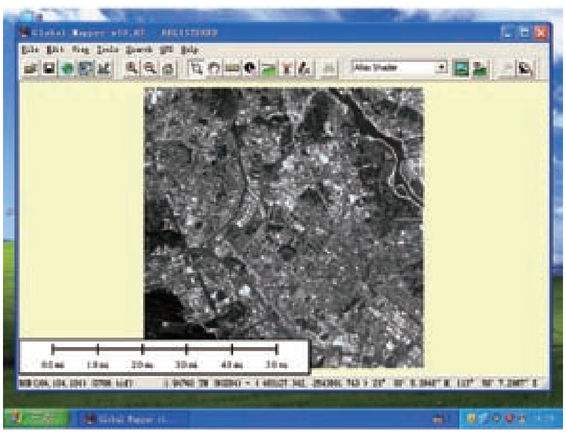

图6 在虚拟机上使用预装处理软件进行遥感数据处理用户界面

空间数据共享的一个关键问题是如何既允许用户自由地使用共享数据，又不允许用户拥有和转移数据的问题。提供数据下载面临数据流失问题，而仅仅提供数据访问接口又往往难以满足应用的需要。这一问题长期以来严重制约着空间数据共享的数据来源和实际应用推广。本原型实现的遥感数据和软件服务模式，为解决空间数据共享问题提供了一个新的基于云平台的技术方案，用户在云平台上可以像在自己的机器上一样自由地使用和处理数据，但又可限制用户将数据转移出云平台，同时云平台还可以全时监控用户对数据和软件的使用，保证数据和软件提供者的权益。这一机制创新对于推进空间数据共享具有重要意义。

7 结论与展望

云计算技术将深刻地改变遥感数据存储、处理技术和服务方式，为遥感技术普及应用和产业化发展带来重大的机遇。基于云计算技术，可将遥感数据、信息产品、处理技术与计算资源打包成类似公共设施(如自来水和电力等)的可计量的服务，提供给用户通过网络或移动终端随时随地按需使用，解决遥感应用中的数据、技术、设备、成本和人员的瓶颈，实现遥感信息技术在政府和公众日常业务中的普及应用。

遥感云服务对于遥感产业化具有以下重要意义：

(1)遥感云服务是遥感业务普及应用的最佳方式。以大规模、社会化和专业化方式提供服务，可以使遥感信息的获取方式更方便、更低廉，降低遥感应用的技术和成本门槛，使社会更快地进入遥感业务应用的普及时代。

(2)遥感云服务是空间数据与软件共享问题的有效解决方案。通过云服务平台提供空间数据、应用软件和计算设施的一体化服务，既可以使用户像在自己的计算机上一样使用共享数据和软件，又可以避免数据和软件的流失，可以有效地解决长期以来使用和拥有共享数据的矛盾，推动空间数据与软件的共享。

(3)遥感云服务是推动行业发展的新引擎。遥感云服务平台有利于沉淀行业技术资源，连通遥感数据采集、遥感信息产品生产、平台服务和业务应用的产业化链条，用户无需关注具体的技术提供方，而可根

据需要访问和使用所需资源和服务，形成用户按需使用、按使用付费、服务提供方按贡献分配收益的商业服务模式，有利于形成产业链协作，形成现代遥感服务业，促进整个产业的快速发展。

(4)遥感云服务是技术创新的高效平台。通过遥感云服务平台，遥感信息和技术服务提供商无需各自进行基础通用功能的建设和维护，而专注于自己的业务发展，有利于降低成本，缩短商品化周期，推动技术、产品和应用创新(Wang，2010)。

遥感应用技术作为IT技术的前沿之一，及时追踪遥感技术和产业发展趋势，发展在云计算技术基础上的遥感信息提取和应用技术与服务模式，既可满足云端时代即将带来的应用需要，也必将使遥感产业和公众用户享受到技术发展和服务模式创新带来的收益。

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