

A Web-based Image Processing Toolkit for High-resolution Remote Sensing Images

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Abstract

An increasing pace of researches on high-resolution remote sensing images leads to demand for heavy load and easy access data processing, even though there are many traditional standalone platforms for remote sensing image processing. In this paper, some online image analysis and processing tools will be designed and developed into a web-based image processing toolkit, based on using standard web services. And the user requests are through web front-end plug-in, so that the processing toolkit can be integrated into other web applications rather than the prototype system. The functions in the toolkit include online projection transformation, basic statistics and histogram analysis, change detection, cluster analysis; and regression analysis.

Keywords: web-based, image processing, high-resolution, remote sensing, web services

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1. Introduction

In the use of high-resolution remote sensing data products, users often expect to be able to understand and excavate the inner information. An important feature of the high-resolution remote sensing products is the huge amount of data. Given the large data systems, how to probe the information from data itself fast and flexibly, in order to apply to further industrial applications, becomes a hot issue. Among many research hotspots, providing online data analysis and data mining, as well as visualization of the data analysis results on high-resolution remote sensing products is very important.

This paper expands the key technologies about on-line analysis and visualization of the high-resolution remote sensing products. The realization of various online data analysis and processing tools will be developed based on standard web services, and the requests are through web front-end plug-in, so that the processing tools can be integrated into other web applications or systems. The two objectives of the study are: 1) providing the online high-resolution remote sensing image processing toolkit based on web services, which will provide online data analysis capabilities; and 2) providing the flexible service integration framework, which can make the tools being flexible to assemble various platforms.

Specifically, the processing toolkit includes the following functions: 1) online projection transformation; 2) online basic statistics and analysis; 3) online comparative analysis (change detection); 4) online cluster analysis; and 5) online spatial regression analysis.

2. Standalone Processing and Web-based Processing

There are many standalone platforms for remote sensing image processing. The ENVI is a desktop platform that processes and analyzes imagery; it also integrates with ArcGIS, which helps to design and manage solutions through the application of geographic. The ERDAS Imagine is a system that incorporates image processing into a package with add-ons offered to expand core functionality. Making use of languages such as C++ or MATLAB to program dedicated software is also feasible. It should be noted that most of standalone image processing tools are unable to adapt to multi-user environments or integrate with other systems within simple steps.

An increasing pace of geospatial research leads to demand for heavy load and easy access data processing. Besides, since no software or service can cover entire requirements from past to future throughout potential and existent users, expansibility should also be considered.

eXtensible Markup Language (XML), which is a technology to format documents to realize both human-readable and machine-readable, can be used, when delivering high-resolution remote sensing products between servers and clients to meet requirements of processing on demand [1]. Standardization has been called on, based on Services Oriented Architecture (SOA) and extends several existing Open Geospatial Consortium (OGC) services via schemas in XML, which facilitates interoperability between web services, and foster business logic layer to separate with presentation layer [2].

Web service is able to be applied to remote sensing image process for its superiority, which can be embodied when handling data in large volume especially within network computing environment [3]. It's convenient for service providers to update and upgrade services while it is the same with users to get access and execute on-demand processing. Taking advantages of web service, remote sensing image distributed processing involves large amount of data, computing and also data transfer under the framework consisting of servers, storages, standardized protocols and lightweight clients. In a distributed processing case, requirements for a client environment are always reduced, and high efficiency is practically implemented.

Web-based tools may take extra time to transmit data between the application server and the data server via Ethernet, while it's not as fast as transmitting data with local drives. Benefiting from simplified system infrastructure, specialized tools are able to realize portability and reusability [4, 5]. It should also be highlighted that commercial systems are usually costly and complex for the sake of wide-ranged application, which may be unnecessary for users concentrated only on some analyses. Moreover, as for web-based processing, the separation of processing modules simplifies data management, enables multi-user and distribute support, makes the tools convenient to update, especially for user end.

The key features that web-based tools differ from previous standalone ones is the separation of modules, namely distributed processing consists of server, user client and network. The advantages, disadvantages and features between traditional standalone and web-based methods are compared in Table 1.

3. Infrastructures and Processing Workflow

The solution of developing the toolkit includes two aspects which are the technology infrastructures and the achievement of image analysis functions.

The key of the technology infrastructures is how to achieve online analysis based on web services which help with shielding various hardware and software environment differences, realizing dynamic assembly with other types of platforms and service integration.

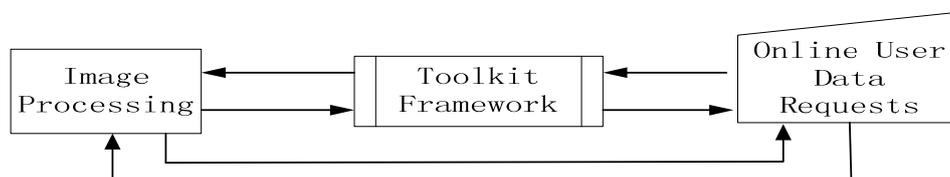


Figure 1. Technology Infrastructures

The realization of the toolkit is based on standard web services and a framework. The results of data processing with XML format are visible through external output interface, to achieve the loose combination of the framework as shown in Figure 1. Online users send requests to the framework. The framework consists of OGC WCS specification, browser-server (B/S) three-tiered structure, and image processing workflow which is illustrated in Figure 2. The framework provides data resource through the OGC WCS. The feedback of result returns to online users after image processing.

Table 1. Compare between Standalone and Web-based Remote Sensing Image Processing

Remote Sensing Image Processing Method	ENVI (commercial)	ERDAS (commercial)	Standalone Toolkit (noncommercial)	Web-based Toolkit (noncommercial)
Processing speed	Very high	Very high	Very high	High
Portability	No	No	Yes with platform independent language	Yes with platform independent language
Reusability	Yes with ArcGIS	No	Yes	Yes
Scope of application	Wide-ranged	Wide-ranged	Specialized for image processing	Specialized for image processing
Price	Very high	Very high	Very low with open-source development kits	Very low with open-source development kits
Demand for operation	Not very high	Not very high	Very low	Very low
Demand for data management	High	High	High	Very low for users
Support multi-user	No	No	No	Yes
Support distribute deployment	Yes with ArcGIS	No	No	Yes
Update	Inconvenient	Inconvenient	Inconvenient	Very convenient for users

There are three steps to achieve image analysis functions - data preparation (parameter setting and data acquisition), data analysis, and data output (visualization), as shown in the Figure 2 which also illustrates the workflow of the image processing. The toolkit acquires the data through the data read interface under the control of parameter interactions. The projection transformation function could be used in the first step before other data processing for the acquired data products. The other data processing tools in this study include basic statistics and histogram analysis, multi-temporal remote sensing change detection, spatial cluster analysis and spatial regression analysis. And the results output in chart forms.

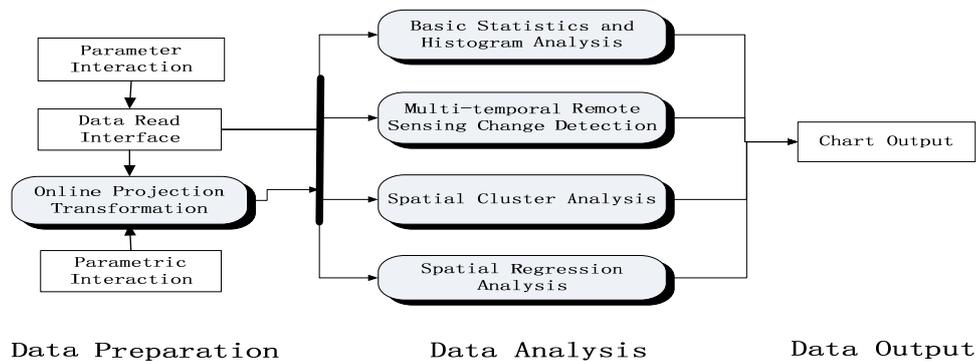


Figure 2. Image Processing Workflow

The following key functions compose the processing toolkit.

- 1) Projection Transformation - The interface of this tool is a visual interactive way to determine the basic parameters of the projection coordinate system.
- 2) Basic Statistics and Histogram Analysis – This function can calculate statistical mean, information entropy, average gradient and standard deviation. For the high-resolution remote sensing color image products, if there are red, green, blue, infrared and other pieces of the synthesis, there are red, green, blue, infrared and other pieces of the histogram.
- 3) Change Detection - The function is a pixel-based change detection analysis for different timings, and the output result is table format.

- 4) Spatial Cluster Analysis - This tool is able to help with getting clustering feature information from high-resolution remote sensing products.
- 5) Spatial Regression Analysis - Through the analysis between different data layers, especially based on regression model, this tool can do data mining expressed in different layers of the relationship between the target objects.
- 6) Visualization – one important objective of this image analysis and mining tool is to provide the visual interfaces for dynamic, interactive user input and output.

4. Implementation

4.1. Toolkit Architecture

There are two servers in the prototype system, a web server and a data server, each one has at least processor of 8 cores and memory of 6 gigabytes by recommend. The operating system in the servers is Ubuntu 12.10, Benefited from web-based architecture, no more than a computer joint network with one of popular browsers is required, for a client, so that user group is readily to expand. Considering transmission rate and data security, network architecture is divided into three tiers: server tier, user tier and network tier. And the tiers are linked by 1Gbps Ethernet.

The Toolkit Architecture is illustrated in Figure 3. The Apache Tomcat, which is an open source software implementation of the Java Servlet and Java Server Pages technologies, is deployed in the Web Server, and it makes the whole system runs on the Java Platform. PROJ.4 originally written by USGS is the key of the toolkit, for providing cartographic projections library. GDAL is a translator library for raster geospatial data formats. As a library, it presents a single abstract data model to the calling application for all supported formats. Orfeo Toolbox (OTB) is also a library for remote sensing image processing, and most functions are also adapted to process huge images (>4GB) using streaming and to take advantages of multicore processor as often as possible. OpenCV was designed for computational efficiency and with a strong focus on real-time applications.

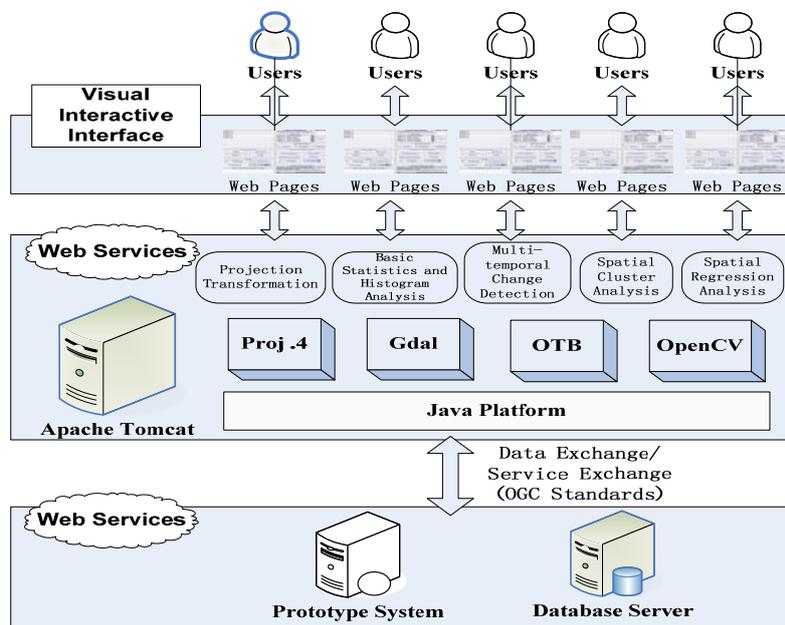


Figure 3. Toolkit Architecture

The toolkit architecture consists of browser-server three tiers structure. On server tier, images, statistics, results, logs and other data are stored on and load from the data server, which is continuously in communication with the web server by using the OGC standards, while on the latter disposes applications including runtime environment, processing program, service

and user authenticate. On user tier, different users can get access to services by creating accounts with authentication. General users together with administrators are both involved in the same network but divided into sub-networks by limits of authority. On network tier, high performance switches are used to set up fast Ethernet, ensuring large throughput capacity under frequent data transmission and act as entrance and exit of the whole network with external modules. Redundancy is also taken into account in case of overload or accidentally crash.

4.2. Toolkit Interfaces

To establish communication between the toolkit and users, user interfaces (Figure 4), and communication interfaces (Figure 5) are established in the prototype system. User interfaces serve as control panel and also monitor of the system. Each function is visual and friendly with default parameters proposed. Besides, processing stage synchronously renew on user interface, informing users of percent completed.

Communication interface links modules or devices. In this paper, OGC service serves to provide images and information. The former is in GeoTIFF format, which is supported by OGC WCS to transmit images. The latter is in XML, which makes it convenient while generic to send and acquire requests.



Figure 4. Example User Interface in the Prototype System

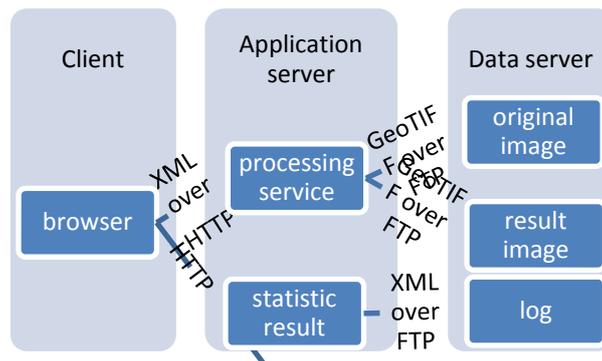


Figure 5. Communication Interface in the Prototype System

4.3. Function Modules

Benefiting from function modules, the toolkit is easy to be integrated into other systems. Table 2 shows the calling relationships between function modules in the toolkit.

- The XmlToolsModule contains a series of processing operations for XML documents.

- The DataInputModule imports image from catalogue provided by the data server in the form of packages. It also receives requests for processing via XML. Requests are linked then organized with relevant images, and sent to the web server.
- The DataOutputModule packages the calculated results together with processed images, transmits the results to data server, and meanwhile reveals the output in browser at the user end.
- The StatusViewModule runs daemon in the background, returning the status of processing to system interface simultaneously.
- The OptionSetModule handles user input parameters.
- The DrawingModule manages how to draw the output charts, and presents the results to the users.
- The ProjectionModule, StatisticsModule, HistogramModule, ChangeDetectionModule, ClusterAnalysisModule and RegressionAnalysisModule are in charge of the high-resolution remote sensing data processing which is illustrated in Section 3.

Table 2. Calling Relationships between Function Modules

Callee/Caller	Projection Module	Change Detection Module	Cluster Analysis Module	Statistics Module	Histogram Module	Regression Analysis Module	DataInput Module	DataOutput Module
XmlTools Module	√	√	√	√	√	√	√	√
DataInput Module	√	√	√	√	√	√		
DataOutput Module	√	√				√		
OptionSet Module	√	√	√	√	√	√		
StatusView Module	√	√	√	√	√	√		
Drawing Module					√			

5. Conclusion

In the paper, the possibility and necessity of applying web-service technique on high-resolution remote sensing image processing is discussed. The web-based high-resolution remote sensing image processing toolkit, which achieves inter-activity, interoperability, visualization, efficiency and convenience, are designed and developed. And the functions include projection transformation, basic statistics and histogram analysis, change detection, cluster analysis; and regression analysis. It should be noted that the toolkit is able to adapt to multi-user environments and can be integrated with other systems or applications within simple steps. Taking advantages of web services, remote sensing image distributed processing occurs, which aims at the shortcomings of standalone solutions. The toolkit framework consists of OGC WCS specification and browser-server three-tiered structure. The toolkit is also a 7*24 hours online solution, and the analysis progress can be checked through some status view tool when doing huge image processing.

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