Development and Evaluation of Satellite Image Data Analysis Infrastructure

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Abstract: Tokyo University of Information Sciences (TUIS) receives Moderate Resolution Imaging Spectroradiometer (MODIS) data and provides the processed data to universities and research institutes as part of the academic frontier project. One of the major fields of the research using MODIS data is the analysis on change of environment. We are currently developing applications to analyze the environmental changes. These applications run on our satellite image data analysis system implemented in a parallel distributed system and a database server. When using satellite data, one common problem is the interference of clouds. In order to remove the interference of clouds, the standard solution is to create a composite data of the same regions during a selected time span, and to patch together data not covered by clouds to create a clear image. We introduced a piece processing algorithm, which separates one satellite image data into many small pieces of image data, making it quicker and easier to analyze and process the time-series satellite data. In this research, we implemented the piece processing and composite processing algorithms in order to increase the analysis speed within the satellite image database. We tested the proposed processing and verified the effectiveness for target applications.

Keywords: Satellite image data, MODIS, Composite.

I. INTRODUCTION

The Academic Frontier Project at Tokyo University of Information Sciences (TUIS) is promoting research on "the sustainable development of economic and social structure dependent on the environment in eastern Asia". As part of this project, TUIS receives and processes Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data, one of the sensors equipped by NASA's Terra and Aqua satellites, to provide to universities and research institutes. One of the major research aims of this project is the analysis on change of environment. For this research, we are developing a satellite image data analysis system to analyze the environmental changes and its effects[1][2][3]. This paper reports on a) an overview of the satellite data analysis system and MODIS data, b) the composite processing algorithm in order to improve the performance and accuracy of the data analysis, and c) the proposed piece processing algorithm to improve the composite processing speed and data utilization efficiency for analytical applications.

II. SATELLITE IMAGE DATA ANALYSIS SYSTEM

1. System Overview

This system works as the main platform of the total satellite image data analysis service, maintains the satellite image data, and implements satellite image data analysis applications. The user can access the system over the network via Web browser or other web applications. Users can request for data analysis, check the results and download satellite image data through the system. The analysis applications currently being developed are 1) search for fire regions in forests and fields, 2) search for similar image data, 3) spatiotemporal analysis of land cover changes of east Asia, 4) creation of east Asian disaster map, 5) Time-series NDVI prediction using auto-regression analysis, and 6) statistical and soft computing analysis for land cover estimation.

Figure 1 shows the system configuration. This system is consists of a Web server, distributed computer nodes, and a database server. The user accesses the Web server with a Web browser, following the guidance on the accessed page. The role of the Web server is accepting requests by web users, execution of specified analysis application at compute nodes, and creating the final Web page of results. The role of the distributed computer nodes are running the analysis applications, and running the piece processing and composite processing algorithm. The role of the database is the management of the original satellite image data and the result data of the composite processing, and piece processing operations.

The satellite image data is extremely large, and direct manipulation of the large data leads to a high load on both the processor and network. In order to improve the throughput and turnaround time of data processing, in the proposed system the computer nodes are configured from high performance servers and multiple PC clusters, implemented as a parallel distributed system. The various analysis applications and piece processing and composite processing operations are run on this distributed computer nodes.

Figure 1 System configuration

2. MODIS

A key instrument aboard Terra (EOS AM) and Aqua (EOS PM), two satellites of the NASA-centered international Earth Observing System project is MODIS (Moderate Resolution Imaging Spectroradiometer). Terra was launched on December 18, 1999, and Aqua was launched on May 4, 2002. MODIS has a viewing swath width of 2,330 km, with a fast orbit covering the entire Earth surface every one to two days. Terra's orbit crosses the equator from north to south in the morning, and aqua passes the equator from north to south in the afternoon. The MODIS detectors measure 36 spectral bands between 0.405 and 14.385μm, acquiring the data at three spatial resolutions, 250m, 500m, and 1,000m, depending on the spectral bands.[4]

TUIS receive MODIS data using a tracking antenna. The reception area is between 105 to 180 longitude east and 15 to 65 latitude north. From the received MODIS data, the proposed system uses the standard MODIS products of MOD02, MOD03, and MOD09.

The Level 1A, Level 1B, geolocation and cloud mask products and the Higher-level MODIS land, ocean and atmosphere products are produced by the MODIS Adaptive Processing System.

MOD02 (Level-1B) is Calibrated Geolocation Data Set. The Level 1B data set contains calibrated and geolocated at-aperture radiances for 36 bands generated form MODIS Level 1A sensor counts. The radiances are in W/(m2-μm-sr). In addition, reflectance may be determined for solar reflective bands (bands 1-19, 26) through knowledge of the solar irradiance.

MOD03 is Geolocation Data Set. The MODIS Geolocation product contains geodetic coordinates, and solar and satellite zenith, and azimuth angle for each 1 km sample. These data are provided as a companion data set to the Level 1B calibrated radiances and the Level 2 data sets to enable further processing.

MODIS Surface Reflectance product (MOD09) is computed from the MODIS Level 1B land bands 1 to 7 at 500m resolution. The product is an estimate of the surface spectral reflectance of each band as it would have been measured at ground level if there were no atmospheric scattering or absorption.

III. COMPOSITE PROCESSING

1. Overview

When analyzing large area satellite data, one common problem is noise caused by cloud interference. In order to remove the interference of clouds, the standard solution is to create a composite data of the same regions during a selected time span, and to patch together data not covered by clouds to create a clear image.

The selected time span for the composite process depends on research objective and region. For example, when analyzing the seasonal variation of vegetation, it is common to use a short 8 day composite. However, when the composite time span is short, there are less data to select from, which leads to a higher possibility of cloud interference remaining in the composite data.

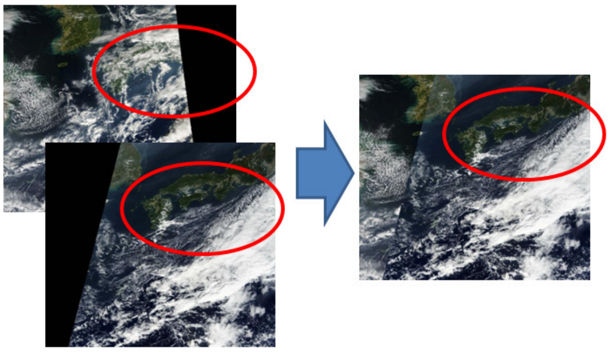

Figure 2 Image of composite processing

2. Effect

Traditionally, it has been the responsibility of the researcher analyzing the satellite data to process the large satellite data and create a composite image for individual research use. Creating a web service to provide systematic composite data processing using large scale computing resource over a parallel distributed configuration, will be valuable for researchers.

IV. PIECE PROCESSING

1. Overview

Satellite image data taken every day from slightly different orbits must be adjusted using some a map projection (e.g. WGS84). For MODIS data, the sensor data (MOD02 or MOD09) are resampled using map coordinate information (MOD03). When a particular map coordinate is out-of-bounds for a given satellite sensor scan, the pixel data for the particular coordinate will be defined an unused parameter value (65000 for MOD02, -10000 for MOD09), as seen in the black area in Figure 3. This leads to large portions of the processed image file being wasted to hold unused data, leading to unnecessary load on the database. Furthermore, analysis applications must process the large image data holding unnecessary data, leading to significant deterioration of calculation time.

2. Effect

In this research, we define "piece processing" as the process of separating a large satellite image data into small squares or "pieces" of equal latitude and longitude sizes.

By piece processing the original large satellite image data, out-of-range data can be eliminated, reducing database size.

Satellite data analysis applications which use the satellite data will also have less data to analyze if out-of-range data is initially removed, leading to improved analysis throughput.

When analyzing satellite data, it is common to focus on specific target areas. For example in the case of Japan, it would be common for researchers to not use all of received MODIS data but limit the region to, for example, northern region (Hokkaido), northeast region (Tohoku), or Central region (Kanto). Piece processing is efficient for selecting limited regions from the total MODIS reception area, making it easier for researchers to select the exact regions necessary, as well as decreasing the analysis computational cost.

The same merit applies to composite data processing. Researchers requiring composite data can request for the exact regions and time span, and with the reduced process area, improve the request turnaround time of on-the-fly composite data processing.

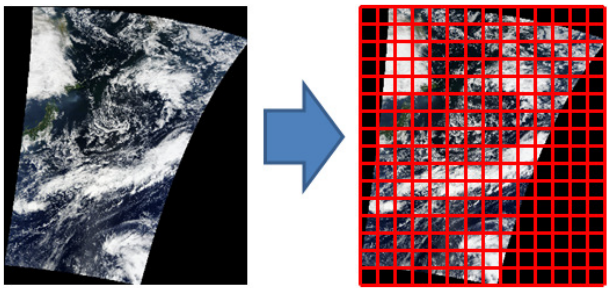

Figure 3 Image of piece processing

V. CONCLUSION

In this paper, a composite processing and piece processing algorithm for effective satellite data handling is proposed. The implemented system is currently under evaluation. It is planned to apply the proposed data preprocess to all of the archived satellite data and open for use by users. For future works, improvement of throughput performance for real-time composite processing will be researched.

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