DEVELOPMENT OF VALUE-ADDED PRODUCT GENERATION SOFTWARE FROM SATELLITE IMAGERY

Hae Yeoun Lee, Wonkyu Park*, S.A.B Kim*, Taejung Kim*, Taehun Yoon*,**
Dongseok Shin*, Young Ran Lee*, Heungkyu Lee**
* Satellite Technology Research Center, ** Department of Computer Science
Korea Advanced Institute of Science and Technology
373-1 Kusung-dong, Yusung-Gu, Taejon, 305-701, Korea
Tel) +82-42-869 8634, Fax) +82-42-861 0064, Email) (hytoiy|wpark)@satrec.kaist.ac.kr

ABSTRACT

Satellite images without value-added processing may be nothing but artistic painting. That is in order to benefit from satellite images acquired from money-drinking satellites, we should utilize the paramount information in scientific world and practical life that can be extracted from image. Hence, the Satellite Technology Research Center has developed a integrated software called "Valadd-Pro". In this paper, the main components of the Valadd-Pro are briefly introduced, its value-added product are compared with PCI® commercial software. Based on the results, the performance of the Valadd-Pro is superior to that of PCI® on 6000x6000 SPOT panchromatic images.

1. INTRODUCTION

As the satellite technology advances, the resolution of satellite images increases, and it is becoming easier to get satellite images in hand. However, satellite images without value-added processing may be nothing but artistic painting. That is, in order to benefit from satellite images, we should extract and utilize the paramount information in scientific area and practical life that can be extracted from satellite images.

Based on these requirements, the Satellite Technology Research Center (SaTReC) has developed an integrated software package called "Valadd-Pro (VALue ADDed PROduct generation software)", for EOC images of KOMPSAT-1.

The main components of the Valadd-Pro are 1) Digital Elevation Model Generation, 2) Precise Geometric Correction, and 3) Ortho-rectification. The Valadd-Pro employed a Kalman-filter-based satellite orbit estimator for precise geometric correction, and for the ortho-rectification, a smart backward transform was employed. The DEM extraction component is the core component in the Valadd-Pro. By designing the stereo matching modules based on the geometry of the satellite and intelligent interpolation scheme, the error and extraction time of DEMs are drastically minimized.

The Introduction to the Valadd-Pro is described in section 2. In section 3, 4 and 5, the precise geometric correction, the Digital Elevation Model extraction, the ortho-rectification components of the Valadd-Pro, respectively, are explained briefly. In Section 6, the performance of the Valadd-Pro on 6000x6000 SPOT panchromatic images is summarized.

2. VALUE-ADDED PRODUCT GENERATION SOFTWARE

The Valadd-Pro (VALue ADDed PROduct generation software) is an integrated software package that generates value-added product from satellite images. Considering the system performance, the Valadd-Pro is developed on the IRIX operating systems using C++ language.

The Valadd-Pro is composed of a number of software components. Main components are listed below.

- Graphical User Interface components
- SPIM (SPOT image format), HIPS, GeoTiff and RAW format image I/O components
- Histogram modification, zoom in/out components
- Digital Elevation Model extraction components from stereo satellite images
- Precise geometric correction components
- Ortho-rectification components
- Map projection components

One of the key issues of software is convenience. Therefore, the Valadd-Pro includes the graphical user interface as shown in figure 1. Also, for the fast and true color display, the software utilized OpenGL® library. For the GUI design, the free software package called *fdesign* was used.

The Valadd-Pro can support frequently used image formats such as SPIM, HIPS and RAW. The major components of the Valadd-Pro will be described in next sections.

3. PRECISE GEOMETRIC CORRECTION

In general, raw satellite images received from satellites have the distortions, due to the rotation of earth and the ellipsoidal shape, etc. Also, each pixel of satellite images does not have an information about the coordinate such as longitude and latitude. Hence, the ground coordinate should be assigned to each pixel, and the geometric distortion should be corrected [Shin and Lee, 1998].

In the Valadd-Pro, the precise geometric correction component consists of three major steps. 1) Ground control points acquisition. 2) Satellite sensor modeling, precise geometric correction and re-sampling. 3) Map projection.

Ground control points (GCPs) represent one point on image and its true coordinate on the ground. Although GCPs can be extracted from the vector map and so on, the GCPs gathered using GPS (Global Positioning System) is more accurate. Hence, the Valadd-pro provides an interface to read GCPs from file. GCPs can be input by clicking points on images and typing the ground coordinates in the GCP input window.

Precise geometric correction is composed of geometric correction and precision correction. In geometric correction, the information such as orbit and attitude acquired from satellite or the orbit elements given by NORAD is used to correct satellite images. However, because the orbit and attitude information include considerable errors, the method for accurate estimation of the velocity, position and attitude of the satellite from GCPs should be incorporated. This procedure is called the precision correction. In the Valadd-Pro, to estimate the position, speed and attitude of the satellite, Kalman-Filter was employed.

Because the shape of the earth is ellipse and the map is on plain, converting satellite image into plain is needed.

This conversion is called map projection. In the Valadd-Pro, TM and UTM that is most common are supported. Also, most of datum and ellipsoid models are supported. The performance of our precision correction algorithm can be found in [Shin *et al*, 1999].

4. DIGITAL ELEVATION MODEL EXTRACTION

The Digital Elevation Model (DEM) is a digital data in which each point represents latitude, longitude and height. The use of satellite images for DEM generation has the following advantages. 1) A scene covers larger area. 2) Satellite images are naturally digital data so that automation can be achieved. 3) Given many remote-sensing satellites being launched, it is becoming easier to get satellite images in hand. However, despite of the advantages stated above, generating DEMs from satellite images suffers from several shortcomings – accuracy, coverage and execution time. In the Valadd-Pro software, these problems can be overcome by stereo matching based on the epipolarity of linear push-broom sensors and intelligent interpolation scheme [Lee *et al*, 1999].

Extracting DEMs consists of five steps. 1) Acquisition of the ground control points (GCPs). 2) Satellite sensor modeling. 3) Stereo matching based on the epipolarity of linear push-broom sensors. 4) Automatic DEM editing. 5) Intelligent interpolation. Each step is crucial to the accuracy and coverage of a DEM. However, such steps used for images from aerial photos or still cameras are not adequate for generation of DEMs from satellite images, taken by linear push-broom camera. Mainly because; 1) Camera type is different. The position of camera changes line by line. 2) The noise due to haze and atmospheric distortion exists. 3) The intensities may be different if images are taken at different dates.

Therefore, in the Valadd-Pro software, we developed an accurate and robust DEM extraction module for satellite image pairs. By considering the geometry of linear push-broom sensors, we could increase the accuracy of a stereo matching algorithm [Lee *et al*, 1999]. Also, by automatic DEM editing and intelligent interpolation schemes, we could acquire accurate DEMs from the elevation data generated by a sensor model and stereo matching.

The techniques used to maximize the performance of stereo matching algorithm are as follows. In the case of the perspective images like airborne images, the epipolarity is represented as a linear equation. However, in linear push-broom type images, it is represented as a non-linear equation. Using such epipolarity, we can estimate the shape of the matching window and the local support region that help finding the accurate match points. If satellite image pairs have different viewing angles from each other, the size of a matching window on one scene differs from the size of that on the other scene that represents the same region. Thus, the patch should be set differently for each scene considering the viewing angles of satellite images. The simple, but robust zero-mean normalized cross correlation is used for similarity measure between two matching windows. By integrating the techniques stated above using intelligent region growing strategy, we could minimize the execution time and increase the accuracy of the stereo matching algorithm.

We have tested various interpolation methods and Gaussian interpolator showed the best performance [Kim *et al*, 1999]. Intelligent interpolation schemes are further developed: (1) center-of-gravity (COG) and empty-center-index (ECI) which quantify how evenly distributed interpolants are within an interpolation radius. (2) Hole segmentation scheme to discern whether or not interpolation should take place in empty holes in stereo matching results. (3) Second segmentation scheme for removing noise-like features. By these schemes, we could remove severe blunders and the erroneous topography.

5. ORTHO RECTIFICATION

In the Valadd-Pro, Ortho-rectification consists of three modules. 1) Sensor modeling. 2) Converting 3D earch coordinate to 2D image coordinate using sensor model. 3) Allocating intensities for each pixels,.

For the sensor modeling, the same model with DEM generation module was employed.

To convert 3D earth ground acquired from raw satellite image and DEM to 2D image coordinate, the Valadd-Pro employed a smart backward transform algorithm [Kim *et al*, 1999]. In this algorithm, first, we estimate the attitude of the satellite, and then we assume the position of the satellite is constant in order to calculate the satellite position. In this way, non-linear equations can be linearized. Solving the linear equations, two dimensional image coordinates can be efficiently calculated.

6. PERFORMANCE ANALYSIS OF VALADD-PRO SOFTWARE

One of the important stages of software development is quality assessment and validation. To analysis the performance of our Valadd-Pro software, we tested our software on SPOT stereo scenes by comparing with 100m resolution DTED by USGS and 60m resolution DEM generated from digitized contours produced by National Geography Institute. Also, to show the superior performance of our software, we compare with PCI® commercial software.

The results of comparison using Seoul-Kyunggi area, Boryung, ChoongNam area, etc are summarized in table 1. Figure 2 shows the Digital Elevation Model of Boryung, ChoongNam area extracted using the Valadd-Pro and PCI®. Figure 3 and Figure 4 shows 6000x6000 raw SPOT image, corrected image and its rectified images, respectively.

Based on the results, the Valadd-Pro software is superior to PCI® software in the accuracy and extraction time of DEM. Also, the accuracy of precision correction and ortho correction is rivalry to PCI® software.

7. CONCLUSION

The Valadd-Pro is an integrated software package to produce alue-added product using satellite images. Its main components are 1) precise geometric correction, 2) Digital Elevation Models (DEMs) Extraction, and 3) Ortho-rectification. Based on quality assessment and validation, the performance of the Vadadd-Pro is superior.

In near future, after KOMPSAT-1 is launched, the Valadd-Pro will be tested on real KOMPSAT-1 images and be validated. Based on current results, we expect to acquire satisfactory results.

ACKNOWLEDGEMENTS

The work presented here is supported by Ministry of Science and Technology of the Government of Korea (Contract No. NN28220)

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Table 1. Performance analysis (on SGI Octane 175MHz 1-CPU, 128Mbyte RAM)

	Valadd-Pro	PCI
Average DEM Extraction Time	30~40 (minutes)	2~3 (hours)
Average DEM Accuracy	20~30 (meter)	40~60 (meter)
Precision Correction Accuracy	15 (meter)	15 (meter)
Ortho Correction Accuracy	10 (meter)	10 (meter)

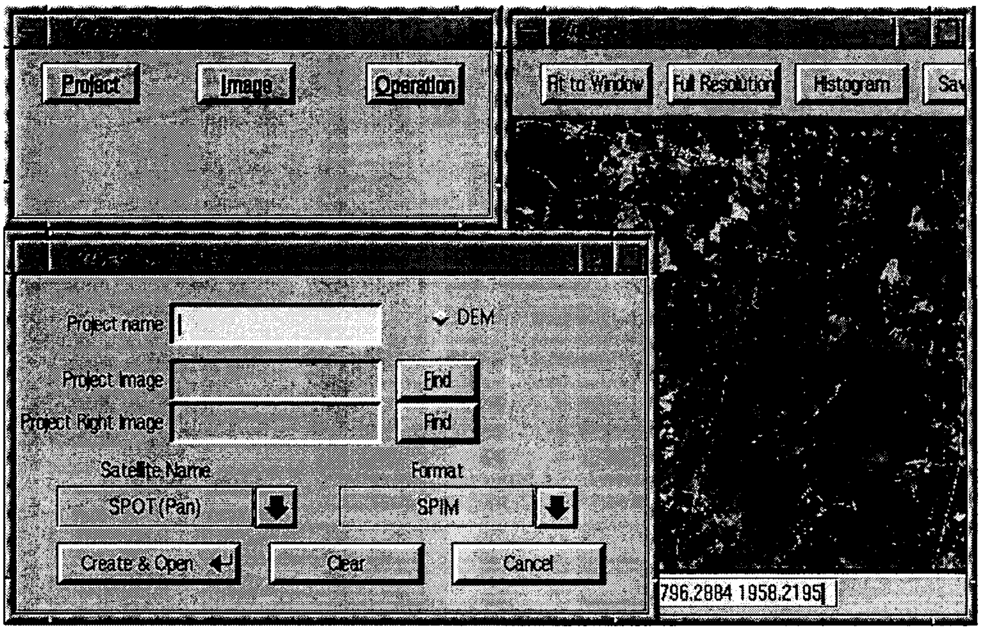

Figure 1. Valadd-Pro Software Interface

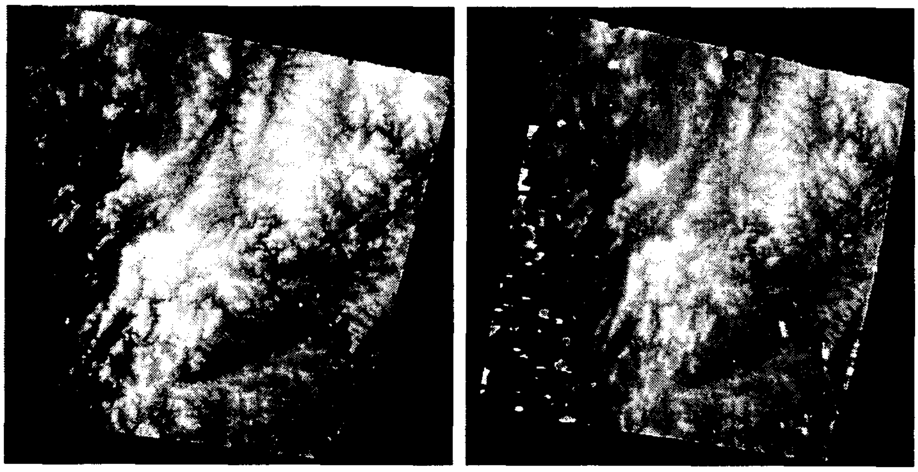

Figure 2. Extracted Digital Elevation Model using Valadd-Pro(Left) and PCI®(Right)

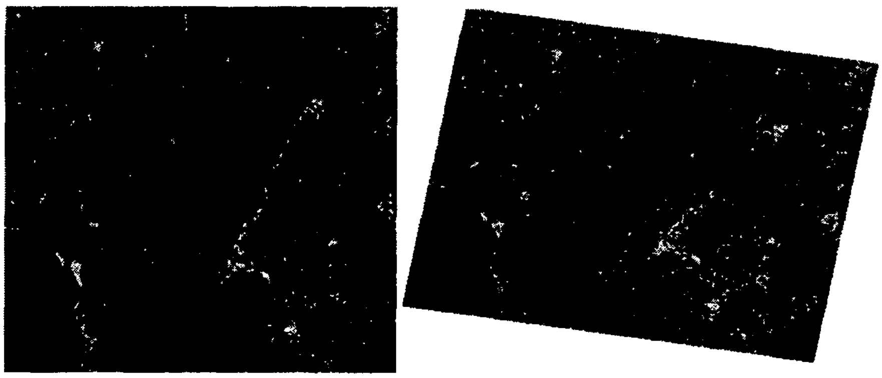

Figure 3. Boyung Raw image (Left) and corrected image (Right)

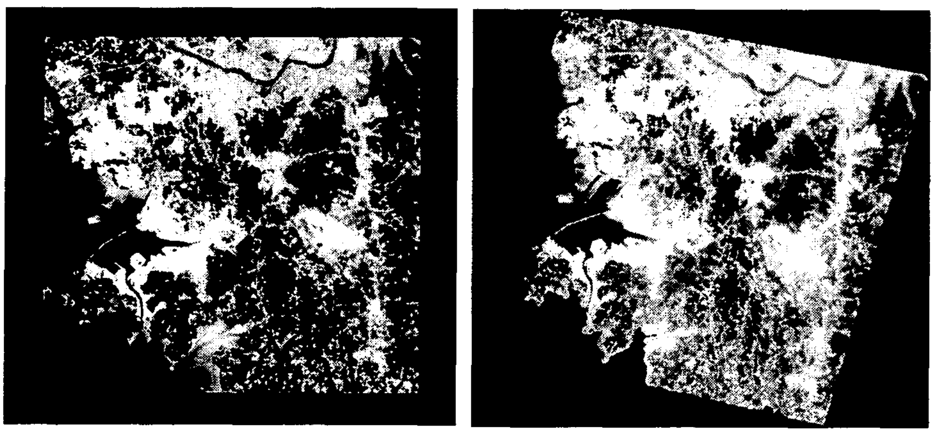

Figure 4. Seoul raw image(Left) and Ortho rectified image(Right)