AN EXPERIMENTAL STUDY ON THE GENERATION OF THEMATIC MAPS USING KOMPSAT-2 IMAGE DATA

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ABSTRACT: The mapping with the high resolution satellite image instead of aerial images is one of the most important applications in the field of remote sensing. The purpose of this study is to investigate the possibility for generating the thematic maps such as digital map, ortho-rectified image, and Digital Elevation Model (DEM) using the second KOra Multi-Purpose SATellite (KOMPSAT-2) stereo dataset. In conclusion, the preliminary experimental results are acceptable for generating the digital map of 1/5,000 scale based on the mapping regulation in Korea. The mapping accuracy of the horizontal and vertical direction was verified using GPS survey data. However, by interpretative measures, it is very difficult to extract all layers which are needed to generate the digital map of 1/5,000 scale. The accuracy of an ortho-rectified image and DEM, which both are generated from the KOMPSAT-2 stereo dataset, was also acceptable. This study verified that KOMPSAT-2 stereo dataset is useful to generate the thematic maps and related applications.

1. INTRODUCTION

Remote sensing can be considered as the identification or survey of objects by indirect means using naturally existing or artificially created force fields (Konecny, 2001). Earth Observation Satellite (EOS) with the very high resolution has been used for various civil applications. Especially, the mapping with the high resolution satellite image instead of aerial images is one of the most important applications in the field of remote sensing. The generation of high resolution imagery using previously-proven defense technology provides an interesting source of data for digital topographic mapping as well as thematic applications such as agriculture, forestry, and emergency response (Kaufmann and Sulzer 1997; Konecny, 2000). In order to fully realize the potential of high resolution satellite image in terms of the mapping and understand accuracy and uncertainty in terms of the products, various studies have been performed with high resolution satellite image. A theoretical analysis based on in-track and across-track stereo mapping techniques demonstrated that high resolution satellite image can be used for the generation and updating of national mapping products in the United States, only if strict photogrammetric processing is employed (Li, 1998). Based on this theoretical analysis, an evaluation of the potential accuracy of ground points has been performed using IKONOS stereo images simulated from aerial photos (Zhou and Li, 2000). The preliminary accuracy tests of IKONOS images were performed with precise Ground Control Point (GCP). The results demonstrated that accuracy is around 2–3 m and then confirmed that IKONOS images have a high potential for the mapping (Toutin and Cheng, 2000; Davies and Wang, 2001).
In recent years, there has been an increasing demand for improving the accuracy and reliability of EOS data (Lee, 2009). It is realized that satellite sensor model might be applied differently in accordance with platform’s attitude control scheme and accuracy due to the comparison of orbit-attitude model between SPOT and the second KORea Multi-Purpose SATellite (KOMPSAT-2) (Jeong and Kim, 2009). Geometric accuracy of the KOMPSAT-2 stereo images was analyzed according to the property of sensor modeling (Seo and Yang, 2009). Stereoscopic 3D modeling approach with KOMPSAT-2 image and Digital Elevation Model (DEM) generation from KOMPSAT-2 image were newly developed and compared to other commercial SWs (Tserennadmid and Kim, 2009; Rhee, Jeong, and Kim, 2009).

The KOMPSAT-2, which was successfully launched on July 28, 2006, has a capability to provide the pass-stereo images with 1m panchromatic image and 4m multi-spectral image from two different orbits. So it can be possible to use the topographic mapping as well as the thematic applications. In the case of the KOMPSAT-1, the possibility was investigated for the topographic mapping using the KOMPSAT-1 EOC stereo images (Jeong, 2001).

The purpose of this study is to investigate the possibility for generating the thematic maps such as digital map, ortho-rectified image, and DEM using the KOMPSAT-2 stereo images. The regulations with the related the mapping are defined by The National Geographic Information Institute (NGII) in Korea, with the consequence that mapping test using the KOMPSAT-2 stereo images should be performed under the related regulations. This paper summarized the results of preliminary mapping test using KOMPSAT-2 stereo images.

2. KOMPSAT PROGRAM

Space development of Korea is now driven by the National Space Development Plan which was prepared in 1995. Peaceful application of space is the final objective of space development in Korea. Korea Aerospace Research Institute (KARI) is playing a key role in the satellite area as a hub of the nation’s space development.

The KOMPSAT-1 and 2 programs accomplished the goal of developing a payload and a bus for Low Earth Orbit (LEO) satellites for the purpose of acquiring high level satellite technology which is essential to meet the national spacecraft requirements as well as to obtain global market share.

The KOMPSAT-1 has operated remarkably well for 8 years in its sun-synchronous orbit since after the successful launch on December 21, 1999. The KOMPSAT-1 accommodates three instruments; i.e., an Electro-Optical Camera (EOC), an Ocean Scanning Multi-spectral Imager (OSMI), and a Space Physics Sensor (SPS), for the mission of cartography, global biological oceanography, and space environmental monitoring, respectively. The mission operating of KOMPSAT-1 was closed in February, 2008. The KOMPSAT-1 data have been used in the various research and application areas of remote sensing and produced the useful results.

KOMPSAT-2 has been operating remarkably well since it was launched on July 28, 2006. The MSC, the on-board camera of KOMPSAT-2, provides a 1m panchromatic image and 4m multi-spectral image with four bands. The standard product for data user is Level 1R and Level 1G which are radiometrically and geometrically corrected, respectively. The KOMPSAT-2 has a capability to provide the pass-stereo images from two different orbits so that it may be possible to use in the field of mapping areas and related application areas.

Subsequent to the KOMPSAT-2, KARI already took a follow-up the KOMPSAT program. The KOMPSAT-5, 3, and 3A are now developing to meet the nation’s needs in terms of the high resolution Synthetic Aperture Rader (SAR), Electro-Optical (EO), and InfraRed (IR) images for the mission of disaster monitoring, Geographical Information System (GIS), and environmental monitoring. In addition, there will be the follow-on series of the KOMPSAT program.
3. EXPERIMENT AND RESULTS

3.1 Study Areas and Materials

The study areas were Daejeon and Damyang which are located in the middle and southern of South Korea, respectively. Topographical characteristics between both areas are somewhat different. Daejeon is one of the metropolitan cities in Korea. Damyang, by contrast, is located in rural area. Table 1 summarized the properties of used image data in this study.

<table>
<thead>
<tr>
<th>Items</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>KOMPSAT-2</td>
</tr>
<tr>
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<td>MSC</td>
</tr>
<tr>
<td>Spectral band</td>
<td>PAN, MS</td>
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<tr>
<td>Product level</td>
<td>Level 1R</td>
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<tr>
<td>Image size</td>
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</tr>
<tr>
<td>Location of area</td>
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</tr>
<tr>
<td>Date of acquisition</td>
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<tr>
<td>Tilting angle</td>
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<tr>
<td></td>
<td>-1.037°(pitch)</td>
</tr>
<tr>
<td>Angle of incidence</td>
<td>18.742347°</td>
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<tr>
<td>Location of area</td>
<td>Damyang</td>
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<tr>
<td>Date of acquisition</td>
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<tr>
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<tr>
<td></td>
<td>0.467°(pitch)</td>
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<tr>
<td>Angle of incidence</td>
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<td>Browser image</td>
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</table>

The accuracy of GCP data is the most important factor in the pre- and post-processing step with any high resolution satellite image. So the requirement of GCP accuracy in this study is very strict for evaluating the mapping accuracy of KOMPSAT-2 stereo images. In order to use a control point and check point, 18 points were surveyed by Differential Accuracy of Global Positioning System (DGPS). An accuracy of GPS survey result is less than 5cm (CE90). The image coordinate accuracy is about one-third less than original pixel resolution. Bi-cubic interpolation resampling method in the ERDAS SW was used to extract directly a precise point from the KOMPSAT-2 PAN image.

3.2 Sensor Modeling

Most of the high resolution satellite only provides the Rational Polynomial Coefficient (RPC), while the KOMPSAT-2 offers both RPC and ancillary data such as the ephemeris data to data user for various researches and applications. The RPC for the KOMPSAT-2 MSC is generated from the result of the KOMPSAT-2 direct sensor model using the Rational Function Model (RFM). The KOMPSAT-2 RFM is forward method which can be calculated from ground coordinate (Latitude, Longitude, Height) to image coordinate (Column, Row). A least-squares approach is used to determine the each polynomial coefficient from a three-dimensional ground coordinates which were generated using the KOMPSAT-2 camera model. The basic relationship of the KOMPSAT-2 camera model that describes the ground coordinates in term of sensor coordinates is realized by the co-linearity condition in which the KOMPSAT-2 MSC perspective center, an image point and the corresponding ground point are assumed to be on one straight line (KARI, 2008). The RFM is as follow;
where,

\[ r_n = \frac{\rho_1(X_n, Y_n, Z_n)}{\rho_2(X_n, Y_n, Z_n)} \]
\[ c_n = \frac{\rho_3(X_n, Y_n, Z_n)}{\rho_4(X_n, Y_n, Z_n)} \]

where,

\( r_n, c_n \): the normalized row and column index of pixels in image
\( X_n, Y_n, Z_n \): the normalized coordinate values of object points in ground space (Longitude, Latitude, Height)
\( \rho_1, \rho_2, \rho_3, \rho_4 \): the polynomial coefficients

In general, the accuracy of RPC is almost the same as the satellite sensor’s accuracy because it is generated using the measured ancillary data from the satellite sensor. It means that the accuracy of RPC should be refined using GCPs and additional model for improving the accuracy of three-dimensional ground coordinates. In this study, the function of Rational Function Refinement in the ERDAS LPS was utilized for determining a three-dimensional ground coordinates. The 1st order polynomial equation was used for the refinement. The results represent that the Root Mean Square Error (RMSE) of sensor modeling with control points and check points was less than 1m. However, vertical error in Damyang area was a little bit high than 1m.

3.3 Experiment of Map Generation

Traditionally, topographic maps have been created with analytical stereo plotters that can digitize the surface features and extract the elevation profiles manually from stereo aerial photograph pairs. Recently, with advancing technology, the Digital Photogrammetric Workstation (DPW) based on the high resolution satellite image is a relatively new technology that is currently being utilized by a cartographer with regard to the topographic mapping, land-use/cover mapping, and etc. The ERDAS LPS was utilized as the photogrammetric system. Figure 1 represents the mapping procedure in this study. The regulations related with the map generation are defined by The National Geographic Information Institute (NGII) in Korea, with the consequence that data processing was performed under the related regulations.

Correction of satellite image for terrain displacement requires a DEM, consisting of a spatial grid of elevation values. After epipolar matching, elevation profiles were digitized and extracted from stereo photograph pairs for generating the grid DEM of 5m by 5m and then it was used to generate
an ortho-rectified image. Figure 2 represents the final mapping results. Each map was generated
the scale of 1/5,000 level from the KOMPSAT-2 stereo images.

Figure 2, The mapping (1/5,000) results (top: Daejeon, bottom: Damyang).

3.4 Accuracy Assessment

The quantitative and qualitative analyses were conducted for evaluating the accuracy of generated
maps using the KOMPSAT-2 stereo images. The baseline of an accuracy assessment is the NGII’s
regulations. Above all, the coordinates between a check point from GPS survey data and a three-
dimensional point on the stereo plotter were compared for evaluating the modeling accuracy.
Figure 3 shows the difference between each point. The accuracy was less than 1.5 m and 1m for
the horizontal and vertical direction. The accuracy of digital stereo plotting was also less than 1m
in both experimental areas. In geometric accuracy terms, these results are acceptable for
generating the digital map of 1/5,000 scale because the guideline of geometric accuracy in the
regulation is 3.5m and 1.67m for horizontal and vertical direction. However, by interpretative
measures, it was very difficult to extract all layers which are needed to generate the digital map of
1/5,000 scale.

Figure 3, The difference between surveying point and 3D point on the stereo plotter.

The accuracy of the grid DEM of 5m by 5m was evaluated with a vertex of contour, which was the
digitized elevation profile. The difference between the generated DEM and a vertex of contour was less than 1m. It was acceptable under the regulation for the grid DEM of 5m by 5m standard. Meanwhile, the ortho-rectified images of Daejeon and Damyang areas were verified using GPS survey data. The accuracy of both ortho-rectified images was within 1.2 m. The regulation defines a 5m for the ortho-rectified image of 1/5,000 scale.

4. SUMMARY

In this study, we investigated the possibility of map generation using the KOMPSAT-2 stereo images. The mapping with the KOMPSAT-2 stereo images was performed by the related regulation in Korea. In conclusion, the requirements of sensor modeling and digital stereo plotting for the scale of 1/5,000 were satisfied with the NGII’s regulations. The accuracy of ortho-rectified image and extracted DEM was also less than the requirement of the NGII’s regulations for the scale of 1/5,000. However, by interpretative measures, we realized that it is difficult to extract all layers which are needed to generate the digital map of 1/5,000 scale. Nevertheless, the results indicated that the KOMPSAT-2 would have a high potential for the mapping the new thematic map and improving the existing thematic map.

REFERENCES


