Article

GeoSoluciones

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The successful operation of the Kompsat-3 satellite provides another sub-meter resolution satellite imagery alternative. With the panchromatic sensor at 0.7m resolution and the multispectral sensor at 2.8m resolution, the data can be used in various applications. This article describes the steps required to generate high accuracy orthos and mosaic of a block of Kompsat-3 data with minimal ground control points.

Kompsat-3 Satellite

Orthorectification and Mosaicking

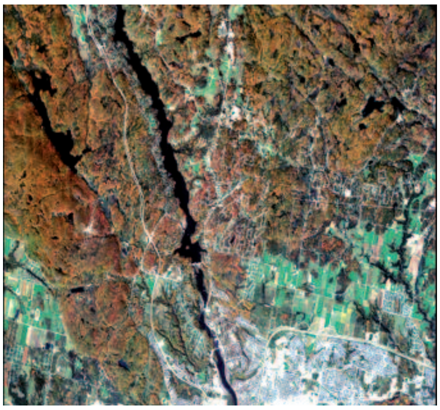

Figure 1A: Kompsat-3 1R top scene

Figure 1B: Kompsat-3 1R middle scene

Figure 1C: Kompsat-3 1R bottom scene

In 1995 South Korea started the KOMPSAT (Korea Multi-Purpose Satellite) program to nurture its national Earth-imaging industry and supply services for remote-sensing applications. Since then, Kompsat-1 with a resolution of 6.6m panchromatic was launched on December 22, 1999, and Kompsat-2 with a resolution of 1m panchromatic and 4m multispectral was launched on July 28, 2006.

On May 18, 2012, Kompsat-3, the first submeter optical satellite developed by Korean observation mission of KARI (Korea Aerospace Research Institute), was launched from Japan's Tanegashima Space Center. The mission started in 2004 and was funded by MEST (Ministry of Education, Science and Technology). The objective is to provide observation continuity from the Kompsat-1 and Kompsat-2 missions to meet the nation's needs for high-resolution optical imagery required for GIS (Geographical Information Systems) and other environmental, agricultural and oceanographic monitoring applications. Orbiting our planet at 685 km, Kompsat-3 collects 14-bit 70cm panchromatic and 2.8m 4-band multispectral (i.e., blue, green, red and near-infrared/NIR) imagery with various imaging modes including single pass stereo. Kompsat-3 has a unique local access time of 1:30 PM. The imaging capability in the afternoon will increase the chance of acquiring cloud-free images over specific targets for the end users. With the Kompsat-3 program, KARI has achieved substantial technical improvements compared to previous programs in terms of resolution and agility. Satrec Initiative, a leading solution provider for Earth Observation missions, is the worldwide marketing and sales representative of Kompsat data.

In this article we will use a block of Kompsat-3 1R images as an example to describe the steps required to generate a high accuracy ortho-mosaics with minimal ground control points (GCPs). The steps are (1) stitching of Kompsat-3 level 1R data, (2) pansharpening, (3) geometric correction and (4) orthorectification and automatic mosaicking.

Kompsat-3 data

Kompsat-3 data is distributed in TIFF format. The products are available with two different levels of processing applied: 1R and 1G. Level 1R is radiometrically corrected only while level 1G is radiometrically corrected as well as geometrically corrected with band to band registration. According to the Kompsat-3 user manual, the horizontal accuracy without using GCPs for Level 1R ranges from 70m to 285m CE90, and 70m CE90 for level 1G product. Rational Polynomial

Coefficients (RPCs) are provided with each data set.
An area surrounding the city of Ottawa, Canada covering about 2800 sq. km was chosen for this study. Although the level 1G product is a good choice because band to band registration has been applied, the level 1R product is preferable for multi-scene areas because it is possible for the user to stitch the overlapping scenes acquired along the same path and same day back into a single continuous strip. Four strips of level 1R Kompsat-3 data with each strip consisting of three overlapping scenes acquired in November, 2013 were provided by Satrec Initiative. The incidence angles range from 10 degrees to 31 degrees. PCI Geomatica software was used to perform the entire process.

Stitching of level 1R data

Most satellite data acquired along the same path and same day are distributed as separate scenes, with overlaps between adjacent scenes. There are two disadvantages of correcting each scene separately. The first disadvantage is that each scene requires a minimum number of GCPs and/or tie points (TPs) in order to compute the geometric model. The minimum number will be increased by N times where there is N number of scenes. This is a problem if there are a limited number of accurate GCPs available, or if GCPs are not available for all scenes. The second problem is discontinuity during mosaicking. If each scene is corrected separately, the orthos will need to be mosaicked together. Any errors in the orthos (due to the geometric modeling, inaccurate GCPs/TPs or digital elevation model) will cause geometric discontinuities between the orthos. Therefore, it is advantageous to first stitch all the overlapping scenes collected along the same path into a single continuous strip. The stitched strip can be treated as a single scene which requires a minimum number of GCPs/TPs to compute the geometric model. Hence, the number of GCPs/TPs required for the entire strip is greatly reduced. Moreover, mosaicking along-strip is no longer required because the final ortho is still a single, continuous strip.

PCI Geomatica software has an automated tool which determines the overlapping areas and stitches the separate scenes into a continuous strip. In addition, a new RPC will be generated for the stitched strip so the user can continue to the next step using the newly generated RPC. In this example the total number of data after stitching is reduced from twelve individual scenes to four continuous strips. Figure 1a, 1b and 1c show the top, middle and bottom scenes acquired along the same path with overlaps, respectively. Figure 2 shows the stitched continuous strip.

Pansharpening of level 1R data

Similar to most high resolution satellites, Kompsat-3 panchromatic and multispectral data provide the opportunity to create multispectral pansharpened images. In the case of Kompsat-3 creation of 0.7m pansharpened imagery is possible. It is always preferable to perform the pansharpening process before geometric correction where an orthorectified pansharpened image is desired, and this method works for most areas with gentle terrain. Performing

Figure 2: Kompsat-3 1R stitched scene

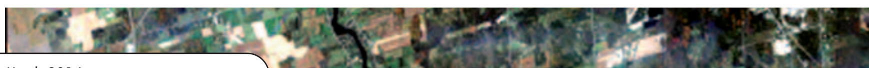

Figure 3: Kompsat-3 1R Pansharpened image

pan-sharpening after geometric correction of the separate panchromatic and multispectral data often results in small misalignments between the orthorectified data due to accuracy and precision limitations in the GCPs/TPs and DEMs used in the orthorectification process.

While level 1G data has band to band registration applied, level 1R panchromatic and multispectral data are not perfectly aligned. Alignment between the panchromatic and multispectral data is a prerequisite for pansharpening. Hence, a process must be applied to align the panchromatic and multispectral data before pansharpening. This process can be applied to a single scene or a stitched strip. An automated process within PCI Geomatica software was developed for this purpose. The software collects tie points automatically between the panchromatic and multispectral images to compute the geometric models relating the two images. The multispectral image is then resampled into a new image such that it is perfectly aligned with the panchromatic image. This process can be applied to any satellite images with similar traits. The PCI pansharpening program was then used to perform the pansharpening. The algorithm is based on least squares approximation of the grey level value relationship between the original multispectral and panchromatic imagery, and the pansharpened image bands for the best possible color representation. Figure 3 shows an example of the pansharpened image.

Geometric Correction

In order to leverage Kompsat-3 images for applications such as GIS, it is necessary to orthorectify the images. A geometric model, GCPs and digital elevation model (DEM) are required. The Rational Function Method (RFM) has been the most popular geometric correction method for orthorectifying high resolution images. This method uses the RPCs provided with the satellite data to perform orthorectification. More details about the RFM can be found in the paper written by Grodecki and Dial (2003). Since the Kompsat-3 1R product is provided with RPCs, RFM can be used to orthorectify the data.

The latest version of PCI Geomatics' OrthoEngine software was used for this testing. This software supports reading of the data, manual or automatic GCP/tie point (TP) collection, geometric modeling of different satellites using RFM or Toutin's rigorous model, automatic DEM generation and editing, orthorectification, and both manual and automatic mosaicking. Since biases or errors still exist in the RPCs, the results can be post-processed with a polynomial adjustment and several accurate GCPs. One of the purposes of this paper is to determine which polynomial order of RPC adjustment is required for Kompsat-3 data. 0 and 1st order polynomial adjustment require a minimum of 1 and 3 GCPs, respectively. 0 order polynomial adjustment is preferable because the GCPs can be collected anywhere on the image. 1st order polynomial adjustment requires the GCPs to be collected uniformly on the image, and covering the entire image extents.

High accuracy control points were collected from 20cm aerial mosaic and 10m resolution DEM. Table 1 shows the results using 0 and 1st order polynomial RPC adjustment with different numbers of GCPs and check points. The average horizontal error is approximately 30m in X and 10m in Y when no GCPs are used. Using 1st order polynomial adjustment gives better result than using 0 order adjustment, with root mean square (RMS) error within 1m.

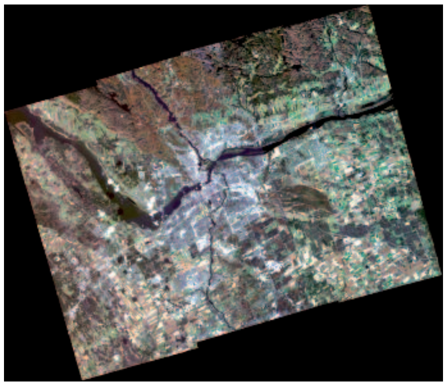

Figure 4: Kompsat-3 mosaicked image

Orthorectification and Mosaicking

After computing the geometric models, the final step is to generate orthorectified strips using a DEM and then mosaic together into a color-balanced mosaic image. The orthorectification process took approximately 10 minutes per strip of file size about15 Gigabytes each. Mosaicking is a time consuming and difficult task if it is to be performed manually. The PCI Geomatica software has a color balancing and mosaicking method which allows the process to be completed automatically. The mosaicked cutlines were generated automatically using an algorithm that finds the optimum path based on the minimum differences. Figure 4 shows the final mosaic of the Kompsat-3 orthos. The mosaic file has a size of approximately 36 Gigabytes and the process was completed within 2 hours.

Summary

It is possible to generate Kompsat-3 0.7m pansharpened ortho- mosaics using a block of data with minimal GCPs. The steps required are stitching, pansharpening, geometric correction, orthorectification and automatic mosaicking. It is possible to achieve sub-meter accuracy RMS using the RPC's provided together with accurate GCPs and a 1st order polynomial adjustment. The author would like to thank Indyware and Satrec Initiative for providing the test data.

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No.of GCPs	No. of Check Points	RPC Adjustment Order	RMS Error/Res (m)		Maximum Error/Res (m)	
			X	Y	X	Y
14	0	0	1.3	1.6	1.6	3.2
14	0	1	0.8	0.8	1.2	1.5
9	5	0	1.8	1.5	3.9	1.8
9	5	1	1.0	0.9	1.6	1.3

Table 1: Error report using 0 and 1st RPC polynomial adjustment