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.

By Philip Cheng

Kompsat-3 Satellite
Orthorectification and Mosaicking

In 1995 South Korea started the KOMP-SAT (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 sub-meter 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. 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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
pan-sharpening after geometric correction of
the separate panchromatic and multispectral
data often results in small misalignments
between the orthorectified data due to accu-
rously and precision limitations in the
GCPs/TPs and DEMs used in the orthorectifi-
cation process.

While level 1G data has band to band reg-
istration applied, level 1R panchromatic and
multispectral data are not perfectly aligned.
Alignment between the panchromatic and
multispectral data is a prerequisite for pan-
sharpening. Hence, a process must be ap-
plicated to align the panchromatic and multi-
spectral 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 geom-
etric models relating the two images. The multi-
spectral 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 approxi-
mation of the grey level value relationship
between the original multispectral and
panchromatic imagery, and the pansharpen-
ed 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 per-
form 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 Geomatica’s
OrthoEngine software was used for this test-
ing. This software supports reading of the
data, manual or automatic GCP/tie point
(TP) collection, geometric modeling of differ-
ent satellites using RFM or Toutin’s rigorous
model, automatic DEM generation and edit-
ing, 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 adjust-
ment 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 mini-
um 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 resolu-
tion 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 poly-
omial adjustment gives better result than using
0 order adjustment, with root mean square
(RMS) error within 1m.

<table>
<thead>
<tr>
<th>No. of GCPs</th>
<th>No. of Check Points</th>
<th>RPC Adjustment Order</th>
<th>RMS Error/Res (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0</td>
<td>0</td>
<td>X 1.3 Y 1.6</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>1</td>
<td>X 0.8 Y 0.8</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>0</td>
<td>X 1.8 Y 1.5</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>1</td>
<td>X 1.0 Y 0.9</td>
</tr>
</tbody>
</table>

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

**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 approxi-
mately 10 minutes per strip of file size about1.5
Gigabytes each. Mosaicking is a time con-
suming and difficult task if it is to be per-
formed manually. The PCI Geomatica soft-
ware has a color balancing and mosaicking
method which allows the process to be com-
pleted automatically. The mosaicked cutlines
were generated automatically using an algo-
then that finds the optimum path based on
the minimum differences. Figure 4 shows the
final mosaic of the Kompsat-3 ortho. 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, geo-
metric 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
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