Pan-sharpening and Geometric Correction

WorldView-2 Satellite

The successful operation of DigitalGlobe WorldView-2 has created another milestone for high-resolution satellites. The high-resolution panchromatic sensor, the four previously unavailable multispectral bands at 1.8 meter resolution and WorldView-2's advanced geopositional capability have provided a range of benefits to different applications.

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On October 8, 2009, WorldView-2 joined its sister satellites, WorldView-1 and QuickBird, in orbit. WorldView-2 is a remote-sensing satellite principally used to capture high-resolution images of the earth. The images provided by the satellite can be used for applications such as mapping, land planning, disaster relief, exploration, defense and intelligence, visualization and simulation of environments, and classification.

WorldView-2 was designed and developed by Ball Aerospace & Technologies Corp, US, and is operated by DigitalGlobe Corporate (DigitalGlobe). The satellite can swing rapidly from one target to another, allowing broad images of many targets. The satellite was launched into orbit through the Ball commercial platform (BCP) 5000 spacecraft bus on the piggyback of Boeing Delta II on 8 October 2009. Worldview-2 can operate at an altitude of 770km with an inclination of 97.2° for a maximum orbital period of 100 minutes. Worldview-2 is the third satellite in orbit in DigitalGlobe's constellation, and joins its forerunners Worldview-1 (launched in 2007) and QuickBird (launched in 2001). The satellite has been designed to have a lifespan of 7.5 years.

WorldView-2's large-area collection capabilities and rapid retargeting are two important features of the satellite. Enabled by the combination of the satellite's 770km orbiting altitude, its state-of-the-art Control Moment Gyroscopes (CMGs) and bi-directional push-broom sensors, WorldView-2's enhanced agility and bi-directional scanning allows for the collection of over 10,000 sq km in a single overhead pass, plus efficient in-track stereo collections of over 5,000 sq km. WorldView-2's advanced geopositional technology provides significant improvements in accuracy. The accuracy specification has been tightened to 6.5m CE90 directly right off the satellite, meaning no processing, no elevation model and no ground control, and measured accuracy is expected to be approximately 4m CE90.

WorldView-2 panchromatic resolution is 46cm and multispectral resolution is 1.8m. Distribution and use of imagery better than 0.50m GSD pan and 2.0m GSD multispectral is subject to prior approval by the U.S. Government. As the first high-resolution commercial satellite to provide eight spectral bands, WorldView-2 offers imagery with a high degree of detail, unlocking a finer level of analytical discernment that enables improved decision-making. In addition to industry-standard blue, green, red and near-infrared, WorldView-2 includes four previously unavailable bands, collected at 1.8m resolution: coastal blue, yellow, red edge and near-infrared 2. These bands offer a range of benefits to analysts, who

Figure 1a: Panchromatic image of Phoenix, USA

Figure 1b: Multispectral image of Phoenix, USA

Figure 1c: Pan-sharpened image of Phoenix, USA

will be able to identify a broader range of classification, (e.g. more varieties of vegetation or water-penetrated objects), to extract more features (e.g. cotton-based camouflage from natural ground cover), to view a truer representation of colors that match natural human vision, and to track coastal changes and infractions.
This article will examine different areas of the WorldView-2 satellite image data.
Firstly, we will test pan-sharpening using WorldView-2 panchromatic and multispectral data. Secondly, the geometric correction method and accuracy of the WorldView-2 data will be examined. Given that the WorldView-2 is equipped with state-of-the-art geo-location accuracy, it would be useful to find out the geometric model accuracy of the WorldView-2 data with and without ground control points (GCPs). Lastly, we will test the geometric correction of WorldView-2 data using Google Earth as a source of GCPs.

WorldView-2 Data

Similar to the QuickBird and WorldView-1 satellite data, WorldView-2 data is distributed in five different levels, i.e., Basic 1B, Basic Stereo Pairs, Standard 2A, Ortho-Ready Standard (OR2A), and Orthorectified. For custom orthorectification the Standard 2A and Orthorectified products are not recommended. Standard 2A product is not recommended because of the coarse DEM correction already applied to the image data.
Basic Imagery products are the least processed of the WorldView-2 imagery products. Each strip in a Basic Imagery order is processed individually and therefore, multi-strip Basic Imagery products are not mosaicked. Basic Imagery products are radiometrically corrected and sensor corrected, but not projected to a plane using a map projection or datum. The sensor correction blends all pixels from all detectors into the synthetic array to form a single image. The resulting GSD varies over the entire product because the attitude and ephemeris slowly change during the imaging process. Basic Stereo Pairs are supplied as two full scenes with overlap, designed for the creation of digital elevation models (DEMs) and derived GCPs.
OR2A has no topographic relief applied, making it suitable for custom orthorectification. OR2A is projected to an average elevation, either calculated from a terrain elevation model or supplied by the customer. It can be ordered from a minimum of 25 km2 from the library, or from 64 km2 for new tasking.
For this article three sets of WorldView-2 OR2A data were obtained from DigitalGlobe. The data include Morrison and Phoenix, USA and Beijing, China. OR2A products are recommended for geometric correction because the panchromatic and multispectral data are resampled to exactly the same geographic extents; hence, it is possible to perform pan-sharpening of the data before geometric correction if a pan-sharpened orthorectified image is desired. This method works for most areas with gentle terrain. Performing pan-sharpening after geometric correction of the panchromatic and multispectral data separately often requires the need to deal with small misalignments between orthorectified panchromatic and multispectral data due to the accuracy of GCPs and DEM used in the orthorectification process

Pan-sharpening

The availability of a WorldView-2 0.5m panchromatic band, in conjunction with the 2m multispectral bands, provides the opportunity to create a 0.5m multispectral pan-sharpened image by fusing these images. Based on the thorough study and analysis of existing pan-sharpening algorithms and their fusion effects, an automatic pan-sharpening algorithm has been developed by Dr. Yun Zhang at the University of New Brunswick, in New Brunswick, Canada. This technique solved the two major problems in pan-sharpening – color distortion and operator dependency. A method based on least squares was employed for a best approximation of the grey level value relationship between the original multispectral, panchromatic, and the pan-sharpened image bands for a best color representation. A statistical approach was applied to the pan-sharpening process for standardizing and automating the pan-sharpening process. This new algorithm is commercially available within the PCI Geomatics software.

In figures 1a, 1b and 1c, examples of the WorldView-2 panchromatic, multispectral and pan-sharpened images of Phoenix, U.S.A., are provided Figures 2a, 2b and 2c show examples of the WorldView-2 panchromatic, multispectral and pan-sharpened images of Beijing, China.

Figure 2a: Panchromatic image of Beijing, China

Figure 2b: Multispectral image of Beijing, China

Geometric Correction Method and Software

In order to leverage the WorldView-2 images for applications such as GIS, it is necessary to orthorectify the imagery. In order to perform the orthorectification process, a geometric model, GCPs and DEMs are required. The Rational Polynomial Coefficient (RPC) model has been the most popular method in orthorectifying high-resolution images because it allows the user to correct an image using no GCP or a few GCPs. More details about the RPC model can be found in the paper written by Grodecki and Dial (Block Adjustment of High-Resolution Satellite Images Described by Rational Functions - PE &RS January, 2003).

For the purposes of testing, the latest version of PCI Geomatics' OrthoEngine software was used. This software supports reading of the raw data, manual or automatic GCP/tie point (TP) collection, geometric modeling of different satellites using Toutin's rigorous model or the RPC model, automatic DEM generation and editing, orthorectification, and either manual or automatic mosaicking. OrthoEngine's RPC model is based on the block adjustment method developed by Grodecki and Dial and was certified by Space Imaging (http://www.pcigeomatics.com/support_center/tech_papers/rpc_pci_cert.pdf).

Morrison Test Results using Survey Points

A total of 13 survey-independent check points (ICPs) with sub-meter accuracy were collected from six OR2A datasets. A zero order polynomial RPC adjustment was used. The ICP root mean square (RMS) errors were 2.6m in X and 1.3m in Y with maximum errors of 5.7m in X and 3.1m in Y. When one GCP was collected from each image, the ICP RMS errors were 0.7m in X and 1.0m in Y with maximum errors of 1.4m in X and 1.4m in Y. Therefore, it is possible to achieve within 1m RMS accuracy with only one accurate GCP per image using the RPC method. Figure 3 shows an orthorectified image of the Morrison dataset overlaid with Google Earth.

Phoenix Test Results using Google Earth

In recent years, the launch of Google Earth has provided users with reference imagery which can be used as a source of GCPs anywhere in the world. For most cities high-resolution data such as GeoEye, QuickBird or airphotos are available. By checking the Google Earth imagery with known survey points, it was found that the accuracy of the Google Earth imagery is approximately within 2m in X, Y and Z directions in most cities in North America. Accuracy outside of North America has not been checked at this time. To test using Google Earth imagery as a source of GCPs, the Phoenix dataset was used. A total of eight Phoenix WorldView-2 OR2A data was used. Forty ICPs were collected from the Google Earth imagery and the RMS errors were 0.9m in X and 0.7m in Y with maximum errors of 1.8m in X and 1.6m in Y. When using one GCP per image, the ICP RMS errors are 1.2m in X and 0.7m in Y with maximum errors of 2.2m in X and 1.6m in Y. Figure 4 shows the pan-sharpened orthorectified Phoenix image overlaid with Google Earth. Therefore, it can be concluded that it is possible to use Google Earth as reference imagery to collect GCPs for near-nadir acquisition angle imagery. For off-nadir acquisition angle imagery, more accurate GCPs should be used.

Figure 3: Pan-sharpened orthorectified Morrison image overlaid with Google Earth

Figure 4: Pan-sharpened Phoenix image overlaid with Google Earth

Figure 5: Beijing pan-sharpened ortho image overlaid with Google Earth

Figure 2c: Pan-sharpened image of Beijing, China

Beijing Test Results using Google Earth

A similar test was performed on an OR2A data set of Beijing, China. Five points were collected using Google Earth imagery as the reference image. The ICP RMS errors were 2.5m in X and 9.1m in Y with maximum errors of 3.7m in X and 8.9m in Y. When one GCP was collected from the imagery, the ICP RMS errors were 2.9m in X and 1.2m in Y with maximum errors of 3.6m in X and 1.9m in Y. As previously mentioned the Google Earth imagery may not be very accurate outside of North America; however, it is still a useful tool if one just intends to update an area of Google Earth. Figure 5 shows the pan-sharpened Beijing image overlaid with Google Earth.

Conclusions

This article examines different aspects of the WorldView-2 data. Pan-sharpening of WorldView-2 data can be performed by using OR2A panchromatic and multispectral products before geometric correction. The RPC model with zero order polynomial adjustment can be used as the geometric model to orthorectify WorldView-2 data. Similar to WorldView-1 data, it is possible to achieve RPC model accuracy within 1m RMS with a minimum of one accurate GCP for WorldView-2 data. For areas without accurate GCPs, Google Earth can be used as a source of GCPs.

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