Geometric Correction, Pan-sharpening and DTM Extraction

Pleiades Satellite

The successful operation of the Pleiades-1A satellite provides another alternative using high resolution satellite imagery. With the panchromatic sensor at 0.7m resolution and the multispectral sensor at 2.8m resolution, the data can be used in different applications. This article shows the data is capable of generating high accuracy orthos using a geometric correction method with a few ground controls. A pan-sharpening method can be applied to fuse the panchromatic and multispectral data to produce high resolution multispectral data, and a DTM can be extracted using the stereo data with a DSM to DTM conversion software.

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Figure 1a: Pleiades panchromatic image of Melbourne, Australia

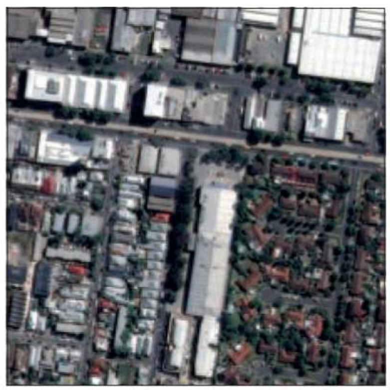


Figure 1b: Pleiades PMS image of Melbourne, Australia

Figure 1c: Pleiades PCI pan-sharpened image of Melbourne, Australia

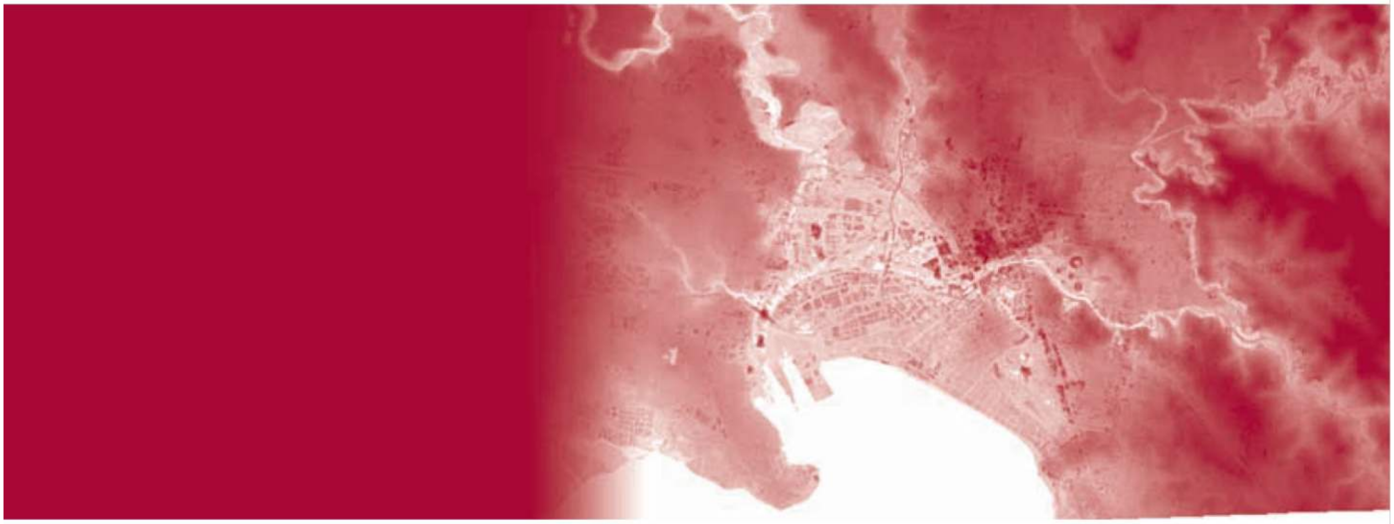
On December 16, 2011, the Pleiades-1A was launched successfully in orbit via a Russian Soyuz ST rocket out of French Guiana. Pleiades-1A is the first satellite of the Pleiades constellation. The Pleiades constellation will be composed of two very high-resolution optical Earth-imaging satellites on a Sun-synchronous orbit at 694km. With Pleiades 1A in orbit and Pleiades 1B scheduled for launch in 2013, the Pleiades constellation will provide very high-resolution optical products in record time, offering daily revisit to any point on the globe and acquisition capabilities tailored to meet the full spectrum of civil and military requirements. Pleiades acquisition capacity and exceptional agility maximize the number of images of a given area of interest, so more requests can be satisfied on the same pass including along track stereoscopy and tri-stereoscopy images. The satellite consists of a panchromatic band with resolution of 0.7m in nadir viewing and four spectral bands (blue, green, red and near infrared) with a resolution of 2.8m in nadir viewing. Image correction accuracy within 1m and 10m can be obtained with and without ground control points (GCPs), respectively.

Pleiades image data is distributed in either JPEG or TIFF format. There are two levels of processing products available: primary and ortho. The primary product is closest to the image acquired by the sensor and restores perfect collection conditions. The sensor is placed in a rectilinear geometry and the image is clear of any radiometric distortion. This level is optimal for users familiar with satellite imagery processing techniques who wish to apply their own production methods (for example orthorectification or 3D modeling). To this end, Rational Polynomial Coefficients (RPCs) and the sensor model are provided with the data. The ortho product is georeferenced images in Earth geometry, corrected from off-nadir acquisition and terrain effects. The user can order bundled (panchromatic and multispectral) product or PMS (pan-sharpened) product.

Most users would like to perform custom orthorectification using primary data. In this article we will examine different methods of processing Pleiades primary data. Firstly, we will test pan-sharpening using Pleiades panchromatic and multispectral data. Secondly, the geometric correction method and accuracy with and without GCPs will be examined. Lastly we will test the digital surface model (DSM) extraction using the tri-stereoscopy data and a tool to convert the DSM to a digital terrain model (DTM). A sample Pleiades primary data set consisting of panchromatic, multispectral, PMS and tri-stereoscopy images of Melbourne, Australia, was provided by Astrium Geo Services. The image consists of mainly urban areas with vegetation and buildings.

Pan-sharpening

Similar to most high resolution satellites, Pleiades panchromatic and multispectral data provide the opportunity to create 0.7m multispectral pan-sharpened images. Although the user can purchase Pleiades pan-



sharpened (PMS) product directly, in some cases the user may want to apply their own pan-sharpening. It is always preferable to perform the pan-sharpening process before geometric correction if a pan-sharpened orthorectified 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 ortho data due to the accuracy of GCPs and DEMs used in the orthorectification process. The PCI pan-sharpening program was used to test this case. The algorithm was written by Dr. Yun Zhang at the University of New Brunswick, Canada. It is based on least squares approximation of the grey level value relationship between the original multispectral, panchromatic, and the pan-sharpened image bands for a best color representation. Figure 1a, 1b and 1c show the panchromatic, PMS, and PCI pan-sharpened Pleiades images of the same area, respectively.

Geometric Correction

In order to leverage the Pleiades images for applications such as GIS, it is necessary to orthorectify the images. A geometric model, ground control points (GCPs) and a digital elevation model (DEM) are required. The Rational Function Method (RFM) has been the most popular geometric correction method in 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 Pleiades primary product is provided with RPCs, RFM can be used to orthorectify the data.

No. of GCPs	No. of Check Points	RPC Adjustment Order	RMS Error (m)		Maximum Error(m)	
			X	Y	X	Y
0	37	0	8.7	6.8	9.1	7.3
1	36	0	1.8	1.5	2.2	2.2
3	34	0	0.9	0.8	1.4	1.6
3	34	1	1.6	1.1	1.7	1.3

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

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 either manual or 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 Pleiades data. 0 and 1st order polynomial adjustment require a minimum of 1 and 3 GCPs, respectively. 0 order polynomial adjustment is always 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 cover the entire image.

High accuracy control points with accuracies within 10-15cm were provided by Professor Clive Fraser from the University of Melbourne, Australia. Pleiades panchromatic image was used for the testing in this case. Table 1 shows the results using 0 and 1st order polynomial RPC adjustment with different number of GCPs and check points. From the table it can be seen that using 0 order polynomial RPC adjustment with a few GCPs give the best results with root mean square (RMS) errors within 1m.

DSM Extraction

A great innovation of the Pleiades system is to offer high resolution stereoscopic coverage capability. The stereoscopic coverage is realized by only a single flyby of the area, which enables collection of a homogeneous product quickly. In addition to the " classical" forward and backward looking stereoscopic imaging, Pleiades can acquire an additional quasi-vertical image (tri-stereoscopy), thus enabling the user to have an image and its stereoscopic environment. In general, a forward and backward looking stereo pair produces the highest accuracy, but this combination is limited to areas with gentle terrain. A nadir and forward/backward looking stereo pair can be used in most kinds of terrain.

A tri-stereoscopy data set of the same area was provided. The along-track viewing angles of the backward, forward and nadir looking images are -14.91, 14.31 and -0.9 degrees, respectively. Using 0 order polynomial RPC adjustment and 3 GCPs collected on each image, the RMS errors of 38 check points on each image area are 0.3m in X, 0.4m in Y, 0.5m in X and 0.5m in Y, and 0.9m in X and 0.7m in Y, respectively. Since the images consist of mostly urban areas with gentle terrain, only the backward and forward looking images were chosen to generate a 2m spacing DSM using PCI OrthoEngine software. Comparing the extracted DSM with the check points, the vertical RMS error is 1.6m with an average error of 1.2m and a maximum error of

Figure 2.1: Pleiades Melbourne image

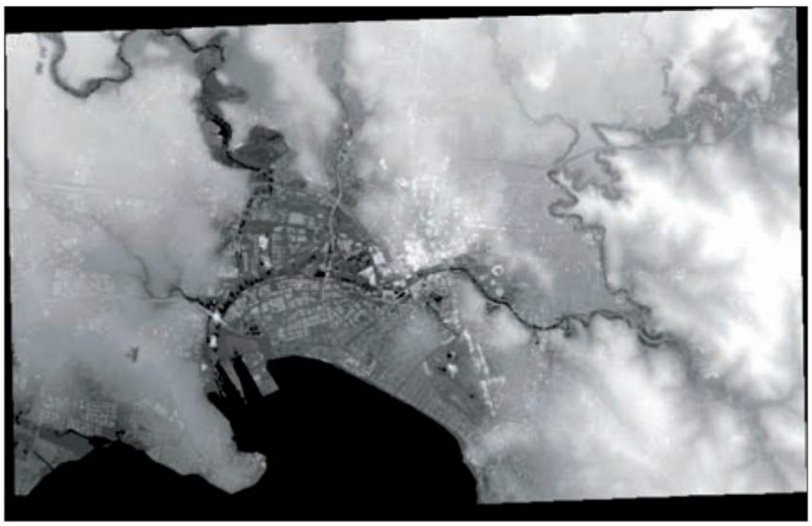


Figure 2.2 : Pleiades Melbourne extracted DSM.

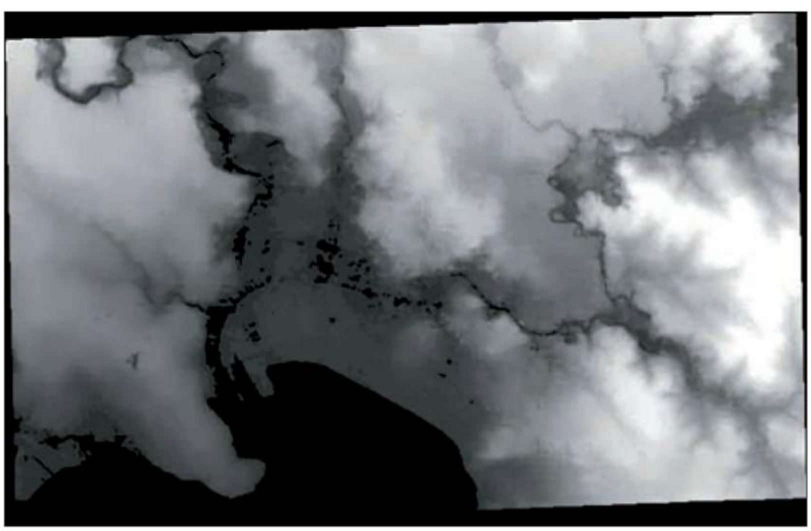


Figure 3 : Pleiades Melbourne extracted DSM converted to DTM

4.0m. Figure 2.1 and 2.2 show the image and corresponding DSM, respectively.

DSM to DTM

A DSM extracted from stereo images represents the earth's surface and includes all objects on it, for examples, buildings and trees. Many applications require the DTM which represents the bare ground surface without any objects. To convert a DSM to a DTM through manual editing is a very time consuming process. An automatic DSM to DTM conversion program was developed at PCI Geomatics. Figure 3 shows the automatically converted DTM of the same area. When comparing the converted DTM with a DTM provided by the University of Melbourne (with vertical discrepancy of 0.6m comparing to 25control points), the average vertical difference was approximately 0.8m.

Summary

It is possible to perform pan-sharpening before geometric correction with the Pleiades primary panchromatic and multispectral data. Using the RPCs provided with the Pleiades data and RFM, it is possible to achieve within 1m and 10m geometric correction accuracy with and without GCPs, respectively. The best accuracy is using 0 order polynomial RPC adjustment with a few GCPs. DSM extraction is possible using the stereo or tri-stereo data. DSM can be converted to DTM using an automatic program. The author would like to thank Professor Clive Frasor of University of Melbourne for providing the control points and DEM.

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