



**Richard Selby\*, Sławomir Mikrut\*\***

**LATEST TOOLS IN PCI GEOMATICA  
FOR ORTHORECTIFICATION AND PAN-SHARPENING  
OF VERY HIGH RESOLUTION SATELLITE IMAGERY**

**NAJNOWSZE NARZĘDZIA W “PCI GEOMATICA”  
DO ORTOREKTYFIKACJI I FUZJI (WYOSTRZANIA)  
WYSOKOROZDZIELCZYCH ZOBRAZOWAŃ  
SATELITARNYCH**

\* *PCI GEOMATICS*

\*\* *AGH University of Science and Technology, Cracow / INS-GIS Ltd. Cracow*

**SUMMARY:** Geomatica 9 is the latest version of PCI Geomatics geospatial image processing software product. It is particularly significant because it brings together into one integrated system advanced tools for remote sensing, photogrammetry, cartography and GIS. This merging of image processing and GIS within a single environment is one of PCI Geomatics key philosophies.

This paper focuses mainly on the capabilities of Geomatica for orthorectifying very high resolution (VHR) satellite imagery. Orthorectified VHR satellite imagery is proving significant in the areas of cadastral mapping, agricultural, forestry and urban monitoring. VHR imagery would include products from the IKONOS, Quick Bird, EROS and SPOT-5 satellites.

Based on rigorous parametric satellite models developed by Dr Thierry Toutin of the Canada Centre for Remote Sensing, Geomatica supports all the commercial VHR sensors. Rigorous sensor models offer the highest theoretical accuracy when orthorectifying imagery. The Rational Polynomial Coefficient (RPC) method of orthorectification is also supported by Geomatica and considered in the paper. Including the latest modification to the RPC model released by Space Imaging for their IKONOS imagery.

Geomatica 9 supports block bundle adjustment of satellite imagery. In the way that block bundle adjustment reduces the number of Ground Control Points required to orthorectify a block of aerial photographs, the same concept is applied within Geomatica to reduce the time and cost required to map large areas.

From sensors such as QuickBird and IKONOS, both panchromatic and multispectral imagery taken over the same area is available. A method of performing data fusion on these data within Geomatica is considered which preserves the original colour and detail of the input imagery.

**KEY WORDS:** orthorectification, PCI, pan sharpening, satellite imagery, VHR

## 1. INTRODUCTION

Recent developments within the areas of photogrammetry and remote sensing have induced changes in conceptions and algorithms implemented within GIS systems. PCI Geomatics decided to combine all tools into one integrated advanced system, “Geomatica 9” being the result.

PCI introduced new functionality to Geomatica 9 particularly for :

- spatial analysis,
- hyperspectral imagery analysis
- integration,
- new sensor models for satellite photogrammetry.

In this paper we focus on the last item; the modules and algorithms connected with it. Geomatica 9 introduced new support for processing data from satellite sensors such as:

- ENVISAT ASAR (Satellite Models module)
- ENVISAT MERIS (Satellite Models module)
- Hyperion (Generic & RPC Models)
- MODIS (Generic & RPC Models)
- EROS A1 (High Resolution Models module)
- SPOT5 (Satellite Models module &/or High Resolution Models)

A new Pan Sharpening module, based on an algorithm written by Dr Zhang, improves fusion of satellite imagery and places Geomatica 9 as one of the best solutions in this area in the world.

In this paper we review some important information about VHR Satellite Systems (section 2), next we explain the idea of rigorous parametric satellite models for the orthorectification of VHR imagery (section 3) and the RPC method of image orthorectification (section 4). We next describe the data fusion of VHR panchromatic and multispectral imagery (section 5) performed by Geomatica 9 followed at the end by a summary (section 6) [6].

## 2. VERY HIGH RESOLUTION SATELLITE SYSTEMS

The first satellite images with very high spatial resolution were used in military systems. In 1990s high resolution images were also available from the Russian camera KFA-1000 (resolution 5–10 m). In 1992 it was possible to buy imagery from KVR-1000 and KFA-3000 with resolution 2–3 m. It gave a new “dimension“ in satellite imagery available to the public. Since then consortia have been established to launch and operate high resolution sensors including, EarthWatch (now Digital Globe), OrbImage, Space Imaging, and ImageSat International.

EarthWatch launched it’s first satellite (EarlyBird-1) in 24 December 1997, unfortunately it failed before it could become operational. The first successful satellite was launched 24 September 1999 by Space Imaging and for 2 years it was the only satellite operating system delivery imagery with 1 meter resolution (IKONOS-2).

On the 5<sup>th</sup> of December 2000 ImageSat International launched their EROS-A1 satellite (Earth Remote Observation Satellite) providing a pixel resolution 1.8 m with

intention to launch future satellites with a higher resolution. Currently imagery from QuickBird-2 (Digital Globe) is also available. Launched on the 18<sup>th</sup> September 2001 with a maximum resolution of 61 cm. The subsequent launch of SPOT 5 means panchromatic imagery with 2.5 m is also available from this platform [5].

From the IKONOS and QuickBird satellites it is possible to acquire panchromatic and multispectral imagery for an area. IKONOS imagery band PAN resolution is 0.82 m and for multispectral 4 m, QuickBird provides imagery with PAN and multispectral resolutions of 0.61m and 2.44 m respectively (in nadir).

It is common practice to improve the spatial resolution and appearance of the multispectral bands using the detail found in the corresponding PAN image. It is done by fusion of the bands of interest. Within Geomatica 9 this process is known as Pan Sharpening. There are many image fusion algorithms. The most popular involve IHS (Intensity, Hue, Saturation) conversion, PCA (Principal Components Analysis), wavlet based fusion and others.

### **3. RIGOROUS PARAMETRIC SATELLITE MODELS FOR THE ORTHORECTIFICATION OF VHR IMAGERY**

The addition of support for new satellite sensors and imagery was one of the main new features of PCI Geomatica 9, released in June 2003. In terms of VHR imagery this covered support for all resolutions of imagery from SPOT5, plus support for EROS 1A imagery. Addition of these new sensors meant Geomatica 9 provides rigorous parametric sensor models covering all the major types of commercial VHR imagery, namely IKONOS, EROS, SPOT5 and Quick Bird.

#### **3.1. What is a rigorous parametric sensor model?**

A rigorous parametric sensor model is sometimes also referred to as a physical or deterministic model [2]. This type of model mathematically accounts for all the physical components of the viewing geometry (satellite, sensor, and terrain environment).

A major feature of physical modeling is that the mathematical functions correspond to the physical reality of the viewing geometry and take into account all the distortions generated in the image formation process [2]. Such rigorous parametric models are complex to develop, requiring a high level of knowledge of image sensor physics and associated mathematics. However, once developed they are available in products such as Geomatica for imagery users to exploit.

#### **3.2. Why is a rigorous parametric sensor model useful?**

Because the model accounts for all the components of the physical geometry, it is possible using a small number of high accuracy ground control points (GCPs) to achieve the best theoretically possible orthorectification ground accuracy. A target accuracy of less than 1 pixel (rms) image resolution. Another feature of the output from this model is that accuracy should be consistent across the entire image.

In summary, such parametric models are useful because they provide the potential to obtain the best orthorectification accuracy possible and the level of accuracy doesn't vary dramatically across the orthoimage.

Numerous VHR images have been orthorectified using the rigorous parametric model incorporated into Geomatica, with results presented and published in internationally recognized journals [2],[3].

### 3.3. Which image products can be processed using the Geomatica rigorous parametric model?

As a rigorous model is calculated using information about the satellite and the sensor, then imagery in it's most unmolested form should be chosen for processing. If a great deal of post-processing is performed on the imagery post-capture, then the relationship between the image and the original geometry at acquisition has been disturbed. Thus it will no longer be possible to create an accurate model.

The following table indicates the image products that the PCI Geomatica rigorous parametric model has been designed to accommodate:

Table 1

Image product designed by PCI Geomatica for rigorous parametric model

Sensor	Image Product
EROS	Level 1A
IKONOS	Geo & Geo Ortho Kit
SPOT5	Level 1A (preferable) & 1B
Quick Bird	Basic (preferable), Standard & Standard Ortho Ready

When reading the distribution files for these data Geomatica OrthoEngine automatically reads any ephemeris information available for each scene. This ephemeris information is then utilized as input to the rigorous model. The ephemeris information is useful also for the RPC method of correction and other types of data processing.

## 4. THE RPC METHOD OF IMAGE ORTHORECTIFICATION

RPC information is supplied with imagery, both by Space Imaging and Digital Globe. The RPC method of orthorectification has a number of positive attributes. Firstly it means that given a DEM, Geomatica OrthoEngine is able to orthorectify imagery with RPC information without the need for Ground Control Points (GCPs). As collection of GCPs is one of the most time consuming aspects of the orthorectification process, then any time saving in this area is of great benefit.

It is also possible to refine the photogrammetric model computed using RPC information by the addition of a small number of accurate GCPs. This refinement improves the accuracy of the computed model and resulting orthoimage. As only a small number of GCPs are required for the refinement, there is also a time saving to be made when compared to other methods which require more GCPs to be collected.

To acquire RPC information with imagery, select the Geo Ortho Kit product from Space Imaging and the Standard Ortho Ready product from Digital Globe.

According to the Digital Globe Product Guide (as of September 2003) "Ortho Ready Standard Imagery" products have a delivered absolute geolocation accuracy of 23-meter CE90%, excluding any topographic displacement and off-nadir viewing angle. When processed using supplied RPCs, a high quality DEM (e.g. DTED Level 2), and submeter GCPs, accuracies in the range of 3 to 10 meters RMSE may be achieved".

According to the IKONOS Geo Ortho Kit technical specification document on the Space Imaging web site (September 2003) "Accuracy: 15m CE90 not including effects of terrain. True accuracy including effects of terrain displacement, may vary several hundred meters in regions of high relief". This quoted accuracy could also be improved quite considerably given a good DEM and some high accuracy GCPs.

Geomatica OrthoEngine can process both these product types either using a rigorous sensor model or the RPC method. So with the same data set the Geomatica OrthoEngine operator has a choice as to which method to use.

Indeed it may suit some projects to perform a rapid orthorectification first using the RPC method, refined by a small number of GCPs. Then later a potentially more precise orthorectification could be performed using the rigorous model.

#### **4.1. What is RPC information?**

An RPC model approximates a rigorous model, without releasing sensor specific information. In theory, any software system taking RPC information and the same DEM should reproduce a model to the same level of accuracy as that produced by other packages. The method by which the RPC model is refined using GCPs may differ between software products.

Geomatica OrthoEngine uses a least-squares offset adjustment method to refine the RPC model with GCPs. Which is the method recommended by Space Imaging.

In summary the main advantage of using RPC information with imagery inside Geomatica OrthoEngine is speed of processing. It is also extremely useful in areas where it is very difficult or impossible to obtain reliable and accurate GCPs. The downside of using the RPC method is that, given a high resolution DEM and sufficient accurate GCPs the achievable accuracy is potentially lower than that which can be attained using a rigorous model.

#### **4.2. Space Imaging Certification of Geomatica OrthoEngine v9.0**

In 2003 Space Imaging modified the RPC information supplied with their Geo Ortho Kit product to facilitate block adjustment of the imagery. Following this change, PCI Geomatics modified the RPC capability within Geomatica OrthoEngine to support this new Space Imaging RPC method for IKONOS. The modification was released within Geomatica OrthoEngine v9.0.

Following the release of Geomatica OrthoEngine v9.0, Space Imaging tested the support within it for the new IKONOS RPC method. The following capabilities of Geomatica OrthoEngine v9.0 were tested [1].

1. Ability to load, display, and read coordinates from IKONOS stereo models.
2. Ability to orthorectify IKONOS stereo models.

3. Ability to block adjust IKONOS stereo models without ground control.
4. Ability to block adjust IKONOS stereo models with ground control.

Results were compared between the output from Geomatica OrthoEngine and Space Imaging's own ground station software. To take into account operator error, the results from Geomatica OrthoEngine had to coincide with the Space Imaging output to within a distance of +/- 1 pixel. Geomatica OrthoEngine passed all tests.

More details of the Space Imaging tests are available on the technical papers section of the PCI Geomatics web site (<http://www.pcigeomatics.com/tech-papers...>).

## **5. DATA FUSION OF VHR PANCHROMATIC AND MULTISPECTRAL IMAGERY**

The Advanced Pan Sharpening module available with Geomatica v9.0 incorporates a new data fusion algorithm for pan sharpening of imagery. The pan sharpening algorithm implemented is based on work by Dr Yun Zhang of the University of New Brunswick, Canada. This algorithm based on least squares adjustment is employed to find the best approximation of the gray value between the original panchromatic, multispectral and the fused images to provide the best colour representation. This method applies statistical approaches to standardize and automate the fusion process, thus it solves two problems in image fusion: colour distortion and operator dependency [7].

The algorithm works particularly well with imagery where the higher resolution panchromatic image is captured close in time to the lower resolution multispectral image. Naturally this means that differences between the contents of the images are reduced. Such a condition is true for all methods of data fusion. It also works better with imagery where the spectral range covered by the panchromatic image overlaps with at least some of the bands present in the multispectral image.

For example with an IKONOS image, the panchromatic band overlaps spectrally with the 4 multispectral colour bands.

Finally the spatial coregistration of the input panchromatic and multispectral bands must be as close as possible. Again, this is true for good results for any data fusion method. Any spatial offset between the input imagery will result in blurring in the output pan sharpened image.

The algorithm implemented within Geomatica is powerful because it removes the need for the operator to alter the fusion parameters to obtain a good fusion for different images. Statistical adjustments within the algorithm mean that the operator only has to signify which imagery to process and which bands to use. This means that the training required for the operator is reduced, it means a high number of images can be processed as part of a batch job, it means the total processing time per image is reduced and it means results will be consistent.

Any number of bands within the lower resolution multispectral image can be processed using this algorithm. The imagery can be processed within its original bit depth without prior compression to 8 bits (and thus data loss) necessary. The output pan sharpened imagery retains a similar spectral profile to the input multispectral image, thus it can still be used for data analysis applications.

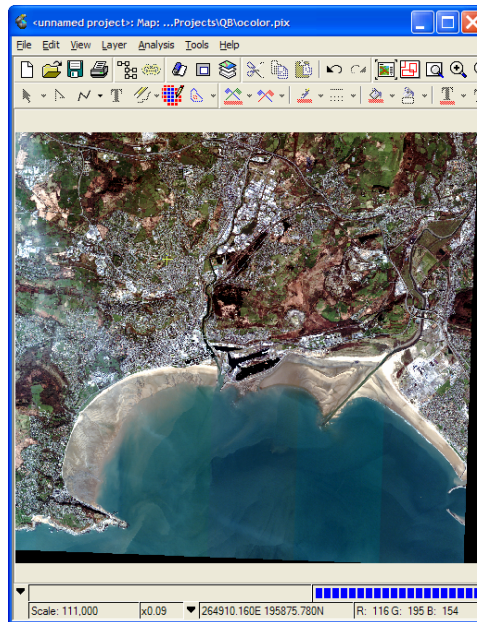


Fig. 1. Orthorectified Quick Bird image of Swansea, United Kingdom, using the Geomatica rigorous model / Imagery courtesy of Digital Globe/

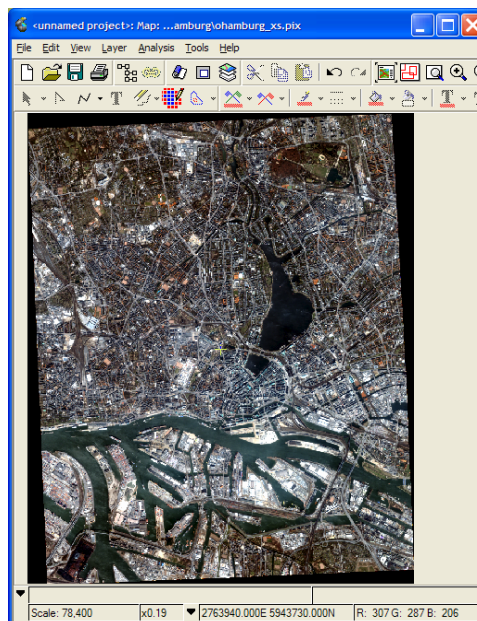


Fig. 2. Orthorectified IKONOS image of Hamburg, Germany, using the Geomatica RPC model (Imagery courtesy of European Space Imaging)

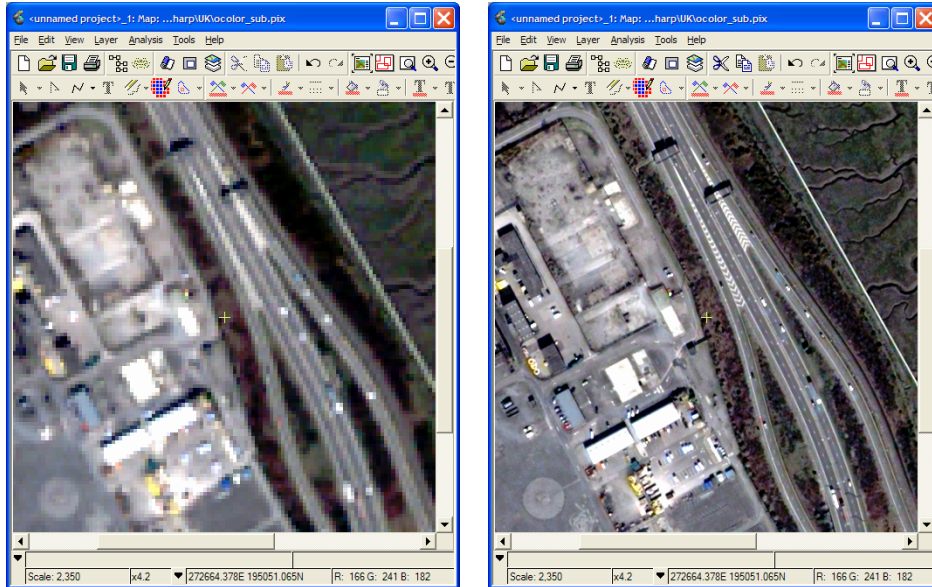


Fig. 3. Geomatica Pan Sharpening of Quick Bird image of Swansea, United Kingdom. Multispectral image before and after PCI Geomatica Pan Sharpening (Imagery courtesy of Digital Globe)

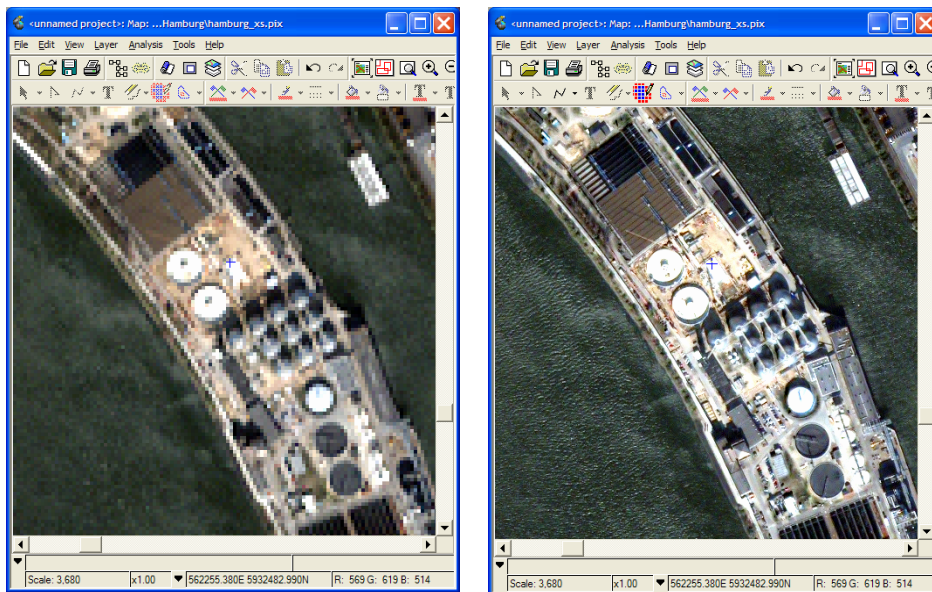


Fig. 4. Geomatica Pan Sharpening of IKONOS image of Hamburg, Germany. Multispectral image before and after PCI Geomatica Pan Sharpening (Imagery courtesy of European Space Imaging)



## 6. SUMMARY

Geomatica 9 provides one seamless environment for the completion of mapping projects based on very high resolution imagery. From photogrammetric imagery correction and feature extraction to GIS database completion and cartographic map production.

The user is provided with several image correction options, from straightforward polynomial adjustment, to use of RPCs and rigorous models. The method chosen depends on the nature of the terrain covered by the imagery, the needs of the project and the availability of supporting data (e.g. GCPs).

The ability to produce on demand a Pan Sharpened image from input PAN and multispectral imagery provides the user with extra information and processing flexibility.

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### **NAJNOWSZE NARZĘDZIA W “PCI GEOMATICA” DO ORTOREKTYFIKACJI I FUZJI (WYOSTRZANIA) WYSOKOROZDZIELCZYCH ZOBRAZOWAŃ SATELITARNYCH**

#### **Streszczenie**

„Geomatica 9” kanadyjskiego producenta „PCI Geomatics” jest najnowszą wersją oprogramowania do geoprzestrzennego przetwarzania obrazów, zintegrowanego w jeden system zaawansowanych narzędzi na potrzeby kartografii, fotogrametrii, teledetekcji i GIS. Połączenie narzędzi związanych z przetwarzaniem obrazów i GIS w jedno środowisko jest jednym z punktów strategii rozwoju produktów PCI Geomatics.

W niniejszym artykule autorzy skupiają się głównie na możliwościach wykorzystania „Geomatica 9” do ortorektyfikacji wysokorozdzielczych zobrażeń satelitarnych. Produkty przetwarzania mogą być wykorzystywane w katastrze, rolnictwie, leśnictwie czy monitoringu

terenów zurbanizowanych. Zobrazowania te obejmują produkty z różnych satelitów takich jak IKONOS, QuickBird, EROS czy SPOT5.

Bazując na dokładnych algorytmach wyznaczania parametrów orbit satelitów rozwiniętych przez Dr Thierry Toutin z Kanadyjskiego Centrum Teledetekcji, Geomatica pozwala na użycie danych z wszystkich komercyjnych wysokorozdzielczych sensorów. Dokładna znajomość parametrów pozwala na uzyskanie wysokiej dokładności dla ortorektyfikowanych zobrazowań. W artykule omówiono metodę ortorektyfikacji – RPC wykorzystywaną przez Geomatica, włączając jej ostatnie modyfikacje dokonane przez „Space Imaging” dla zobrazowań satelity IKONOS.

Dla zobrazowań satelitarnych „Geomatica” wykorzystuje wyrównanie metodą niezależnych wiązek, która pozwala zredukować liczbę niezbędnych fotopunktów potrzebnych do ortorektyfikacji bloku zdjęć. Ta sama koncepcja jest zastosowana w Geomatica w celu redukcji czasu i kosztów kartowania dużych obszarów opracowania.

Zobrazowania z QuickBird i IKONOS są dostępne zarówno jako panchromatyczne jak i wielospektralne (kolorowe). Metoda fuzji (wyostrzenia) tych samych danych, jest w Geomatica wykonywana z zachowaniem oryginalnych kolorów i szczegółów zobrazowań wejściowych.

SŁOWA KLUCZOWE: ortorektyfikacja, PCI, fuzja, wyostrzenie, zobrazowania satelitarne, VHR

Recenzent: prof. dr hab. Józef Jachimski, AGH, Kraków