

# ORTHORECTIFICATION OF SPOT IMAGES WITH THE SAME-PASS CONSTRAINTS

M. Erdogan, O. Eker, A. Yilmaz, O. Aksu

General Command of Mapping, Photogrammetry Department, 06100 Dikimevi Ankara, Turkey  
(merdogan, oeker, ayilmaz, oaksu)@hgk.mil.tr

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## ABSTRACT:

SPOT images are one of the most widely used satellite images in middle scale mapping applications for its stereo capability, wide coverage area and well-known satellite model which is supported nearly in all photogrammetric software. Stereoscopic imaging capability of SPOT allows generating digital elevation models (DEM) from a pair of overlapping images. DEMs based on satellite images are essential for many applications when you need up-to-date and cost-effective information about terrain relief. Topographic mapping contouring and orthoimage generation are the two widely used application areas.

The accuracy of orthoimages is a function of many variables, one of which is the accuracy of the ground control information used in a simultaneous adjustment and updating the satellite model parameters. Both the number and distribution of the ground control points are of great importance. Some techniques can reduce the needed number of ground control points in the modelling of SPOT images. This is important when the control points are acquired by expensive differential GPS measurements.

GCPs are used to calculate the position and orientation (i.e. roll, tilt, and yaw) of the imaging system at the moment of image taken. This calculation is accomplished using standard photogrammetric algorithms, such as a space resection or bundle adjustment. In these algorithms, same constraints may reduce the number of the ground control point needed. For SPOT system, when the images are taken in the same-pass, some additional constraints can be added to the adjustment process which will reduce the number of unknowns resulting reduction of the number of GCPs. By this way, the production cost and time will be also reduced.

In this study, a block with two columns each of which consists of three SPOT frames from the same pass was used. Finally, the accuracies were investigated.

## 1. INTRODUCTION

Remotely sensed images offer a unique perspective of the Earth, its resources, and human impact upon it. In little more than a decade, remote sensing technology has proven itself as a cost-effective source of valuable information for numerous applications including mapping, urban planning, environmental monitoring, agricultural management, oil exploration, market development, real estate siting and many others. In many ways, the value of remotely sensed satellite images has become obvious. They provide an overhead look at the features on Earth surface and help to understand relationships among these features.

Up-to-date maps are the basic need in many applications. The need for up-to date information drives the use of satellite imagery in mapping technology. Classical methods need years to produce a map, which is not preferable for the rapidly changing world. Remote sensing has become a solution for that problem and new technologies were developed through the up-to-date map needs. One of these technologies, which is very rapid and easy to use for mapping purposes, is the digital orthoimage, a photographic image that has been orthorectified to meet the precision and accuracy standards of a map.

In orthorectification, the distortions induced by the imaging platform, film and three-dimensional shape of the Earth are digitally removed from the space imagery. The final result is an image that has a precise geometry of a map which is a very popular product due to its diversity of use, particularly in its use as base information for Geographic Information Systems (GISs). Applications in many disciplines integrate the existing line data with digital images. One useful and very common integration is that of orthorectified images input directly into a GIS. This is quite advantageous for providing a base for a new data set or for updating existing databases. Another remarkable advantage of digital orthophotos is that they provide a more readily usable data source for a GIS when compared with conventional data sources. Because the information is not filtered through a cartographic interpretation, it remains unbiased. The relationships among land features such as buildings, transportation networks, etc. are presented in their natural form without being skewed by data conversions and interpretation. In addition, digital orthophotos are already in digital form and unlike hardcopy maps, they can be integrated directly into a GIS. Digital orthoimages serve as the backdrop with which older vector data can be updated or corrected. With the launch of new high-resolution satellites, an increasing number of orthoimages will be seen to be integrated into GISs.

A significant portion of the total cost of producing digital orthoimages is that creating the Digital Elevation Model (DEM) and ground control points (GCP) required in the orthorectification process. Therefore, it seems logical to attempt to realize cost reductions from this part of the production workflow. If DEMs generated from various sources can be used to orthorectify medium spatial resolution image (5 to 100 m. spatial resolution) such as SPOT imagery and the number of GCPs is decreased, then the orthoimage production cost can be reduced significantly (Erdogan, 2000).

Various studies were performed about orthoimage generation and their accuracy assessments. Different methods and data inputs were tested to achieve better accuracy. In one of these studies conducted by Chen and Lee (1993), an orthorectification method for SPOT images developed by the authors was tested and the accuracies of the produced orthoimages were assessed. They found that accuracies better than two-thirds of a pixel could be achieved with their orthorectification methods.

Another study conducted by El-Manadili and Novak (1996) was again the orthorectification process. They used a Direct Linear Transformation Model for precision rectification of SPOT Imagery. Especially, they worked on the effects of the number and quality of ground control points and base-to-height ratio of the images over the accuracy of produced orthoimage. The results show that sub-pixel accuracy can be achieved similar with the above study.

Heipke et al. (1992) tested SPOT Imagery for point determination, DEM generation and orthorectification with the automatic photogrammetric processing.

In a study conducted by Radhadevi et al. (1994), the geometric correction accuracy of SPOT stereo pairs was tested by using a single ground control point for orbit attitude modelling. Terrain coordinates are derived up to an accuracy of 28 meters in latitude and 40 meters in longitude and 27 meters in height with only 1 ground control point.

Pala and Pons (1995) tested the incorporation of relief in polynomial-based geometric correction of SPOT and Landsat TM imagery. It is investigated that sub-pixel accuracy can be reached with this method.

Above studies show that the accuracy orthorectification process and the orthoimages are the concern of remote sensing society yet and many researches have been performed to develop the accuracies of these products, to reduce the production time and cost. Since SPOT imagery is widely used by public for DEM and orthoimage production, SPOT imagery has been used in many of these researches. When the needed number of ground control points is decreased significantly in that process, objectives are accomplished.

## **2. SPOT SYSTEM AND THE SAME PASS CONSTRAINTS**

### **2.1 SPOT System**

SPOT satellites began a new era in space remote sensing, as it is the first satellite system to include a linear array sensor and employs pushbroom-scanning techniques. It is also the first system employing pointable optics. This enables side-to-side off-nadir viewing capabilities and it efforts full-scene

stereoscopic imaging from two different tracks allowing coverage of the same area.

The SPOT sensors can acquire stereoscopic image pairs for a given geographic area. This is achieved by making two observations on successive days such that the two images are collected at angles on either side of the vertical. Stereoscopic imaging capability of SPOT allows generating DEMs from a pair of overlapping images. DEMs based on satellite images are essential for many applications when you need up-to-date and cost-effective information about terrain relief. Topographic mapping contouring and orthoimage generation are the two widely used application areas. A study conducted by Theodossiou and Dowman (1990) has shown that SPOT data could be used for mapping at 1:50.000 scale with 20-m. contours. And that if the data are very good and the ground control is sufficient, 1:25.000 scale plotting may be possible. Toutin and Beaudoin (1995) applied photogrammetric techniques to SPOT data and produced maps with planimetric accuracy of 12 m. with 90 percent confidence for well identifiable features and an elevation accuracy of 30 m. with 90 percent confidence.

### **2.2 Same Pass Constraints**

The accuracy of orthoimages is a function of many variables, one of which is the accuracy of the ground control information used in a simultaneous adjustment and updating the satellite model parameters. The satellite model used in orthorectifying the images is a mathematical representation of the physical law of the transformation between the image and ground spaces. It corrects the entire image globally and also takes into consideration the distortions due to terrain. Unlike the polynomial models, which require a large number of well distributed GCPs in order to avoid degradation of the model in some part of the image, the required number of GCPs is lower in the mathematical model. This is important when the control points are acquired by expensive differential GPS measurements.

GCPs are used to calculate the position and orientation (i.e. roll, tilt, and yaw) of the imaging system at the moment of image taken. This calculation is accomplished using standard photogrammetric algorithms, such as a space resection or bundle adjustment. The position and orientation of the imaging system are expressed as six values: x, y, z, roll, tilt, and yaw (or alternatively, x, y, z, omega, phi, and kappa), which collectively define the exterior orientation of the imaging system for each image. They are needed in order to map each pixel of the digital image to its precise location on the ground. These processes can change according to the characteristics of the imaging system.

The other issue to consider include the distribution of ground control in the image and the requirement for additional control points to provide redundancy. Ground control necessary for producing orthoimages often comes from ground surveying which would help to reduce the propagation of the error source into the orthophoto pixel positions. However, ground surveying techniques are usually costly. Alternatively, the ground control measurements may come from the aerial photographs or from hardcopy maps of the project area.

Orthoimage generation uses the method of space resection to determine the relation between the object space and image space. Thus, the accuracy of the ground control used in the

process effects the accuracy of the digital orthophoto. The absolute accuracy of an orthoimage depends also upon the quality of the ground control information.

Some ASTER, IKONOS, QuickBird, and SPOT images may be delivered as image tiles. If the image tiles were cut from a strip of data acquired on the same day in a single pass of the satellite, the tiles can be tied with same pass constraints and the orbital data is rebuild for the whole strip. This process offers some advantages:

- Fewer ground control points (GCPs) to collect since fewer math models are computed.
- More coverage by the math model by bridging over obscured areas, such as areas under cloud cover, where GCPs cannot be collected.

### 3. METHODOLOGY

In this study, the affect of the same pass constraints on the adjustment results was investigated. The aim of the study is to investigate could the usage of these constraints reduce the needed GCP number or with the same number of GCP could a better accuracy reached. A block with two columns each of which consists of three SPOT frames from the same pass was used. At the first step, the block is adjusted using the 29 ground control points and 102 tie points distributed homogeneously over the block. GCP distribution is shown in the Figure 1. Some GCPs are measured on several images. So, the number of GCP measurement is 40. The results of this block adjustment are accepted as reference. The adjustment results are given in the Table 1.

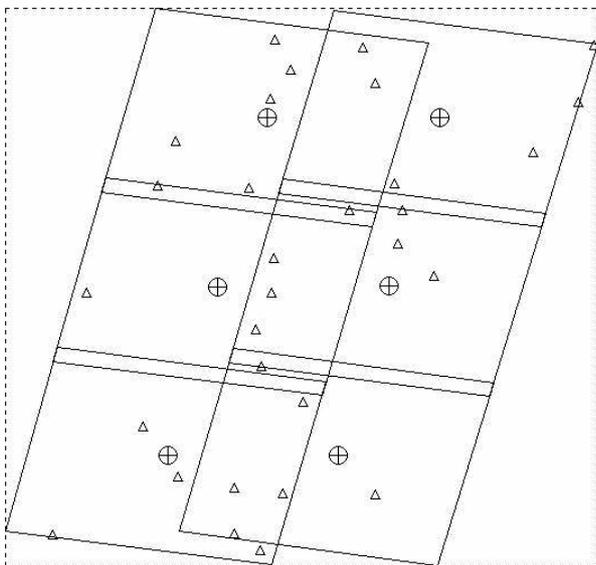


Figure 1. SPOT block with all GCPs

		X	Y	Z
GCPs	Average Error (meter)	3.524	3.097	2.606
	RMSE (meter)	4.337	3.734	3.818
Tie Points	Average Error (pixel)	0.17	0.27	-
	RMSE (pixel)	0.27	0.39	-

Table 1. Reference adjustment results

At the second step, only the ground control points over the two images at the north of the block was used. The number of GCPs is 13 and the number of GCP measurements is 15. GCP distribution is shown in the Figure 2. The adjustment results are given in the Table 2.

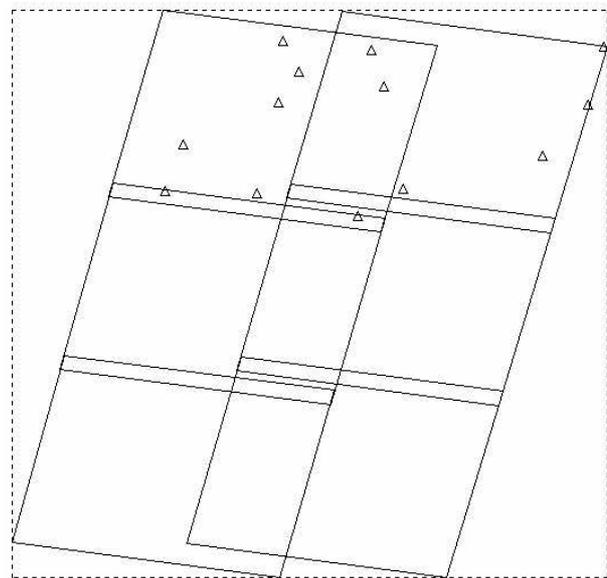


Figure 2. SPOT block with fewer GCPs

		X	Y	Z
GCPs	Average Error (meter)	4.091	5.428	0.667
	RMSE (meter)	4.655	6.202	1.121
Tie Points	Average Error (pixel)	0.29	0.25	-
	RMSE (pixel)	0.40	0.34	-

Table 2. Adjustment results with fewer GCPs

Lastly, the second block, which has fewer GCPs at the North, was adjusted using the same pass constraints. The number of GCPs is 13 and the number of GCP measurements is 15. The adjustment results are given in the Table 3.

		X	Y	Z
GCPs	Average Error (meter)	2.986	3.011	2.608
	RMSE (meter)	3.922	3.647	3.949
Tie Points	Average Error (pixel)	0.22	0.24	-
	RMSE (pixel)	0.32	0.34	-

Table 3. Adjustment results with same pass constraints  
Finally, the adjusted coordinates of the GCPs and tie points, which were calculated from the fewer point adjustment and same pass constraint adjustment, were compared with the reference coordinates. The results are given in Table 4.

		X	Y	Z
Fewer point adjustment	Average Error (meter)	20.857	3.083	63.054
	RMSE (meter)	33.681	4.927	110.130
Same pass constraints adjustment	Average Error (meter)	10.423	2.008	30.443
	RMSE (meter)	16.255	2.507	52.160

Table 4. Point errors

#### 4. RESULTS AND CONCLUSIONS

When the same pass constraints are used in the adjustment process, the accuracies changes completely when compared with reference coordinates. The usage of same pass constraints reduces the errors approximately two times. In similar projects, choosing the images acquired by the single pass of satellite and using fewer GCPs with same pass constraints would provide better results.

Further studies can be possible by using different distribution and number of GCPs over an imagery block. Such studies would be useful to determine an equation between the usage of many GCPs or fewer GCPs with same pass constraints.

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