# ACCURACY OF SPOT TRIANGULATION
# WITH VERY FEW OR NO GROUND CONTROL POINT

I. Veillet

Institut Géographique National - France
IGN - DT/GOM - 2 av Pasteur - 94160 Saint Mandé - FRANCE

## ABSTRACT

It is possible to compute global adjustment on Spot images blocks without any ground control point at all. This kind of computation is the worse case for Spot accuracy. The resulting relative accuracy on 200 km x 200 km test areas is around 20 meters.

Keywords :
Accuracy, Aerotriangulation, Block adjustment, Photogrammetry, Stereoscopy, Space mapping, Spot triangulation.

## 1. INTRODUCTION

Besides its image quality, the main advantage of Spot system is its geometric accuracy, and so, topomapping was quickly thought to be one of its applications. Many experiments were made to prove that Spot system could, at least geometrically, fit most standards of 1:50000 topographic maps.
In order to be able to use it on projects spreading over large areas, and so over many Spot stereopairs, production processes could include block triangulation, that is global adjustment of all the Spot images on the project to lower the number of required ground control points (GCP) and to tie adjacent images.

The introduction of on board measurements, and provided position of Spot satellite, which is necessary for accurate modelisation, give the opportunity to modelise without any ground point at all. Looking for results on badly controlled projects, results with no GCP are the worst ones that could be expected with Spot system.

Producing relative topographic maps could also be interesting in areas were there is no ground control points available. And so, some tests were already been made on single stereopair [Tateishi 1990], but not extended on a larger block.

## 2. SPOT GEOMETRIC PROCESSING

### 2.1. Block triangulation

As mentionned above, the context is topographic mapping, that is extracting three-dimensionnal information about the shape of Earth surface. This application is based on stereoscopic potential of Spot system. Areas where this method is used to supply a new map can assessed to be quite extended, and so required to use many images.

The basic aim of block adjustment is to keep, all over the project, the same geometric accuracy at least relative accuracy, and, as possible absolute accuracy. The borders between original data sets of the project are to be ignored, at least on a geometric point of view. First aim is to insure a good geometric tying between the individual images or stereopairs.

This point is very important whatever is the further geometric processing : from 'traditional' stereoplotting, to generation of digital terrain model by automatic correlation. And it is important how it can still be fit without any ground point.

The second interest is that this technique allowed to lower the number of ground control points. Either GCPs are gathered by field work, which is always cost and time consuming, or they are picked on existing maps, which thus are not always enough reliable, in case of a brand new topomapping project. In both case, it is interesting to be able to use as less points as possible, and even no point.

### 2.2. About Spot modelisation

The major point in block triangulation is to deal with particular Spot geometry, which is push-broom acquisition from a linear sensor.
In fact, images acquired successively the same day along the same track by the same HRV instrument are basically part of a same entity, which is called a strip. A block could then be considered to be a set of strips.

The modelisation includes the expression of image-ground relationship using provided information about position and attitude, and also the chosen parameters introduced to establish this relationship.

The main question to solve, while speaking of Spot modelisation, is how to use at is best the provided information about position (given approximate orbit) and attitude (on board mesurements) of satellite, in the simplest way but enough elaborated to insure a good modelisation whatever could be the external conditions, for example, the number of control points.

Different modelisations were developped by different organisms, leading nearly to the same results, for various configurations of control points, as it was shown by the tests conducted by OEEPE [OEEPE 1992, Veillet 1992].
A criterion to chose the best way to modelise Spot geometry could also be to have "Good" results with no GCP.

### 2.3. Control configuration

To fix the minimum number of GCP required to control a block, the minimum condition is to be able to keep over this whole block, composed of many images, the same accuracy than the one obtained on a single one.

This minimum number was shown to be 3 points for a stereopair of strips (an average number twice the number of strips for blocks) [Veillet 1990,1991,1992] reaching less than 10 m in XY and than 6 m in Z.

Looking for the results on not enough controlled blocks is working on configurations of one or two points, and the step was very short to go on configuration with no GCP. So we will focus on this type of configuration.

## 3. RESULTS WITH NO GCP

### 3.1. Tests sets

The test sets used were gathered for complete experiments on Spot acuracy.

| | number of Spot images | number of Spot strips | strip lenght | number of points XY | *number of points Z* |
|---|---|---|---|---|---|
| MT | 2 | 1 | 1 | 52 | *53* |
| ADEF | 32 | 8 | 4 | 493 | *514* |
| DJI | 30 | 10 | 1 to 3 | 28 | *189* |

The reference taken as results on well controlled block is computed with all given points used as controls.

**All GCP**, all points provided as control points

| | RMS XY | *RMS Z* |
|---|---|---|
| MT | 13,1 | *3,6* |
| ADEF | 7,9 | *4,2* |
| DJI | 8,5 | *5,0* |

in meters

### 3.2. Internal accuracy

The relative, or internal accuracy is evaluated by the standard deviation of differences between ground coordinates and computed coordinates on check points, while the accuracy of well controlled blocks is evaluated by RMS on those differences.
The resulting figures follow :

**No GCP**, all points as check points

| | **STD XY** | ***STD Z*** | RMS XY | *RMS Z* |
|---|---|---|---|---|
| MT | **21,7** | *6,9* | 571,4 | *228,1* |
| ADEF | **7,5** | *14,1* | 363,9 | *462,4* |
| DJI | **11,7** | *22,3* | 256,7 | *33,6* |

in meters

Roughly, those figures lead to 20 meters accuracy in planimery and in altimetry.

Those figures relie on ground points accuracy. The important thing is to look how the not controlled model is distorted towards the well controlled model.

### 3.3. Block distortion

The evaluation of the deformations of the block not controlled towards the well controlled block was made by looking for the best translation T, and rotation R between computed coordinates of the points on the not controlled block ($M_{NO}$), towards computed coordinates of the same point on the well controlled block ($M_{ALL}$).

$$M_{NO} = T + R\ M_{ALL}$$

Least squares were used for that and RMS on residuals computed.

Translation in meters :

| | Tx | Ty | Tz |
|---|---|---|---|
| MT | -223,6 | -530,1 | -228,1 |
| ADEF | 58,3 | -358,2 | 464,1 |

Rotation angles in microradians

| | Rx | Ry | Rz |
|---|---|---|---|
| MT | 80 | -90 | -291 |
| ADEF | -109 | -51 | 58 |

Distortion residuals in meters :

| | RMS X | RMS Y | *RMS Z* | **RMS XYZ** |
|---|---|---|---|---|
| MT | 11,6 | 3,2 | *2,2* | **12,2** |
| ADEF | 4,0 | 2,2 | *11,7* | **12,6** |

The residual distortion on those 2 examples is 13 meters. this figure requires to be confirmed on other data sets, but it already gives a first evaluation of relative accuracy of Spot triangulation with no GCP.

## 4. CONCLUSION

This could be inserted in a production process as relative orientation is used in aerial triangulation, to check firstly the internal consistency of the data, before controlling the block on ground points.
The resulting relative accuracy is not too bad, and can fit some particular applications. This allows to do some topographic work from Spot system even without any ground point at all.

Next question is how this is linked to the size of the block, or the length of the strips.

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