# Effect of control points distribution on the orthorectification accuracy of an Ikonos II image through rational polynomial functions

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## Abstract

*This paper evaluated the orthorectification of a high resolution image for distribution of points between a flat and a rugged area, using the rational polynomial functions. An Ikonos II image was orthorectified using a DEM from contour maps and points obtained in an orthophoto. Fifty-seven points were collected over the entire image, from which 13 and 8 control points were randomly selected from the flat and rugged areas. Thirty points from the entire area and 15 points randomly selected from these were also used in the orthorectification process for comparison purposes. The remaining points were used as check points. The vector errors using 30 or 15 points had the same standard deviation and errors increased with altitude. From the flat area 8 or 13 points yielded the same results and vector errors increased with terrain height. When points were only from the rugged area the average vector errors were smaller as compared with the points only from the flat area. A high correlation between height and vector errors was found when 30 points all over the area were used. It is concluded that the orthorectification using the rational polynomial functions is sensible to ground height and the point distribution.*

**Keywords**: orthorectification, rational polynomial functions, Ikonos II.

## 1. Introduction

Several cartographic applications requires the image geometric correction, i.e. to extract metric information it is essential the pre-processing of the image. The level of the geometric correction depends on the application accuracy in use and the orthorectification is the best recommended technique.

The orthorectification process uses the central perspective image to create a rectified image (vertical image corrected errors relative to the sensor attitude during the image acquisition) and corrected of the relief displacement due to the central projection of image acquisition. A Digital Elevation Model (DEM) of the area of the image is needed for the relief displacement correction.

Traditional orthorectification involves the use of stereo pairs from which elevation is extracted directly to be used for production of DEMs. However the cost and time of acquiring and processing stereoimages may not be justified if the purpose is to do orthorectification only. Thus many researches were realized using external elevation information for orthorectification of image (Behdinian, 2002; Mercer, *et al.*, 2003; Upakan, *et al.*, 2009).

The mathematical models for image orthorectification can be considered as the rigorous model and generalised model. The use of the rigorous model, or physical model, needs the knowledge of the attitude parameters, calibrations and sensor orbit. The mathematical function of rigorous model is based on the collinearity equations. However the use of the generalised model is independent of the sensor parameters and platform (Elashmawy *et al.*, 2005). These models are vastly used when the sensor parameters are unavailable (Okamoto *et al.*, 1998; Di *et al.*, 2003).

The rational polynomial function (RPF) can be more appropriate for pushbroom sensors than the rigorous model due the geometry of the images acquisition (Fraser *et al.*, 2006). The RPFs are established from the direct relationship between the image and terrain coordinates through coefficients (Tao and Hu, 2001). These equations are showed at Equation (1).

$$
\begin{aligned}
r_n &= \frac{p1(X_n, Y_n, Z_n)}{p2(X_n, Y_n, Z_n)} \\
c_n &= \frac{p3(X_n, Y_n, Z_n)}{p4(X_n, Y_n, Z_n)}
\end{aligned}
\qquad (1)
$$

Where: $r_n$ and $c_n$ are the image coordinates pixels, $p_1$ to $p_4$ are the polynomials and $X_n$, $Y_n$ and $Z_n$ are the ground coordinates. For the best performance of the RPF are recommended the use of many and good distribution ground control points (GCPs) (Tao and Hu, 2001).

The process of orthorectification using RPF requires the use of Rational Polynomial Coefficients (RPCs) in order to reconstruct the object space from the image space. Basically two sources of RPCs can be used in this process: estimation from ground control points or can be provided by the image producer (Tao and Hu, 2001; Fraser *et al.*, 2006). The first case is referred as terrain-dependent and the second as terrain independent (Fraser *et al.*, 2006). One example of terrain-independent RPCs is the set of coefficients provided with the Ikonos II Ortho Kit.

The terrain-dependent approach is of great interest as the terrain-independent RPCs are not available in many cases. However, a disadvantage of the terrain-dependent approach is that the number of control point tends to be large (Tao and Hu, 2001).

In order to provide an accuracy assessment of the orthorectification of an Ikonos Geo image of one meter resolution using the rational polynomial functions the experiments of this paper have been designed for the following purposes:

- to evaluate the influence of the number of GCPs in the orthorectified image accuracy;
- to evaluate the influence of the distribution of GCPs in the orthorectified image accuracy;
- to evaluate the correlation between the relief roughness and the orthorectified image accuracy.

## 2. Material and Methods

The pan sharpened Ikonos II Geo image from Seropédica-RJ-Brazil was used for the orthorectification tests using the terrain-dependent approach. These tests were designed to evaluate orthorectification accuracy on the same frame. The image covers a flat (below 50 meters) and a rugged area (from 50 to 363 meters). The DEM used at orthorectification tests was generated from contour maps at the 1/10,000 scale and points obtained from orthophotos with 1 meter pixel size. Fifty-seven points were collected over the entire image. Thirty points from the entire area were also used in the orthorectification process for comparison purposes. Figure (1) shows the distribution of the 15 GCPs from flat areas (triangles) and the 15 GCPs from rugged area (squares).

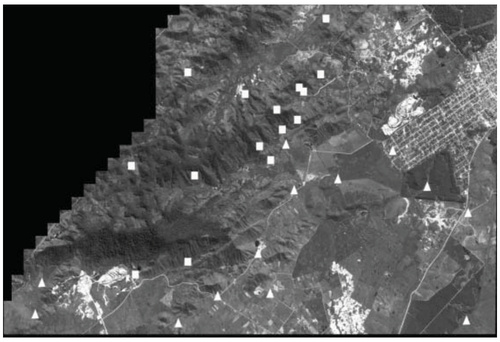

**Figure 1:** Ground Control Points distribution at flat and rugged areas.

Six orthoimages were generated to evaluate the influence of the number and distribution of GCPs in the image orthorectified accuracy . From the fifteen GCPs of the flat area, 13 and 8 control points were randomly selected and two orthoimages were generated with only GCPs from flat area. The same procedure was performed with the points from rugged area. Thirty points from the entire area and 15 points randomly selected from these were also used in the orthorectification process for comparison purposes. The processing was carried out by using the PCI Geomatica 9.0 software package. The orthoimages were produced using the DEM and the resampling method was sin(x)/x with a window of sixteen by sixteen pixels (Toutin, 2004).

The 27 remaining points were used as check points to calculate vector errors and the Root Mean Square Error (RMSE). Figure (2) shows the 27 check points used for the accuracy evaluations of the orthoimages.

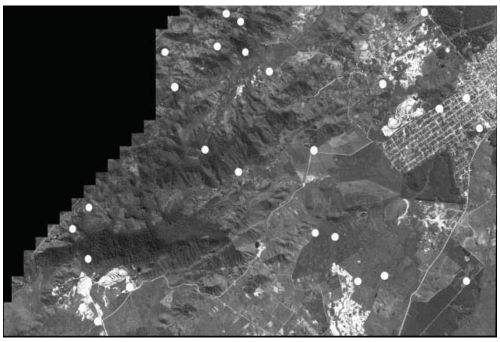

**Figure 2:** Check points distribution.

## 3. Results

Six orthoimages were obtained with a variable number of GCPs. Table 1 shows the Root Mean Square Errors (RMSE) resulting from the discrepancies of 27 check points used for the evaluation of the six orthoimages.

**Table 1:** RMSE (m) of check points in the six orthoimages.

| **Orthoimages with points from Flat Area** | | | |
|---|---|---|---|
| **13 GCPs** | | **8 GCPs** | |
| **E** | **N** | **E** | **N** |
| 24,30 | 28,02 | 22,72 | 28,35 |
| **Orthoimages with points from Rugged Area** | | | |
| **13 GCPs** | | **8 GCPs** | |
| **E** | **N** | **E** | **N** |
| 14,99 | 31,23 | 17,31 | 30,62 |
| **Orthoimage with All GCPs** | | **Orthoimage with Random GCPs from the Entire Area** | |
| **30 GCPs** | | **15 GCPs** | |
| **E** | **N** | **E** | **N** |
| 12,82 | 29,55 | 15,44 | 28,31 |

From the flat area 8 or 13 points yielded practically the same results. When points were only from the rugged area the average vector errors were smaller as compared with the points only from the flat area. The use of a larger number of GCPs, thirty points, distributed across the entire image resulted in smaller RMSE values. The RMSEs were smaller even when only fifteen GCPs distributed randomly were used. These results demonstrate that the distribution of GCPs in the entire image is more important than the number of GCPs used in the orthorectification process.

To evaluate the correlation between the relief roughness and the orthorectified image accuracy the graphics of the Figures 3, 4 and 5 have been produced. These figures show that the vector errors increased with the terrain height. Even using a smaller number of GCPs produced similar same results. A high correlation between height and vector errors was found when 30 or 15 points all over the area were used.

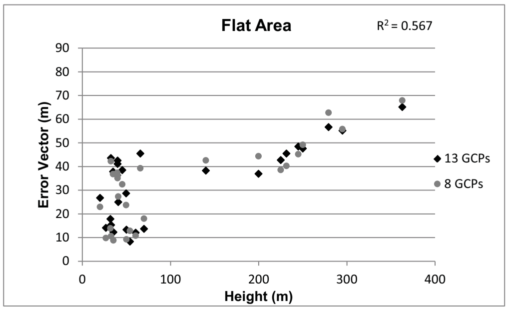


**Figure 3:** Error vector of check points of the orthoimages generated using GCPs from the flat area.

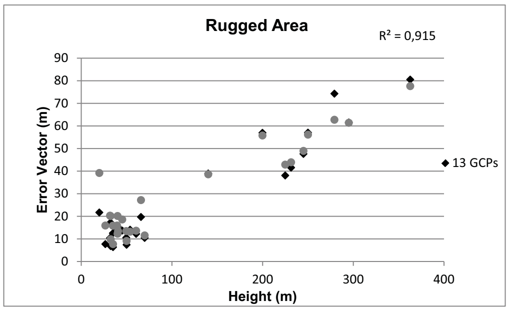


**Figure 4:** Error vector of check points of the orthoimages generated using GCPs from the rugged area.

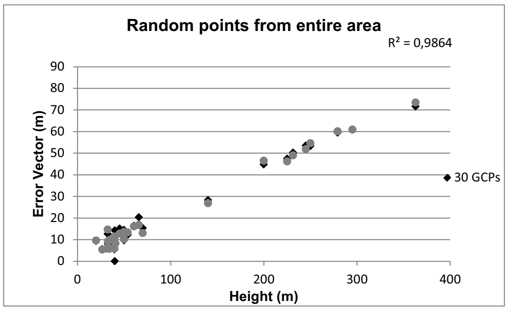


**Figure 5:** Error vector of check points of the orthoimages generated using random GCPs.

## 4. Conclusions

This paper provided a comparative evaluation between six different approaches in the processing of Ikonos II scene using rational polynomial functions. The results allowed the following conclusions:

- Increasing the number of GCPs from eight to thirteen in a specific area or from fifteen to thirty in entire area made no significant difference in the quality of correction results of the system tested;
- The distribution of GCPs in the entire image has more influence on the accuracy of the orthoimage than the number of GCPs used;

- Vector errors increased with terrain elevation and a high correlation was found between vector errors and elevation, except for the flat area where the height difference were no large;

The high correlation between vector errors and height suggest the orthorectification process by rational polynomial functions is height dependent. Thus one should be careful when processing images with height differences. It is recommended that at least eight GCPs are used for better results in the orthorectification. It is also recommended that the GCPs should be uniformly distributed over the image, not only horizontally but also in height, thus avoiding the concentration of GCPs only on flat or rugged terrain areas.

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