

THEMATIC MAPS BY PHOTOGRAMMETRIC TECHNIQUES ON SATELLITE IMAGES

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ABSTRACT

The idea of working on the cartographic production at scale 1: 100.000 comes from the real need of completing the cartographic information about the Natural Province Park called 'BAHIA BLANCA, BAHIA FALSA Y BAHIA VERDE', localized in the SW of Buenos Aires province, in Argentina. Following a simple photogrammetric approach, we did a digital rectification of a satellite image from LANDSAT, generated an important document for a good and up-to-date knowledge of the terrain and thematic maps describing quantitative and qualitative land information.

1 THE IMPORTANCE OF THE THEMATIC MAPS

The monitoring of continuous changes in the environment is a subject of increasing interest not only in the scientific community. In the last period the particular attention for the environmental disasters and their interactions with the human activities has induced the geodetic and cartographic sciences to improve new instruments and new approaches for the analysis of these problems (Bellone, 1997).

In fact is of general agreement the utility and the power of some technologies finalized to the land surveying (photogrammetry and remote sensing). These techniques can provide a new kind of instruments to observe and analyze the complex phenomena occurring on the earth. Moreover, thanks to the recent progress, data can be acquired and processed in a shorter time, so a fast cartographic production and a good updating can be achieved.

The images used in photogrammetry and remote sensing are usually taken from satellite platforms, which provide continuous land information for a dynamic control of the evolution of the phenomena (Bellone, 1996b).

The first elements that can be identified from raster satellite images are natural and human structures well identifiable on the land. In fact the sensors carried on the satellite platforms record the different energy coming from natural and human structures on the earth. The differences in the spectral firms describe the distinctive characteristics of the environment, that is, they represent a very important survey information. Due to the flight height, thematic maps obtained by satellite images are always at small scales. The scale reduction of a map is of big importance, because it influences the amount of elements that can be contained in the map.

By means of photogrammetric techniques, it is possible to provide cartographic representations, using analytical instruments or new procedures implemented in digital systems. These may be of different types, according to the single applications (Bellone, 1996a).

A technical map, in form of vector map, is a good way to represent the observed changes, but it is not always suitable to a dynamic control of the environment. On the other hand, other cartographic products, i.e. orthoimages, differential rectifications, planar rectifications, without or with the overlay of the vector elements, can achieve the task. These kind of maps, called raster maps, are an alternative but also a complementary representation to realize complete thematic maps, which describe different phenomena.

A raster map contains all the elements that were contained in the original aerial or satellite image. It is very rich of information, sometimes too much, but it is necessary to realize a good thematic map. The thematic map can be overlaid on the raster rectified image, then other elements like toponyms, break lines, altimetry, .. can be added in order to provide a complete representation of the territory.

Raster and vector data describing a territory can be collected in a GIS (Geographical Information System). Technical and thematic maps are important data set for a GIS; the data base, containing a lot of information about the

environment, can generate thematic maps regarding not only the metric and morphologic aspects, but also qualitative, economic, social and political information.

The thematic maps obtained by a direct survey regarding a specific characteristic of the environment are used as basic thematic maps. On the other hand, the thematic maps of synthesis are generated by an expert analysis of different kinds of land objects and collect more information.

The qualitative aspect of an image is of great importance when a vector representation becomes sometimes a simple and restricted map. In a GIS, raster information is connected or connect vector information.

2 A SIMPLE PHOTOGRAMMETRIC APPROACH

When digital rectification of a raster image is useful to survey the territory, a simple photogrammetric approach can be used. It becomes necessary to use a method the fastest and simplest as possible, in order to reduce production time and costs, and to avoid highly qualified personnel.

Photogrammetry is a technique that allows to survey 2D and 3D shaped real objects starting from the stereo - analysis of the images. It is mostly used to survey lands and to produce the cartographic database for a GIS.

The data acquired by digital sensors (CCD camera - Three-Line Camera, Landsat, Spot) or analogue sensors (film) can be transformed by analytical techniques in a basic document to study the reality: the map.

The transformation from the image space to the object space, using photogrammetric techniques, produces 2D and 3D representations of the reality (DEM, DTM, orthoimages, rectifications, etc.) (Albertella, 1998). These data are an important instrument to obtain a good and up-to-date knowledge of the terrain.

In the following we show a photogrammetric approach to produce a digital rectification of a satellite image over a flat land and, in a second time, a series of vector thematic maps at a small scale. We obtained a map using only one image, because the terrain was considered flat (sea level) and the omographic relations could be applied. In this case, simple rectifications can be easily generated with a straight-forward interactive procedure, just identifying control points with a pointing device. On the other hand, if the object surface can not be approximated by a plane or by a sequence of parallel planes, differential rectification must be used, and a DTM is required in order to generate an orthoimage. If even the orthoimage is not suited to the purpose, an alternative representation consists in the solid model of the object and in its texture mapping (Malinverni, 1998). This is obviously the 3D full description of the object.

The raster image can be constituted by a gray value matrix (a regular grid of picture elements called pixels) or by three-color matrices. The algorithms and procedures that can be apply to the image are: radiometric processing to improve the semantics, recognition of morphologic characteristics (feature extraction) and automatic or semi-automatic correlation in stereo viewing to acquire metric information (image matching). It is also possible to use a multi-resolution procedure to have good results in short time.

The digital rectification is not possible if the land is not geometrically flat or roughly flat. The shift from the planarity is defined as a function of the acceptable error at the scale of the final map.

The analytical expressions used to provide the rectification are the collinearity equations applied to the planar case ($Z_{\text{object}} = 0$), that is, an omographic relation with 8 parameters.

$$X = \frac{a_1x + b_1y + c_1}{ux + vy + 1} \quad (1)$$

$$Y = \frac{a_2x + b_2y + c_2}{ux + vy + 1} \quad (2)$$

The solution can be calculated using one image and at least four control points, known in the object and in the image system. By using more than four points, it is possible to obtain a least square solution, which is more reliable and consistent.

3 THE APPLICATION

The idea of working on the production of cartographic maps at scale 1: 100.000 comes from the real need of completing the cartographic information of the Natural Province Park called "BAHIA BLANCA, BAHIA FALSA Y BAHIA VERDE", founded in 1996. This region is localized in Argentina, on the Atlantic coast, in the SW of Buenos Aires province, approximately at 39° South latitude and 61° West longitude. Thanks to the amount of information contained and the techniques used, this cartographic work can be considered a starting point for future investigations: in fact the complete cartographic information doesn't exist and if it does, it is not always available.

The cartographic information available at the beginning of the work consisted of the Map of I.G.M. (Geographic Military Institution in Argentina) at scale 1:100.000 of Bahia Blanca and Estancia El Algarrobo and the Topographic Map of I.G.M. at the scale 1: 500.000 of Bahia Blanca Region. The original image used to generate the thematic maps is a LANDSAT scanner image at the scale of about 1:2.000.000, provided by IADO (Argentine Institute of Oceanography), with 16 millions colors and of 65µm (400 dpi) of geometric resolution (Figure 1).



Figure 1. The original satellite image

We transformed this image in a gray value image for the rectification. Then, after measuring 25 control points localized on the image and recognized on the maps at different scales, the original image was transformed in a correct image map at scale 1:100.000, by using the collinearity equations applied to the plane case. In fact the area, covering the coast of the Bahia and the saltworks, is flat, so the height is assumed approximately constant, referring to the sea level. The mathematical solution has been obtained using a software implemented at the DIAR - Polytechnic of Milan (Italy) (Malinverni, 1996), based on a least square solution. The first solution of the 8 parameters of the omography is in table 2; with $\sigma_0 = 0.189780$ km.

| |
|-----------------------|
| $a_1 = 12906.7339$ |
| $a_2 = -217.452185$ |
| $b_1 = 52.0979263$ |
| $b_2 = 13053.748$ |
| $c_1 = -852509.058$ |
| $c_2 = -855760.32$ |
| $u = -9.4660043E-05$ |
| $v = -1.40032915E-05$ |

Table 2. The omographic parameters of the first solution

In a second time, to obtain a better solution, we used the same observations, but with different weights: the observations, whose residuals were higher than a threshold value (t), equal to 10 meters (half the graphic error for a map at a scale of 1:100.000), were under-weighted. So in the new solution the weight was calculated as:

$$p = 1 \quad \text{if} \quad |v_i| \leq t \tag{3}$$

$$p = \frac{v_i}{t} \quad \text{if} \quad |v_i| > t \tag{4}$$

The solution was good (see table 3) with $\sigma_0 = 0.039302$ km.

| |
|-----------------------|
| $a_1 = 12937.4603$ |
| $a_2 = -211.875195$ |
| $b_1 = 50.8291291$ |
| $b_2 = 13083.7958$ |
| $c_1 = -855277.08$ |
| $c_2 = -860506.208$ |
| $u = -9.26556231E-05$ |
| $v = -1.02941106E-05$ |

Table 3. The omographic parameters of the second solution

The values are still high for the production of a map at scale 1:100.000, but they are good result if we consider that the satellite image was at scale 1:2.000.000.

The estimated parameters of the omographic transformation have been used for the digital rectification of the original image. The distortion adjustment has been provided by assigning to each pixel its correct geometric position and a new radiometric value, calculated from a linear interpolation of the four neighboring pixels, localized in the original image by means the inverse omographic expressions:

$$x = \frac{(b_2 - vY)(X - c_1) - (b_1 - vX)(Y - c_2)}{(b_2 - vY)(a_1 - uX) - (b_1 - vX)(a_2 - uY)} \quad (5)$$

$$y = \frac{(a_2 - uY)(X - c_1) - (a_1 - uX)(Y - c_2)}{(a_2 - uY)(b_1 - vX) - (a_1 - uX)(b_2 - vY)} \quad (6)$$

The rectified image is at scale 1:100.000 (Figure 4).



Figure 4. The rectified image

Later, other information (place names, geographical coordinates, cartographic elements, like borders of vegetal formations, water and salt pans, etc.) have been overlaid on the image, to obtain a series of vector, raster and thematic maps (figure 5, 6, 7).

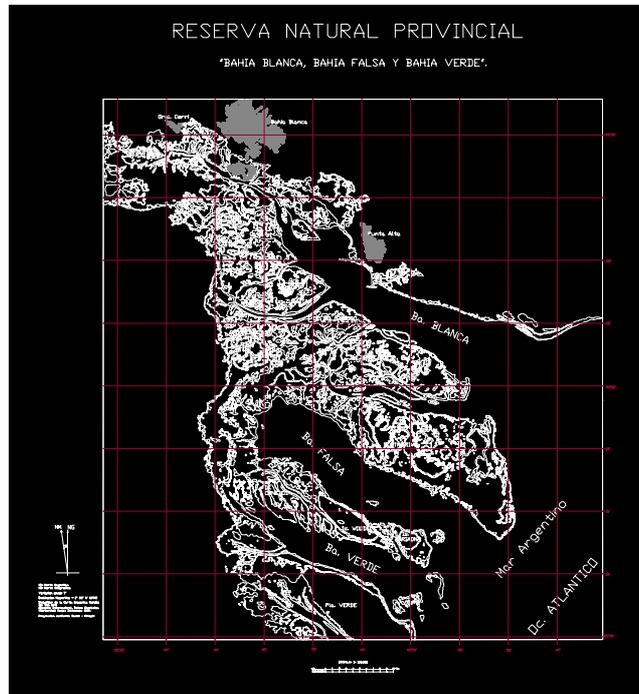


Figure 5. A vector map

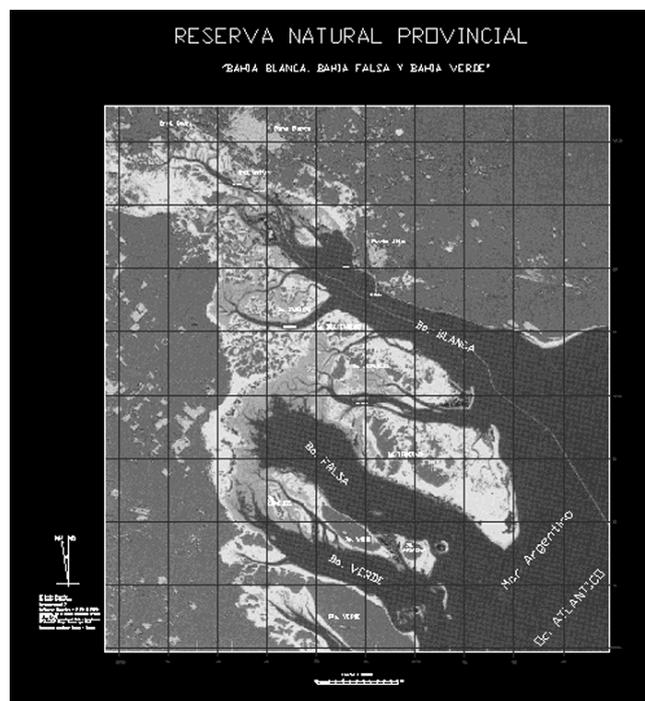


Figure 6. A raster map completed with geographical information

These vector elements have been digitized on video on the digital map and overlaid on the same image. The good accuracy of the results and organization in a thematic map depend on the estimated omographic parameters and the geometric resolution of the original image.

The quality and the quantity of information are very good.

Finally, the complex thematic map obtained by this simple approach can be considered a good instrument for further environmental studies.

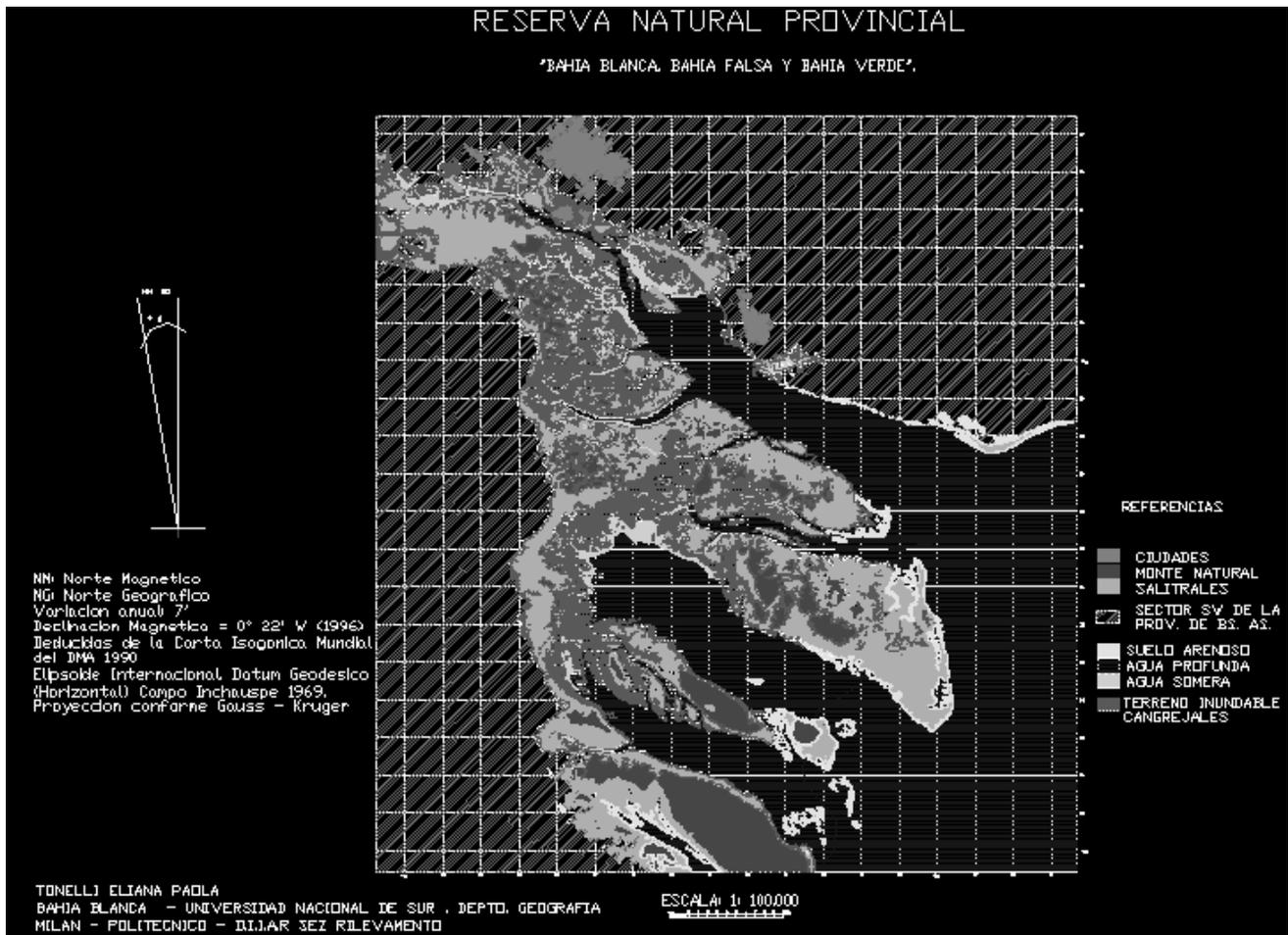


Figure 7. A natural thematic map

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