TRUE ORTHOIMAGE GENERATION IN URBAN AREAS

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ABSTRACT

Digital orthoimage is a widely used cartographic product, either as a complement to the traditional topographic map -when the latter has not been updated- or to allow the extraction of different kinds of information. The geometric precision of an orthoimage is strongly dependent on the quality of the Digital Elevation Model (DEM) and the geometric correction algorithm used. It is well known that the results obtained with the standard procedure over urban areas, when working with high-resolution pictures, are inappropriate. So, a different approach is suggested that builds a 3-D model for the existing structures, determines the hidden parts in each image and combines (mosaics) all the orthoimages that come from different views of the same area and contribute to the generation of a product free of geometric shadows.

1 INTRODUCTION

It is obvious that the amount of images of the Earth being available for a great number of applications is quickly increasing. At the same time the diversity of available products is also growing, both from the spectral and the spatial point of view. On the one hand hyperspectral data is today obtained not only with airborne sensors but also with space ones; on the other hand, from the spatial point of view, high-resolution satellite images are available as, for example, those acquired by Ikonos or Quickbird. Must of these images require a geometric correction process as a previous step for the information extraction. Often, the image geometric and radiometric correction is a product by itself.

Standard procedures for orthoimage generation usually reduce the problem complexity, either working with a Digital Terrain Model (DTM) that represents ground level irregularities in a regular grid, or considering that the area to be mapped from one image is completely visible in it. When working with high-resolution images in urban areas or over human built structures both hypothesis are wrong. First, the available DTMs have been compiled from existing cartography, which represents the terrain at ground level and avoids the representation of existing structures over it, as trees or buildings. Secondly, buildings use to cause hidden parts in a geometrical corrected image, that is, areas that should be visible in the orthogonal terrain projection and being hidden by a building in the original image (Lee, 1991) (Nagy, 1994) (Floriani & Magillo, 1994).

The present paper reviews the main aspects concerning the true orthoimage generation. It describes first the basic differences between a standard orthorectification and that one required for true orthoimage generation that needs a hidden parts removal process. Later describes the features and structure for the required DEM and the effects in the orthorectified image caused by relief inaccuracy. Finally, it reviews the difficulties and status of the mosaicking process needed to combine the different images over the same area, which were captured from different positions.

2 STANDARD AND TRUE ORTHORECTIFICATION

The algorithm for a standard orthoimage generation must be described in a simple way (see Figure 1): for each point in the orthoimage space it corresponds a point in the original image according to a geometric model appropriated for the specific sensor that acquired the image. For aerial photography the model is described by the collinearity equations. In the lower part of the Figure 1 it is represented the orthoimage plane, while in the higher part it is the *p* plane corresponding to the captured image presenting geometric distortions due to tilt, perspective and relief (described by a DEM).

Lets first observe positions *a* and *a'* in the orthoimage plane, which are projected to the same point in the plane *p*. These points define the limits of a hidden area. Emphasized with a white line (see Figure 2) it is a building edge in the original image (plane *p*) that corresponds to that kind of boundary (see the black geometric shadow in Figure 4).

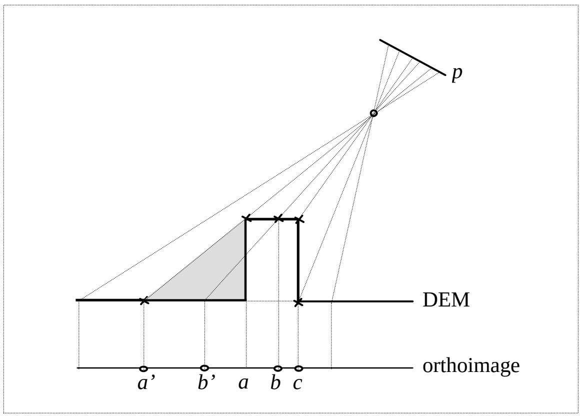

Figure 1. Basic geometry for image acquisition and orthoimage generation

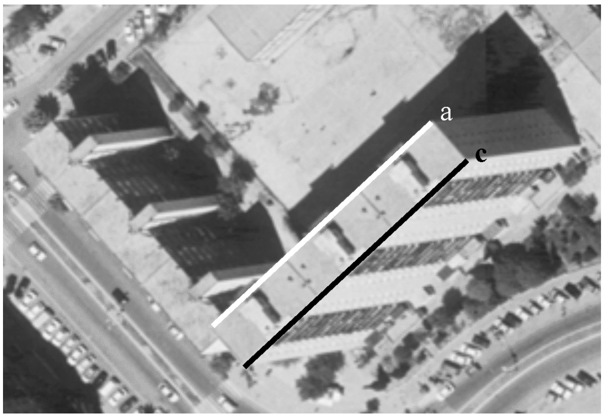

Figure 2. Original image

When using a standard backward rectification, each orthoimage pixel value is computed from its projection in the original image, where some kind of interpolation technique is applied. That is why a standard orthorectification algorithm, without hidden parts detection, would present unacceptable structures duplication (see Figure 3, where building rooftops are visible twice). It is easy to understand having a look to positions *b* and *b'* (see Figure 1) that again correspond to the same point in the original image, but *b* is visible and *b'* is not.

Another special orthoimage position to be reviewed is *c* (see Figure 1), belonging to the boundary between two visible areas connected by another one, the building wall, visible in the original image and that should not be present in the orthoimage. Observe how the black line emphasized in Figure 2 meets the street in the orthoimage (see Figure 4).

All that cases must be considered for a true orthoimage generation during the orthorectification process (Rognant *et al.*, 2000), applying different techniques for the DNs reconstruction or interpolation according to each mentioned case.

Figure 3. Standard orthorectification without hidden parts removed

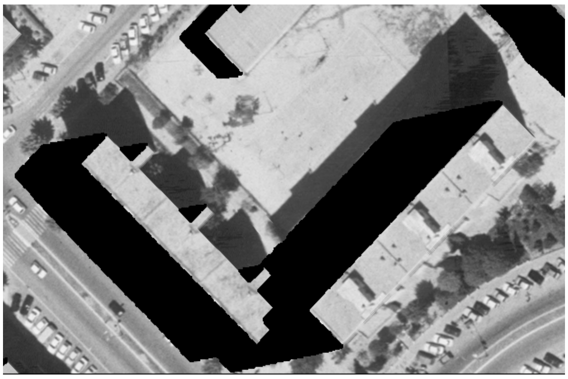

Figure 4. Hidden parts removal orthorectification

3 DIGITAL ELEVATION MODELS (DEMs)

In order to obtain precise positioning for all the orthoimage pixels it is obvious that an also precise representation of the urban structures or "shapes" is required. In contrast to this need we have the reality of the existing data that have been elaborated for work at lower scales or to generate level contours. This information was stored using data structures designed for an apparently easy handling and upgrade and, at the same time, thought for obtaining the best results using the available algorithms.

Regarding the DEMs that have been elaborated for cartographic use, in general they describe the terrain without the structures built on it (they are, in fact, DTMs) and a regular digital grid is used as data structure, with a spacing precise enough for the standard non-urban case. Even having a fine mesh (that is very precise altitude information) there is an inherent inaccuracy due to the grid structure disagreement with city models.

The above considerations lead to the need of storing the relief information in a different way, accomplishing the following requirements or features:

- <u>Adaptive information density</u>, having as more information as more complex is the terrain.

- <u>Vectorial capture and storage</u>, avoiding that way the original inaccuracy due to the sampling. Moreover, vectorial information makes the abundant computations involved in the thereafter hidden parts removal process easier.

Triangulated Irregular Network (TIN) models respect perfectly both properties. They approach the relief by means of triangles connecting a set of irregularly distributed vertex with well-known elevation. A constrained Delaunay triangulation that models a surface defined by a set of points and straight-line segments that must belong to its representation is usually applied (Preparata & Sanmos, 1985) (Floriani & Puppo, 1992). This technique guarantees the creation of a set of triangles as much equilateral as possible, each one accomplishing that its circumcircle does not contain any other point in its interior.

4 EFFECTS IN THE ORTHORECTIFIED IMAGE CAUSED BY DEM INACCURACY

The dissimilarities between the digital terrain model and the real terrain shape produce some undesired effects in the true orthoimage. Some of them will be reviewed in this paper.

One of the most common is due to an uncompleted digitization of a building volume, not having into account minor structures as, for example, balconies or rails (often opaque) over the terraces at the top of the buildings. These small structures may hide some areas that will not be considered occluded during the process. That is why a region in the orthoimage that should be an occlusion (in black in the orthorectified image) will display the rails or balconies as projected on the ground. They are placed very close to the geometric shadow caused by the building and separated from it (see Figures 5 and 6).

Similar effects, although more exaggerated regarding its visual impact, may occur due to an information miss-updating problem: the available DEM was generated in a date and the images were captured in a different one. Some buildings may have been built or demolished during that time, especially in urban areas. In case of demolition, a nonsensical and undue geometric shadow we'll be observed in the orthoimage. In the other situation, when a new building grew during the elapsed time, the already commented and common duplications of the standard orthoimage we'll be obtained.

In addition, the real impossibility of representing all the details from the real world has some unavoidable repercussion in the othoimage geometric quality. An appropriate model for the objects in concordance to the working scale is required, even though some objects are very difficult at any scale:

trees, cars, structures and substructures over the rooftops. Annoying in special are the dynamic objects, as the moving cars.

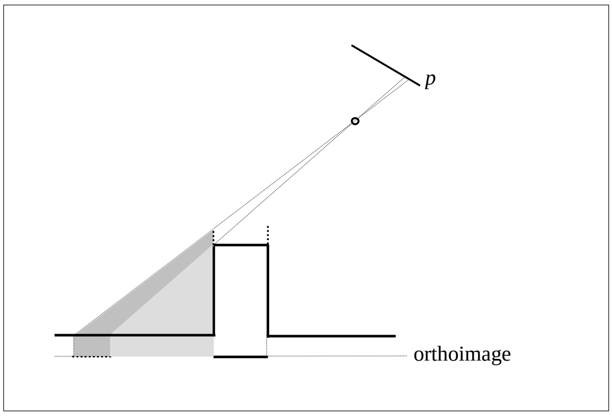

Figure 5. Geometry for the terrace rails effect

Figure 6. Terrace rails and balconies effect in the orthoimage

5 MOSAIC OF THE DIFFERENT VIEWS

The next step in the process is the assembling of all the images acquired from different observation positions with the purpose of obtaining a complete true orthoimage free of occlusions. It is then expected that any orthoimage point may be seen from, at least, one of the acquired images.

During the assembling some problems must be solved:

1) Radiometric compensation and balance of the set of images, that is especially difficult for the areas with solar shadows. Moreover, the shadows are moving as the time goes from the first to the last acquisition. Whenever is not possible to obtain the involved images in a single day and during a short time is not possible, very similar illumination conditions for all the campaign days must be pursued.
2) The commented effects related to the DEM imperfections (as the rail problem over the terraces).
3) The non-modeled objects, as trees, containers, urban furniture and, in general, small structures.
4) The moving objects, as cars.

The present solution to these problems requires a patient manual work performed by an expert operator and, at the same time, the use of a set of images with an important overlapping, both along and across the track.

6 THE TEST

A color true orthoimage corresponding to a 550 m. by 450 m. area of Barcelona has been produced from aerial photography. The photogrammetric camera was a ZEISS RMK-TOP, mounting a 150 mm. focal length lens. The flight altitude was 750 m. over the ground, obtaining in consequence 1:5000 scale pictures. The final orthoimage pixel size is 10 cm. and displays some important buildings besides the Diagonal Avenue. In order to fulfill the occlusions, a set of 24 photographs was taken with 60% overlapping in both directions. In fact, only 18 of these scenes were scanned and used for the mosaic.

A TIN obtained from the existing urban 1:5000 topographic map was created for the precise orthorectification of the photographs, having approximately 11000 points and 21000 triangles. The topographic map specifications are not ideal for true orthoimage generation, but part of the experiment goals were the problem determination and evaluation when using available information. Must of the problems are those reviewed above (in section 4) and require a supplemental effort during the mosaicking process. The final result is displayed in Figure 7 and Figure 8 shows a perspective view of the 3-D scenario described by the DEM and the true-ortho combination.

Figure 7. True-ortho of Barcelona

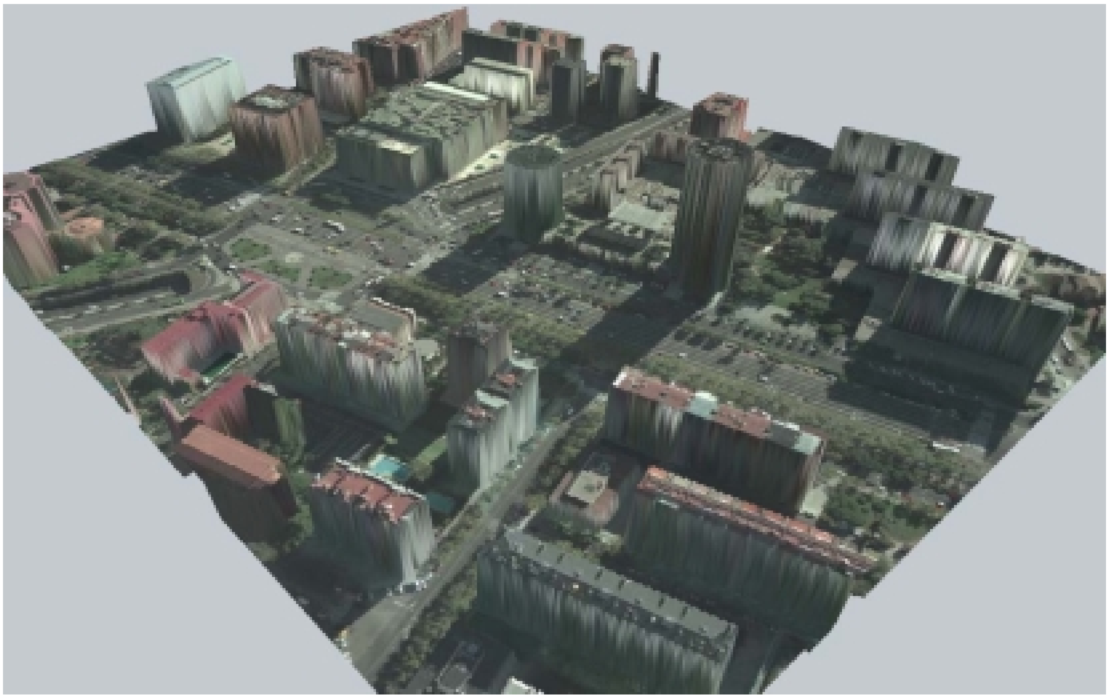

Figure 8. Perspective combining the DEM and the true-ortho

7 CONCLUSIONS AND FUTURE WORK

In order to generate true orthoimages over a complex terrain, as is the case in urban areas, a very precise DEM and a specific algorithm for the hidden areas detection are needed.

Tools for the manual assembling of the different geocoded or orthorectified views (each one with the hidden parts removed) are available, so a true orthoimage is a real product.

The future works will focus on two main goals:

- The analysis of the DEM acquisition specifications appropriated for true orthoimage generation, regarding both the drawing up of an inventory of objects to be taken into account and the digitizing method for each one to reach enough geometric precision.

- The development of semi-automatic procedures for the mosaicking process.

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