

TRUE ORTHOIMAGE GENERATION IN CLOSE RANGE PHOTOGRAMMETRY

Efstratios Stylianidis

Dept. of Cadastre, Photogrammetry and Cartography, Aristotle University of Thessaloniki,
stratos@geoimaging.com.cy

Commission V, WG V/4

KEY WORDS: Photogrammetry, Algorithm, Orthoimage, Close Range, Digital

ABSTRACT:

Digital orthoimage compose an efficient and economic way for the representation of two-dimensional texture information. This kind of information is functional when the user has to evaluate, analyze or measure the objects presented in the image. If the projection has to be performed on a single plane and the form of the object is not rough, the process is simple and well-known as simple rectification.

The orthoimage production of rough objects is still an on-going problem especially in close-range applications (for example architectural or archaeological applications) where the major problem is that of the complication of the description of the analytical shape of the object. In most of the cases the points with identical XY co-ordinates display different heights. Regular grids are the most established solutions used to build-up a mathematical shape description of an object. In this way a conventional orthophoto cannot provide the ultimate representation of the object through the rectification process. In the last few years a novel expression, the «true orthoimage» raised to describe the ideal illustration of the object through the rectification development.

This paper is a contribution on the research for the true orthoimages. The on-going study focuses on the description and test of a solution which uses a 3D model for the creation of a true orthoimage in close range photogrammetric applications.

1. INTRODUCTION

The architectural objects consist of adequate items or structures that can be described mathematically. The structures are principally shaped by straight-line elements and usually are highly characterized by rapid changes in surface continuity.

It is well known that the abrupt changes in surface represent boundaries in the image and natural breaklines in the object model. The development of tools and techniques that automatically or semi-automatically detect and extract such useful features has been discussed in various papers (Stylianidis et. al., 2002; Stylianidis & Patias, 2002).

The increasing requirement for quick and accurate production of surface models is a fundamental sub-process in the framework of orthoimage generation. The development of orthoimages requires a known surface, what is usually described as DTM, DSM or DEM.

On the other side, orthoimage is one of the most attractive photogrammetric product. The need for a quick production is always a fundamental process in geomatics. Basically, orthoimages can be separated, according to its production method, into two categories: the conventional and the true one.

The conventional orthoimage production does not take into account objects that mathematically can be described like buildings; due to the fact that the used DTM does not model such kind of objects. This has the result to distort the features from their correct position.

On the other side, based on a 3D or a 2.5D model the orthoimage production process may take into account several additional information for the production of a true orthoimage.

Various researches from different backgrounds and perspectives. Amhar and Ecker (Amhar & Ecker, 1996) proposed a novel solution for the generation of true orthoimage. The procedure, applied to the production of orthoimages in urban areas, use a DSM, which is been managed by means of a relational database. Bocardo et al. (Bocardo et al., 2003) developed software that uses terrestrial laser scanner data (very dense DEM) in order to produce true orthoimage.

The paper describes the results of a research attempt for the true orthoimage generation. The proposed framework is of special interest in close-range applications.

2. PROBLEM DEFINITION

In close-range problems, particularly in architectural, industrial or archaeological applications objects that are represented on the images consist of mathematically structured surfaces, for example planes. Such cases are frequently seen in building facades where alcoves, balconies or any other similar structures appear.

Under the above circumstances, three different approaches are realistic:

- Single rectification
- Conventional orthoimage
- True orthoimage

In the first case of single rectification, a mean plane of projection is used for the rectification process. This is an easy and well-known method. Features that are from both sides of the mean plane are actually distorted. Thus, the orthoimage does not reflect the strict reality and the accuracy depends of the position of the points in regard to the plane. An example of this case is given in Figure 1b.



(a)



(b)



(c)

Figure 1. (a) The original image. (b) An example of single rectification where feature distortion is obvious. (c) Interest point for DTM generation.

In conventional orthoimage production, a DTM that may have been extracted through an image matching process is used for the rectification. Such a DTM cannot illustrate the exact model and structure of the object unless all the breaklines of the objects are precisely described. In this case, the single plane is replaced with a surface. Even if the surface does not accurately express the whole structure, the result of this process is better than the previous one.

Figure 1c gives a picture on how the interest points, used for DTM generation, are distributed throughout the whole object area. The points' irregularity is not enough to reflect the exact model of the object.

The third case, the one that is of principal interest in this paper is been elaborated in the next sections.

3. THE PROPOSAL FOR GENERATING A TRUE ORTHOIMAGE

The need for generating true orthoimage came up as a need in order to outline in a better and accurate way the product of the rectification process.

In the following a few reasons for the need of true orthoimage generation are presented:

1. The more precise representation of the object under rectification.
2. The conditions for object restitution are better, especially in the areas where the surface continuity changes.
3. The documentation restrictions are controlled better with a true orthoimage.
4. GIS applications suited under more well-defined specifications.

Focusing in close-range photogrammetric applications the motivation is the accurate documentation of architectural, archaeological or industrial objects. The orthoimage product can be used both for the accurate raster documentation and the extraction of vector data.

3.1 The use of a 3D model

According to the presented approach, the only structural background needed for the orthoimage generation is a 3D model describing the surfaces of the object.

A descriptive 3D model for the object may have a structure like the following, where each surface is described by the coordinates of its nodes.

```
begin
X1, Y1, Z1
X2, Y2, Z2
X3, Y3, Z3
X4, Y4, Z4
0,0,0
X5, Y5, Z5
X6, Y6, Z6
X7, Y7, Z7
0,0,0
.....
end
```

An example of such a 3D object model is given in the following by Figure 2.

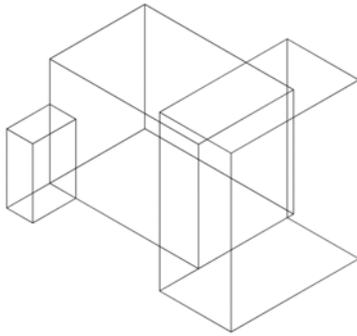


Figure 2. 3D object model

Each surface of the object corresponds to a single rectification plane. Combining all the planes of the structure the 3D model is constructed.

3.2 True Orthoimage generation

The true orthoimage is an image that is based on an orthographic projection taking into account the strict structural condition of the object.

The true orthoimage does not show any relief displacement as a result of the existence of a “perfect” structural model of the object. In this case, the orthographic projection directs the projecting rays in a perpendicular way to a horizontal plane. Consequently, obscured areas cannot be presented in a true orthoimage.

The height information in a 3D model is used to remove the height of hidden effects from the perspective image by reprojection. Frequently, for the production of an orthoimage more than one image can be used to acquire the full texture information.

Fundamentally, there are two basic approaches (Novak, 1992; Mikhail et al., 2001) for the generation of an orthoimage:

1. Forward projection
2. Backward projection

In the first case of forward projection, the pixels from the original image are projected on top of the DTM of the 3D model and the pixels’ object space coordinates are calculated. Then, the object space points are projected into the orthoimage. Because of the gap between the points projected into the orthoimage fluctuates -due to the terrain deviation and perspective effects- the final orthoimage pixels are generated by interpolation between the projected points.

In the other case of backward projection, the object space X,Y coordinates related to every pixel of the final orthoimage are determined. The height Z at a specific X,Y point is calculated from the DTM or the 3D model and then the X,Y,Z object space coordinates are projected in the original image in order to acquire the gray level value for the orthoimage pixel. Interpolation or resampling process in the original image is

essential because of the fact that the projected coordinates will not fit accurately at the original image pixel centres.

The main target of the true orthoimage process focuses on the representation of regions where abrupt changes of elevation appear.

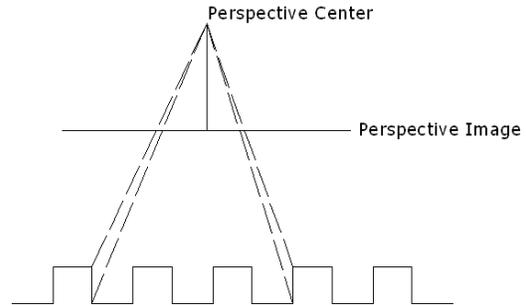


Figure 3. The “cavity problem” is crucial for true orthoimage generation

In Figure 3, the “cavity problem” is explained in a plan view outline. Due to the perspective geometry these areas must be eliminated during the true orthoimage generation. A 3D model like the one presented in Figure 2, is the appropriate material for the solution of the problem.

3.3 Explaining the algorithm

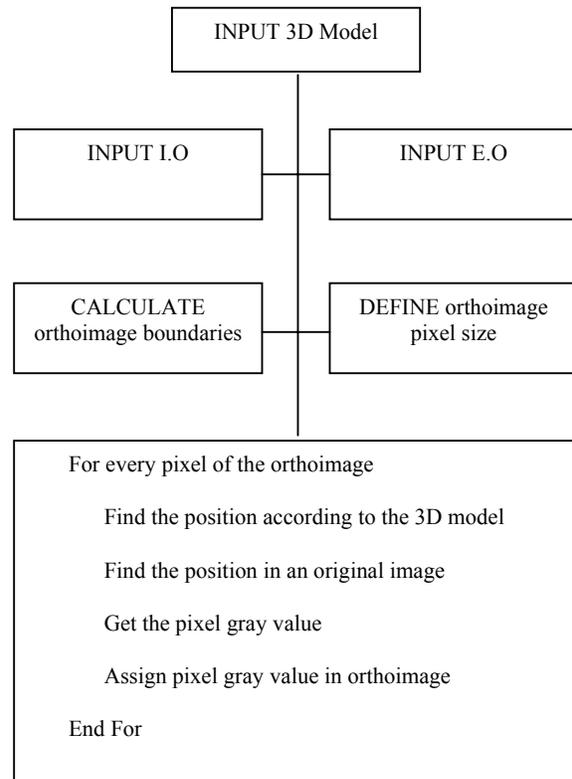


Figure 4. The true orthoimage framework production

The developed algorithm uses a set of data in order to produce a true orthoimage:

1. Interior Orientation
2. Exterior Orientation
3. 3D Model

In Figure 4, the build up algorithm for true orthoimage is illustrated.

The input data refer to the structure of the 3D model, the interior and exterior orientation. According to the needs of the orthoimage the output pixel size is defined. The extents of the orthoimage are determined by the boundaries of the 3D model.

Every pixel in the true orthoimage is calculated according to its position inside a specific close region of the 3D model. The texture for pixel values is taken backwards from the original images through the exterior orientation and the collinearity equations.

The developed algorithm is applied under real conditions, in an architectural Photogrammetry case study. The building shown in Figure 5 is under renovation and the photogrammetric restitution of all the facades is needed.

In Figures 5 (a) and (b) the products of conventional orthoimage and the true orthoimage respectively are illustrated. The differences are mainly visible in areas where the building lean problem is obvious.

4. TESTING THE ALGORITHM



(a)



(b)

Figure 5. (a) The conventional orthoimage. (b) The true orthoimage.

References from Journals:

Novak, K., 1992. Rectification of digital imagery. *Photogrammetric Engineering and Remote Sensing*, 58(3), pp. 339-344.

References from Books:

Mikhail, E. M., Bethel, J. S., McGlone, J. C., 2001. *Introduction to Modern Photogrammetry*. Wiley, New York, pp. 234-238.

References from Other Literature:

Amhar, F., Ecker R., 1996. An integrated solution for the problems of 3D man-made objects in digital orthophotos. *The International Archives of Photogrammetry & Remote Sensing*, Vienna, Austria, Vol. XXXI, Part B4, pp.

Schikler, W., Thorpe, A., 1998. Operational procedure for automatic true orthophoto generation. *The International Archives of Photogrammetry & Remote Sensing*, Corfu, Greece, Vol. XXXII, Part 4, pp.

Stylianidis, E., Sechidis, L., Patias, P. and Spatalas, S., 2000. Generating orthoimages for close-range objects by automatically detecting breaklines. *In: 4th International Symposium «Turkish-German Joint Geodetic Days»*, April 3-6, Berlin.

Stylianidis, E. and P. Patias, 2002. 3D object reconstruction in close-range photogrammetric problems. *The International Archives of Photogrammetry & Remote Sensing*, Corfu, Greece, Vol. XXXIV, Part B5, pp. 216-220.

References from websites:

Boccardo, P., Dequal, S., Lingua, A. and Rinaudo, F., 2003. True digital orthophoto for architectural and archaeological applications
http://www.arkeologi.net/index1.php?id=view_news&ct_news=131 (accessed 23 Apr. 2004)