DIGITAL ORTHOPHOTO USING MULTI IMAGE MATCHING

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ABSTRACT:

The paper describes the new possibility for the production of digital orthophotos. With the method of multi image matching it is possible to include many images for the computation. In this case the problems with covering regions are cancelled, because the information for the whole object exist.

First results in architectural photogrammetry will be presented.

KEY WORDS: Multi Image Matching, Digital Orthophoto

1. INTRODUCTION

In all fields of photogrammetry there is a tendency to automate the diverse procedures as far as possible. This tendency is supported by improvements in software and hardware (e.g. bigger capacities, shorter computing times) and by the development of new algorithms.

The same holds for the production of digital orthophotos which aims at a maximum degree of automation, too. However, in the field of digital orthophoto the problems with covering regions have not been solved yet. Uneven surfaces and protruding objects (e.g. columns) still represent a problem for the exact survey of pieces of architecture.

An object can only described exactly and completely by means of several images from different angles (Fig. 1-1).

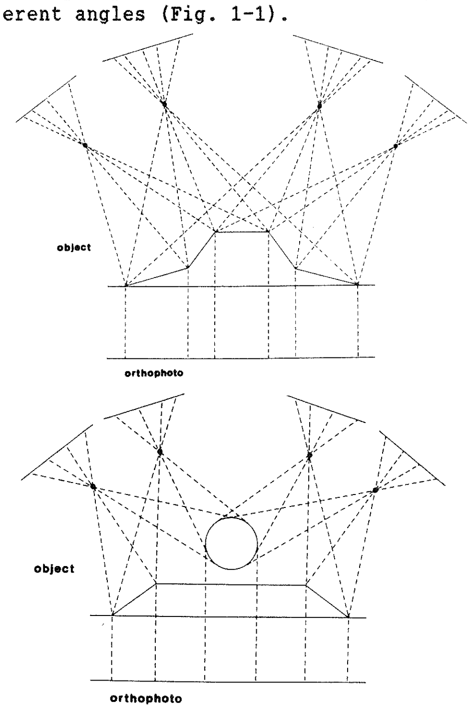


Figure 1-1 : Image configuration for the description of an object

In this paper I will present the method of digital multi image matching which is capable of including several pictures at once in the computation. It thus produces a complete image of the object, which is then called : digital multi image orthophoto.

The realization of this method is based on the program system PROSurf (Photogrammetric Reconstruction of Object SURFaces) as described by /SCHNEIDER 1991/. Similar methods were introduced by /HEIPKE 1991/ and /WEISENSEE 1991/.

In the following, the algorithm necessary for the program, and the preparatory procedures will be presented, as well as two examples of the production of digital multi image orthophotos.

2. THE FUNDAMENTAL PRINCIPLES OF THE METHOD

This method is based on an algorithm used for object-based multi-image matching /EBNER ET. AL 1987, /WROBEL 1987/, /HELEVA 1988/. The eventual aim of the method is the reconstruction of an object surface from digital images, in accordance with the photogrammetric imaging rules. In order to achieve this, it is necessary to construct a functional interrelation between the gray values of the image [g(x',y')] on the one hand, and the radiometrical and geometrical model of the object surface on the other hand.

When a square grid in the X-Y plane is used for the description of the object surface, the grid points will generate the functions Z(X,Y) for the geometrical model and G(X,Y) for the radiometrical model.

The grid areas of the geometrical model and the radiometrical model are called surface meshes and surface elements respectively. Each surface element corresponds to a certain gray value of the image (Fig. 2-1).

With the surface structure and the orientation parameters given, the image coordinates of the surface elements can now computed. After transforming the image

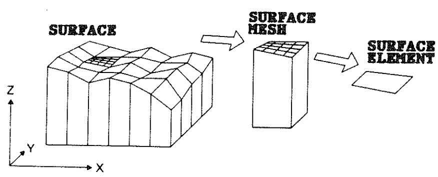


Figure 2-1 : Description of the surface with surface meshes and surface elements (from /SCHNEIDER 1989/)

coordinate system into the coordinate system of the digital image, and thus creating the image points, one can assign certain gray values to these image points.

In view of the reflective qualities of the surface, the imaging of the gray value of a surface element is identical with the gray value of the surface. Therefore the imaging can be regarded as an observation.

While up to now, the knowledge of the surface has only been assumed, the surface is now described by approximate coordinates of the grid points. When a surface element of an image is transferred to the other images of the same object with the help of the above-mentioned approximate coordinates, the coordinates and the gray value of the element change.

The discrepancy between this new gray value and the corresponding gray value of the object is the residual. The square sum of the residuals can be minimized through adjustment according to the method of the least squares, with the image gray values being the observations and the object gray values being the unknowns.

The functional model of the adjustment includes the following observation equation for each image gray value :

$$v_{i,j} = G_i - g_{i,j}\ (Z,O) \qquad (2.1)$$

with :
- v = residuals
- i = number of the surface elements
- j = number of the images
- G = object gray value
- g = image gray value
- O = orientation parameters
- Z = $Z_1,\ldots,Z_4$, grid coordinates

After a Taylor linearization in O and Z, the equation can be solved according to the known adjustment algorithm /EBNER, HEIPKE 1988/.

By using the approximate unknowns, which are defined through iteration processes, new image gray values can be found and applied as observations in the following adjustments.

For the creation of digital multi image orthophotos it is necessary to simultaneously define the radiometrical corrections. This can be achieved by using the gray value spectrum of one image as a constant and adjusting the other images and their gray values to it (2.2). The corrections of the surface meshes remain constant in this procedure.

$$g_{i,j} = r1_j + r2_j\ g'_{i,j} \qquad (2.2)$$

with :
- $g'_{i,j}$ = image gray value
- $g_{i,j}$ = corrected gray value
- $r1_j, r2_j$ = radiometrical corrections

3. PREPARATORY PROCEDURES

Digital images are the fundamental data for digital multi image matching. Basically, there are two ways of producing these digital images.

First, CCD-sensors can be used for the creation of images. They produce digital images right away, which is an advantage for further procedures. These sensors were examined and tested with regard to their photogrammetric applicability and their geometric and electronic precision e.g. by /LUHMANN, WESTER-EBBINGHAUS 1986/, /BEHR 1989/, /BÖSEMANN ET. AL 1990/.

Second, if only analog images are available, or if the resolution of a common film can not be done without, the images have to be digitized by scanners which operate on different kind of sensors. Hard- and software which are able to support this technique were described by /SINNREICH 1989/ and /FAUST 1989/ e.g..

For the computation of digital multi image orthophotos the orientation parameters of the digital images have to be known. Therefore, it is necessary to measure homologous points in the images first. The orientation parameters can then be defined by means of photogrammetric bundle triangulation and adjustment according to the method of least squares /WESTER-EBBINGHAUS 1985/.

Bundle triangulation can help define the parameters of the interior orientation as well (simultaneous camera calibration) /PEIPE 1985/, /WESTER-EBBINGHAUS 1986/.

4. PERFORMING MULTI IMAGE MATCHING

As mentioned above, the method for the computation of digital multi image orthophoto is based on the program system PROSurf.

Before the actual computation can be started, size and number of the surface elements must be defined. These control parameters depend on pixel size, imaging scale and the structure of the object; these features fundamentally determine the quality of the orthophoto.

The starting data, i.e. the starting coordinates for the multi image matching, can be yielded by defining points manually or by using points from the previous adjustment.

It is indispensable for the creation of orthophotos that the surface meshes are contiguous, if the object is to be described in its entirety. For this purpose, a measuring strategy has been developed which processes the images in a meander-shaped way. Furthermore, the approximate figures of the surrounding heights serve as heights for the grid points of the surface meshes.

It is inevitable to test the convergence rate and to set up stopping rules for the computation, as the orthophotos are computed iteratively. The standard deviation of the weight unit, the average unknown corrections, or the average residuals of the observations can be employed as characteristics. If the system does not converge, or if there are gross errors, the characteristics minima will not be reached, so that the set number of iterations is exceeded. This will stop the computation.

In addition to those characteristics already mentioned, a correlation coefficient which serves as similarity rate is used in multi image matching. This coefficient defines the similarity between the gray dispersion of the object surface and the corresponding gray scale dispersion of the image; it is computed for each image according to equation (4.1) /SACHS 1973/.

$$r_i = \frac{[g_{i,j} * G_j] - [g_{i,j}] * [G_j] / n}{(([g_{i,j}{}^2]-[g_{i,j}]^2/n)*([G_j{}^2]-[G_j]^2/n))^2} \qquad (4.1)$$

with : r_i = correlation coefficient
$g_{i,j}$ = image gray value
G_j = object gray value
n = number of surface elements
i = image index
j = surface element index

Réseau crosses, total reflexion or lacking object structure may cause signal disturbances in the images. In this case, the correlation coefficient is considerably lower than the average of all coefficients.

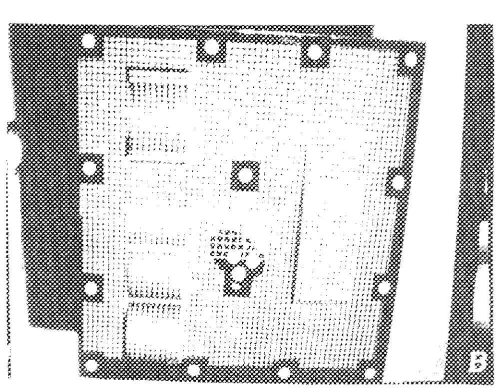
In the method that is being presented in this paper, images with signal disturbances will be excluded from further computations by means of the correlation coefficient.

5. APPLICATIONS

In the following, two examples will be presented to illustrate possible applications of digital multi image orthophotos and the method of its computation.

5.1 Example 1 : Testfield

A testfield with an affixed texture serves as a first example (see Fig. 5-1). In this case CCD-sensors were used to create digital images.



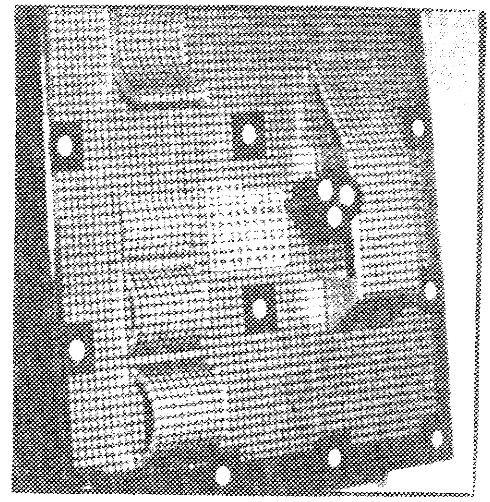


Figure 5-1 : Digital images of the testfield

The parameters of the interior and exterior orientation were defined during preliminary measurings. For the computation of the multi image matching, the size of the single surface elements was set at 1 x 1 mm². The number of elements per mesh was 15 x 15.

Figure 5-2 shows the operating display of the multi image matching.

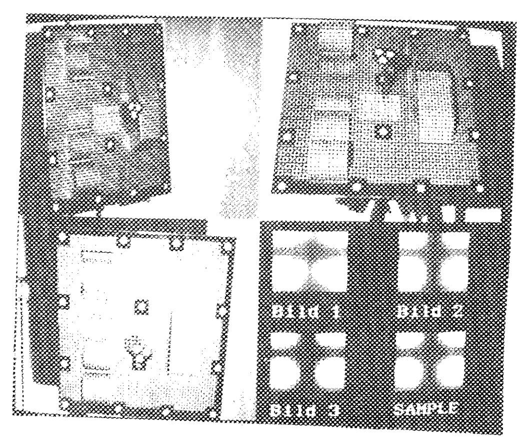


Figure 5-2 : Operating display

The meshes of the single images and the result of one iteration (see SAMPLE) is shown in figure 5-3.

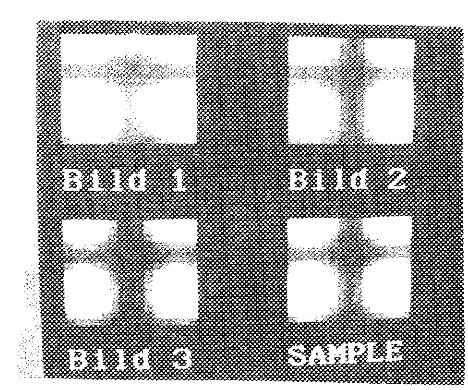


Figure 5-3 : Control display

In order to display the advantages of multi image matching, only the middle part of the testfield was processed. Figure 5-1 and 5-2 show, that different areas are covered in the different images.

The digital multi image orthophoto, on the other hand, reconstructs the complete field without any covering areas (Fig. 5-4).

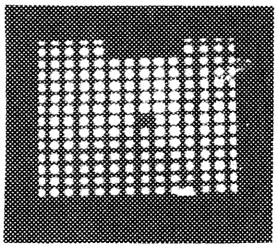


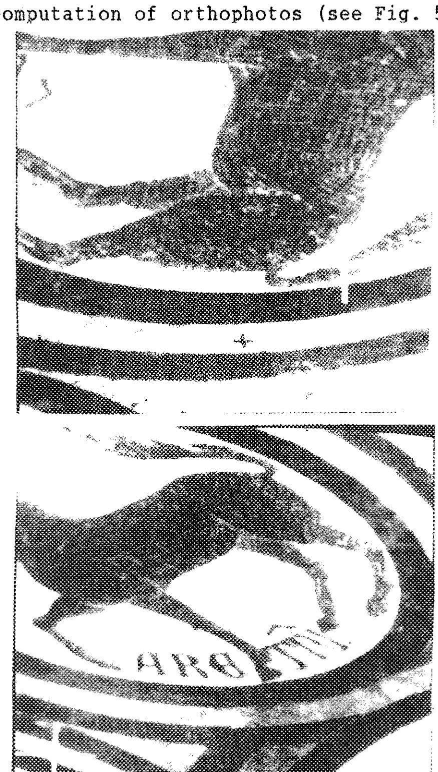
Figure 5-4 : A sector of the multi image orthophoto

5.2 Example 2 : Natural object

A natural object from the field of architecture photogrammetry was selected as a second example : the tessellated floor in the cathedral of Siena (Italy).

A Rollei 6006 camera was used to take the photographs, and a Rollei RS_1 scanner digitized the photographs /SINNREICH 1989/. The parameters of the interior and exterior orientation were defined in preparatory measurings. For this example, the size of the surface elements was 1,5 x 1,5 mm², the size of the mesh was 15 x 15.

Figure 5-5 shows the different sections of the mosaic. This example proved that natural textures also supply sufficient information for the computation of orthophotos (see Fig. 5-6).



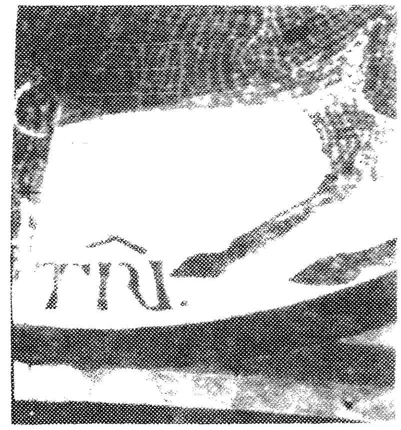


Figure 5-5 : Sections of the mosaic

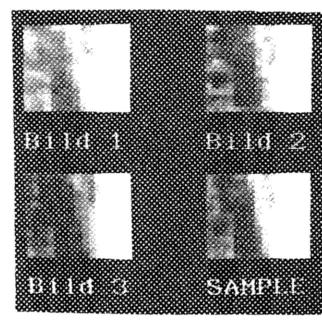


Figure 5-6 : Surface meshes of the single images and resulting mesh

The overall result of this multi image matching is satisfactory (see Fig. 5-7). As the number of white sectors in the figure indicates, there are only very few failures left after the computation. However, more appropriate configurations of the recording stations and/or photographs of higher quality should diminish or completely eliminate the failures.

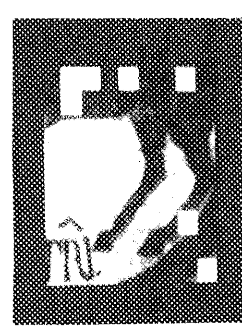


Figure 5-7 : A sector of the multi image orthophoto

6. CONCLUSION

In this paper I concentrated on simple examples from the initial stages of digital multi image matching and the creation of digital multi image orthophotos.

At present, the IPB is engaged in preparing self-controlled concepts for digital orthophotos, that means, for example, searching criteria which guarantee the exclusion of failures and lead to exact surface reconstructions.

Finally, the digital multi image matching has proved to be an appropriate and practicable method for the creation of digital orthophotos.

7. LITERATURE

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