DIGITAL ORTHOIMAGES IN ARCHITECTURAL PHOTOGRAMMETRY USING DIGITAL SURFACE MODELS

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ABSTRACT:

The paper describes a new approach for the generation of architectural orthoimages using digital surface models, based on a CAD model of the object. The model is supposed to consist of surface elements, plane or curved. All surface elements of the CAD model are orthogonally projected onto the reference plane. For each grid element the elevation above or below the reference plane are calculated and stored in a corresponding digital surface model with the same grid distance as the required orthoimage. Higher elevations replace lower elevations. The result is a matrix with the maximum elevations over the reference plane. To calculate the grey value of each pixel in the orthoimage the corresponding position in the distorted image has to be determined. This can be achieved using the collinearity equations, the data of the interior and exterior orientation of the distorted image and the digital surface model. Occluded areas have to be excluded from the calculations.

KURZFASSUNG:

Es wird ein neuer Ansatz zur Erstellung digitaler Orthophotos in der Architekturphotogrammetrie beschrieben. Er basiert auf einem Digitalen Oberflächenmodell, welches aus einem CAD-Modell des Objekts hergeleitet wurde. Das CAD-Modell muß aus ebenen oder gekrümmten Flächen bestehen. Das Digitale Oberflächenmodell ist ein Raster mit der Rasterweite des gewünschten Digitalen Orthophotos. Für jedes Rasterelement wird die senkrechte Höhe über der Projektionsebene berechnet und registriert. Liegen über einem Rasterelement des Oberflächenmodells mehrere Flächen, wird die höchste gewählt. Um den Grauwert jedes Pixels des Orthophotos zu ermitteln, muß die entsprechende Position im verzerrten Bild berechnet werden. Hierzu sind neben dem Digitalen Oberflächenmodell in den Kollinearitätsgleichungen die Daten der inneren und äußeren Orientierung des verzerrten Bildes erforderlich. Sichttote Räume müssen aus der Berechnung ausgeschlossen werden.

1. INTRODUCTION

The application of photogrammetry in civil and building engineering is not so much customary as experts on photogrammetry would like it. One of the reasons is the time delay between the acquisition of images and the delivery of the restitution results as well as the costs of the restitution process. Another reason is that the customer receives the result of an interpretation process of the photogrammetric operator. The purchaser has often problems to describe exactly, which data he needs and in some cases the photogrammetric operator misunderstands the order.

In aerial photogrammetry orthoimages are cheap and fast available products with the geometric properties of maps, containing however the entire information of the image. The customer may extract the required data by himself from the geometrically exact orthoimage.

Non-parametric approaches, like the projective rectification, deliver good results if the objects surface is completly plane. Fig. 1 shows a typical architectural image, Fig. 2 the result of a projective rectification and the limitations of this approach. If the surface consists of several planes the rectification may be carried out in separate steps and the results have to be combined afterwards (Marten et al. 1994). But the interactive partitioning is a tedious task and is not suitable for irregularly curved surfaces. Therefore a parametric approach using the exterior orientation of the image and a Digital Surface Model (DSM) is desirable.

In architectural photogrammetry the difference between the shortest and the longest distance to the object is much larger than in aerial photogrammetry. Therefore errors in the digital surface models have an enormous influence on the accuracy of the produced orthoimages. Errors in the planimetric position of discontinuities of the object's surface lead to unacceptable results.

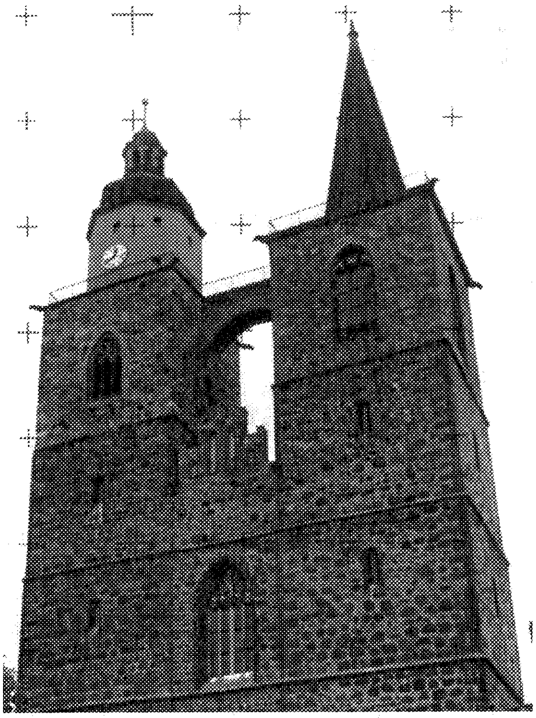

Fig. 1: Raw image from a Rolleiflex 6006 metric with 50 mm focal length

The presented example is the western facade of the Nikolai Church in Jüterbog, south of Berlin, Germany. The image is not optimized for the generation of an orthoimage, but it is well suited to present the nature of the new approach.

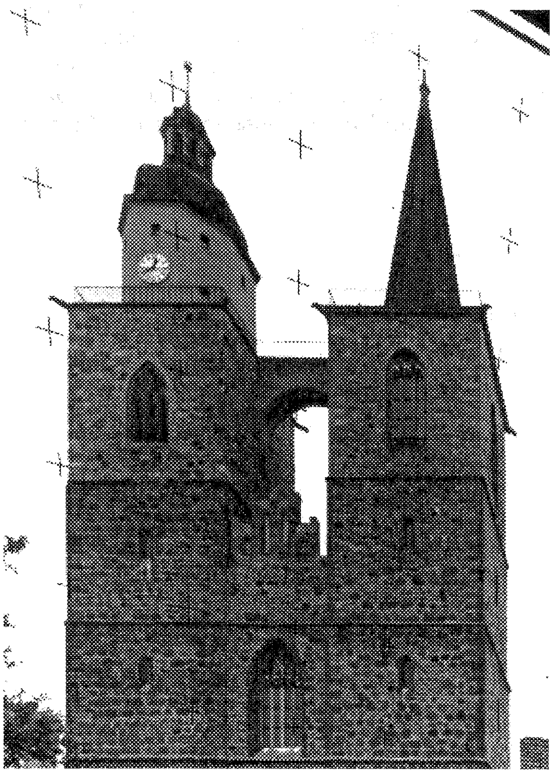

Fig. 2: Rectified image using projective transformation (scale 1:400)

2. DIGITAL SURFACE MODEL

Customary software products for the generation of surface models are designed for digital terrain models. Consequently they are well suited to handle changes in the slopes of surfaces, but not discontinuities in the surface itself.

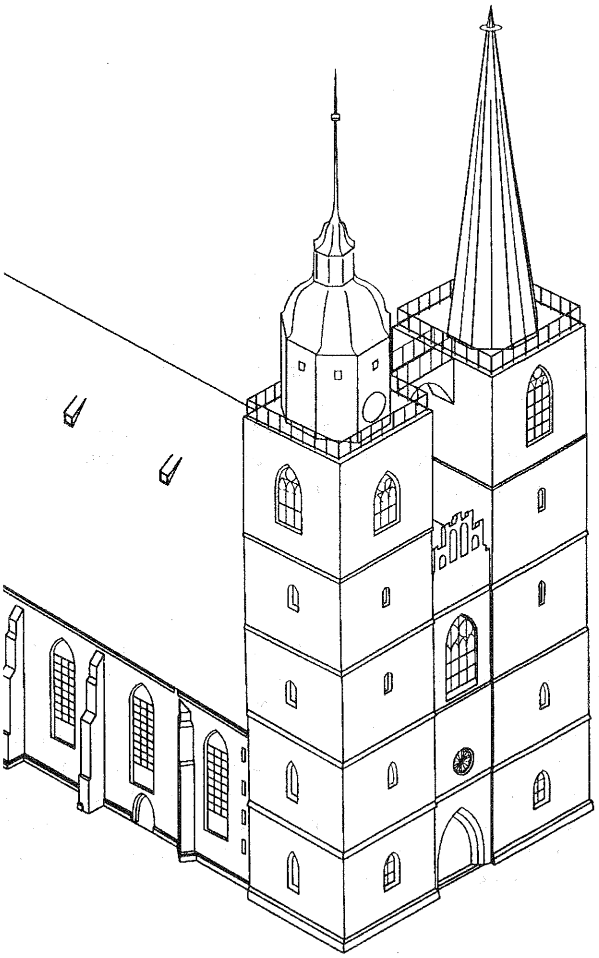

Fig. 3: Plot of a CAD Model of the object

The new surface modelling approach is based on the usage of a CAD model (Fig. 3) of the object to generate a Digital Surface Model (DSM). The CAD model may be the result of a reduced restitution process only taking such edges into account, that have an influence on the shape of the surface. In some cases already existing CAD models may be used. The model is supposed to consist of surface elements, plane or curved, or of volume elements (Li 1993). If only a point or wire model is available, surfaces have to be generated by connecting the existing points and lines.

In this example a digital photogrammetric measurement tool (IMDIS), a meshwise numerical transformation between pixel coordinates and metric image coordinates making use of the réseau crosses, and bundle adjustment (PICTRAN) were used in order to calculate image orien-

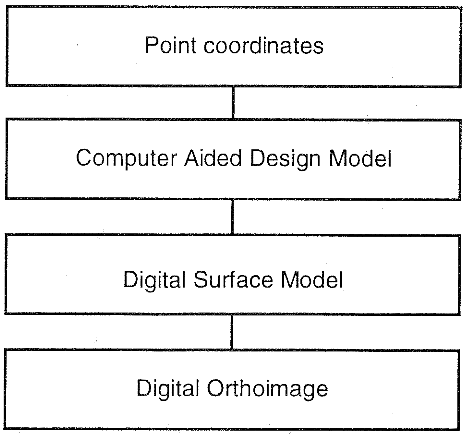

Fig. 4: Typical flow of geometric data

tations and object coordinates. The object points have been connected to closed polygons to build up a CAD model, consisting of surfaces.

The next step is to define a reference plane for the desired orthoimage. Usually it will be parallel to one of the buildings facades. On this reference plane an orthoimage grid with the required resolution has to be defined. Each grid element has corresponding object coordinates. The relations between the pixel matrix of the orthoimage and the object coordinates are usually linear.

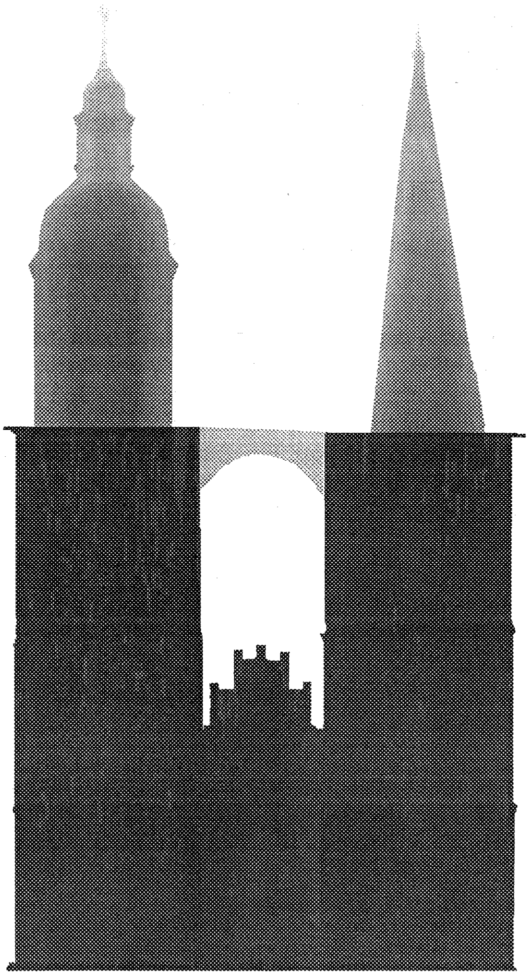

Fig. 5: Digital Surface Model (scale 1:400)

A second matrix, equivalent to the requested orthoimage and with the same grid distance, will be generated to store the data of the DSM. All surface elements of the CAD model are orthogonally projected onto this reference plane. For each grid element the elevation above or below the projection plane has to be calculated and stored in the DSM matrix. Higher elevations replace lower elevations. The result is a matrix with the maximum elevations over the projection plane. Fig. 4 shows the geometric data flow.

Fig. 5 shows a pictorial representation of the used Digital Surface Model. Closer points on the surface are displayed darker than points further away. Linear features, like the fence around the platforms on the towers, are not represented in the DSM.

To refine the DSM matching techniques may be used. This will be necessary in areas where surface elements, e.g. sculptures, can not be described by a traditional CAD model. Whereas image based matching may refine the surface between edges, feature based matching may improve the three-dimensional accuracy of detected edges. This technique was not yet used in this example project, but it is under development.

3. DIGITAL ORTHOIMAGE

Before starting the calculation of the digital orthoimage, the data of the exterior orientation should be transformed into a new coordinate system. The result is a rectification coordinate system, with the XY-plane parallel to the reference plane, and the scale of the object coordinate system. If the reference plane is parallel to a coordinate plane of the object coordinate system, this can be done by changing axes. This rectification system reduces calculations in the time consuming detection of occluded areas and accelerates the rectification process.

In the past the calculation time for digital orthoimages has been a matter of concern (Mayr & Heipke 1988). For a long time, anchor techniques have been used to accelerate the calculations. This is no more necessary because of the improvements in computer performance. Consequently a pixel by pixel process can be used. Each pixel of the orthoimage has to flow through the calculations cascade illustrated in Fig. 6.

Starting at the row and column in the image matrix of the orthoimage the metric coordinates of the point on the defined reference plane can be calculated. The results are the X and Y coordinates in the rectification system.

The elevation of the point can be extracted from the digital surface model and we get a full 3D coordinate triple.

If the ray between the object point and the rectification coordinates of the projection center intersects the DSM, the point lies in an occluded area and no grey value can be defined. The process has to restart with the next pixel of the orthoimage. In the present state of the software for orthoimage production this step is the most time consuming and needs further optimization.

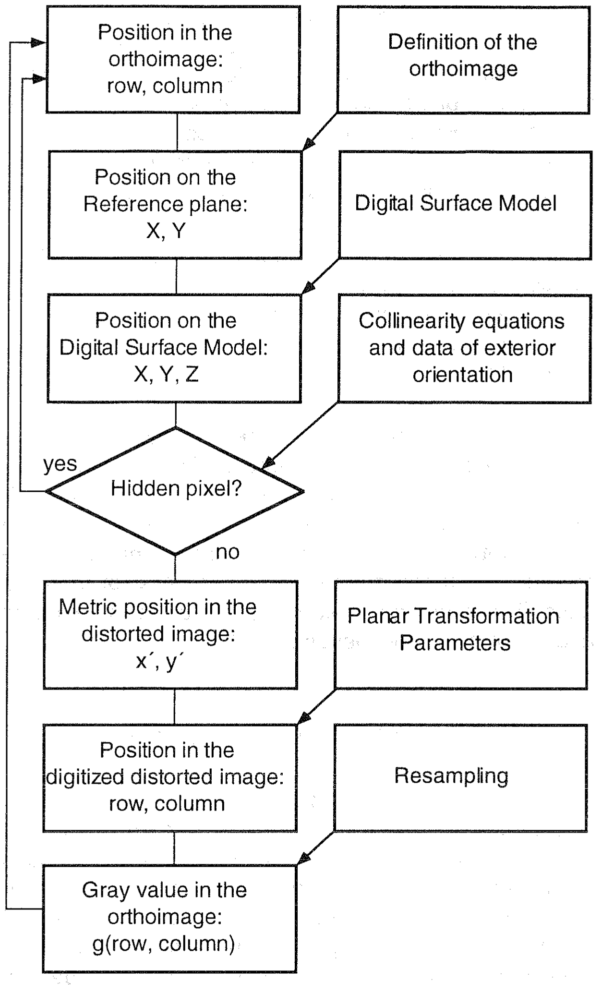

Fig. 6: Calculation cascade for each pixel of the orthoimage

Using the collinearity equations, the transformed data of the exterior orientation and the data of the interior orientation of the distorted image the metric image coordinates in the distorted image are calculated.

Planar transformations, like affine or projective approaches, are usually used for the transformations between the metric image coordinates and the matrix of the digital images. A meshwise transformation to be integrated in this calculation cascade is under development. The row and column of the point in the digital matrix of the distorted image is determined in sub-pixel accuracy.

The grey value of the point is calculated by resampling techniques, like Nearest Neighbour or Bicubic Interpolation, and transferred to its corresponding position in the digital image matrix of the orthoimage. In the example an improved Bilinear Interpolation has been used. For colour images only this final step has to be repeated for each band.

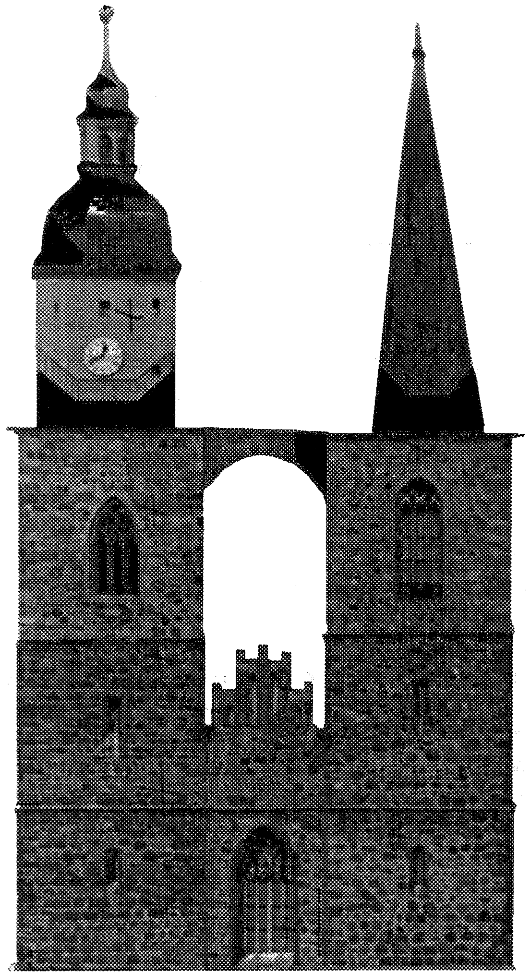

Fig. 7: Orthoimage (Scale 1:400)

Fig. 7 shows a digital orthoimage, derived from the image displayed in Fig. 1. This example clearly demonstrates the advantages compared to the classical approach (Fig. 2), but also the limitations of the new approach compared with the optimum solution. Fig. 8 shows an image, taken from long distance with a long focal length, which provides an impression of the product we would like to produce.

The calculations have been carried out on a Silicon Graphics computer with 150 MHz and took about 4:30 min for the combined calculation of the DSM and the digital orthoimage. The resolution is 2.5 cm on the objects surface, the DSM and the orthoimage have 1100 · 2050 grid elements.

For white areas no DSM data are available, black pixels represent occluded areas. On the upper left part of the left tower, we see hidden areas and unsharp regions as a result of the extremely small angles between the surface of the object and the imaging rays.

An other problem comes from object elements, which are not represented in the Digital Surface Model, like the

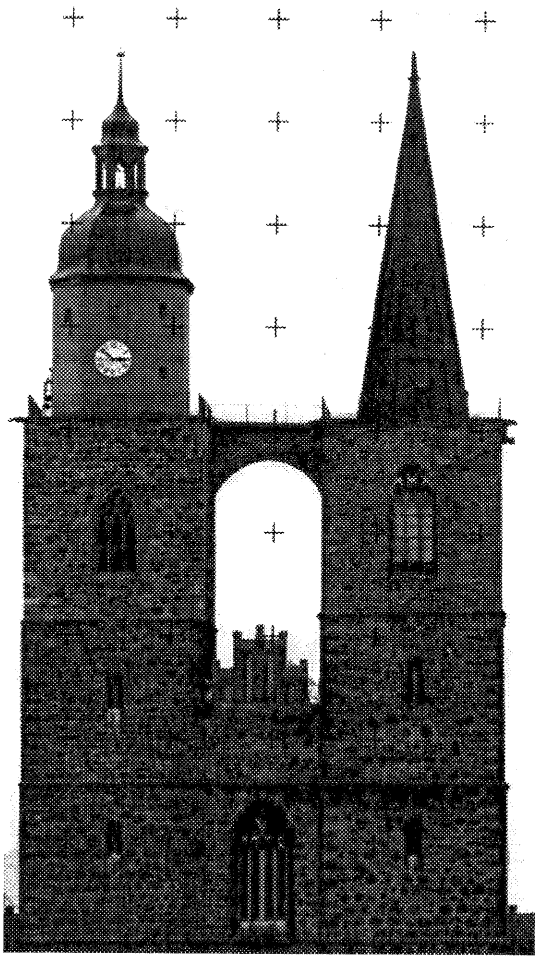

Fig. 8: Comparable image from a distant point of view, taken with a Rolleiflex 6006 metric, focal length 250 mm

fence around the platforms on the towers. This objects are displayed at wrong positions. Problems like this could only be resolved by refining the DSM.

4. POST PROCESSING

The generation of orthoimages may be carried out with more than one distorted image. The necessary information to fill occluded areas may be extracted from a second image. But in this case differences in the radiometric information (brightness, contrast etc.) of the two orthoimages have to be considered. This may be achieved by radiometric mosaicking developed for mapping purposes (Scholten 1996).

An additional post processing technique may be the geometric comparison of two orthoimages, interactively or automatically by matching techniques. If the images have been exposed at the same day, local geometric differences of the two orthoimages can be explained as errors in the DSM. If the two images are from different exposure dates the differences may be the results of changes of the object. This approach could be used for automatic damage analysis.

5. CONCLUSION

At present the generation of the CAD model is the most tedious task in the production of orthoimages. New developments, such as semi-automatic or automatic digital restitution techniques, will accelerate this process and provide the necessary data fast and cheap (Streilein 1994). New users of orthoimages can be anticipated in the world of computer graphics. Orthoimages are well suited for texture mapping in Virtual Reality Models.

Architectural photogrammetric data may be used for the documentation of historical sites and monuments, for the determination of damages, or for civil and building engineering purposes. The requirements for such data are undisputed (Waldhäusel 1992) and permanently confirmed by the news about destroyed buildings we see every day on TV.

The rectification of architectural imagery has a very long tradition. But thanks to the digital image processing also a successful future, and new users can be anticipated.

REFERENCES

Li, R., 1993. Generation of geometric representations of 3D objects in CAD/CAM by digital photogrammetry. ISPRS Journal of Photogrammetry and Remote Sensing, 48(5): pp. 2-11.

Marten, W., L. Mauelshagen & R. Pallaske 1994. Digital orthoimage-system for architecture representation. ISPRS Journal of Photogrammetry and Remote Sensing, 49(5): pp. 16-22.

Mayr, W. & Ch. Heipke 1988. A Contribution to Digital Orthophoto Generation. In: International Archives of Photogrammetry and Remote Sensing, Kyoto, Japan, Vol. XXVII, Part. B11, pp. 430-439.

Scholten, F., 1996. Automated Generation of Coloured Orthoimages and Image Mosaics Using HRSC and WAOSS Data of the Mars 96 Mission. In: International Archives of Photogrammetry and Remote Sensing, Wien, Austria, Vol. XXXI, Part. B3.

Streilein, A., 1994. Towards automation in architectural photogrammetry: CAD-based 3D-feature extraction. ISPRS Journal of Photogrammetry and Remote Sensing, 49(5): pp. 4-15.

Waldhäusl, P., 1992. Defining the future of Architectural Photogrammetry. In: International Archives of Photogrammetry and Remote Sensing, Washington, USA, Vol. XXIX, Part. B5, pp. 767-770.