Digital Architectural Photogrammetry for Building Registration

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Abstract

Architectural photogrammetry is a technique to acquire 3D geometric data of buildings for a CAD model from images. In this paper the state of the art in architectural photogrammetry and some developments towards automation are described. Special attention is put on digital methods, from digital image acquisition to restitution methodes, supported by digital image processing.

Kurzfassung

Architekturphotogrammetrie ist eine Technik zur Erfassung dreidimensionaler geometrischer Daten über Bauwerke aus Bildern. In diesem Aufsatz wird der Stand der Technik und einige Entwicklungen in Richtung Automation beschrieben. Besondere Aufmerksamkeit wird digitalen Methoden entgegengebracht, von der digitalen Bildaufzeichnung bis zu Auswertemethoden, die von digitalen Bildverarbeitungsmethoden unterstützt werden.

1. Introduction

For many purposes geometric information about existing buildings in plans or CAD models is necessary, e.g. planing of conservation or reconstruction. If the data are still available from the construction process, they may have insufficient actuality. In a modern planing environment 3D CAD data are preferred, showing the actual state of the building. This data may be acquired by a manual measurement using ladders and scaffoldings, by geodetic survey using theodolites or reflectorless tachymeters, or by photogrammetry.

1.1 Advantages of Photogrammetry

Photogrammetry is an indirect technique to acquire 3D geometric data without touching, but using images of the object. The architectural photogrammetry was introduced during the late 19th century by the civil engineer ALBRECHT MEYDENBAUER.

The field operations are reduced to the image acquisition and the geodetic survey of a few control points. The main work will be done at any time and any place independently from the building, because the geometry of the object is stored in the images. Images contain much more data than any construction plan. If the building is destroyed or damaged and images are available, photogrammetry can provide sufficient data for reconstruction.

1.2 Measurement of Image Coordinates

In photogrammetry we usually measure the 2D image coordinates of points in two or more images and calculate the 3D coordinates in a superior coordinate system.

Therefore an instrument for the measurement of image coordinates is necessary. In classical photogrammetry this is usually done with special high precision (and expensive) hardware, like comparators or analytical plotters. In a first step towards digital techniques, digitizers have been used for the measurement on photographic enlarged copies. In digital photogrammetry this is done on screen using the pixel coordinate system defined by rows and columns. If analogue image sources have to be used, they must be scanned on an image scanner. One of the advantages is, that digital image processing techniques can be used to accelerate the measurement process. The measured coordinates refer to a comparator, a digitizer or a screen coordinate system.

2. Photogrammetric Process

2.1 Image Acquisition

The first part of the photogrammetric process is the acquisition of the images with analogue photographic or digital cameras. The analogue imaging devices can be metric, semi-metric or amateur cameras. During the last years some digital cameras have been developed using a CCD arrays. But whereas the low budget cameras have an insufficient resolution, cameras with larger CCD arrays are still expensive. But a development towards cheaper and better digital cameras can be anticipated for the near future. This will allow a fast digital data flow, avoiding the time consuming wet photographic processes.

Each point, which is required for the complete restitution of the object, has to be displayed on at least two images from different points of view. If it is desired to view the object in a stereoscopic manner, the images have to be taken according to the so called *normal case of photogrammetry* with nearly parallel directions of view from two points on a horizontal base, perpendicular to the viewing directions. This arrangement is similar to the arrangement of the human eyes.

If the pictures are acquired especially for photogrammetric purposes, the imaging team will survey a few control points by geodetic techniques. Control points are points with 3D coordinates in a superior coordinate system, which can be identified and measured in at least one image. They are necessary for the orientation to follow, which is the second step of the photogrammetric process.

2.2 Orientation

The orientation procedure consists of the reconstruction of the interior orientation, which describes the geometry of the ray bundle in the camera, and the exterior orientation. The interior orientation specifies the functional dependencies between the principal point and the point, where the light ray intersects the image plain. The position of this intersection point is described by image coordinates. If the used camera is calibrated, this may be done by transforming the measured coordinates into a calibration system, defined by fiducial marks or reseau crosses. If no calibrated camera has been used, an independent set of parameters of the interior orientation is necessary for each image. In frame cameras independent parameters of the interior orientation are only required if the zoom factor or the focus of the camera has been changed during the image acquisition.

The exterior orientation describes the position and the viewing direction of the camera in a superior object coordinate system and is today usually calculated by a bundle adjustment. This is the simultaneous calculation of the data of the exterior orientation, the data of interior orientation (if required) and the 3D coordinates of the points, of which two or more pairs of image coordinates are available. For this purpose at least three control points and 5-10 tie points per image are required. Tie points have to be identified and measured in at least two images. For each image at least six unknowns (three coordinates for the position, three rotations and if required parameters of the interior orientation) and for each object point three coordinates have to be estimated. The unknowns can be calculated by a least squares adjustment if more observations than unknowns are available. The more control and tie points are available, the better the results of the orientation process in terms of accuracy and reliability can be obtained.

2.3 Photogrammetric Restitution

The conventional photogrammetric restitution is usually done on special photogrammetric hardware providing a stereoscopic view of the situation and a 3D floating mark. The floating mark can be moved over the object following edges and lines. The motion of the floating mark will be recorded on paper or digital in a CAD model. For each point to be registered, three parameters (the 3 coordinates) have to be adjusted. A result of a stereophotogrammetric restitution on a analytical plotter is displayed in Fig 1.

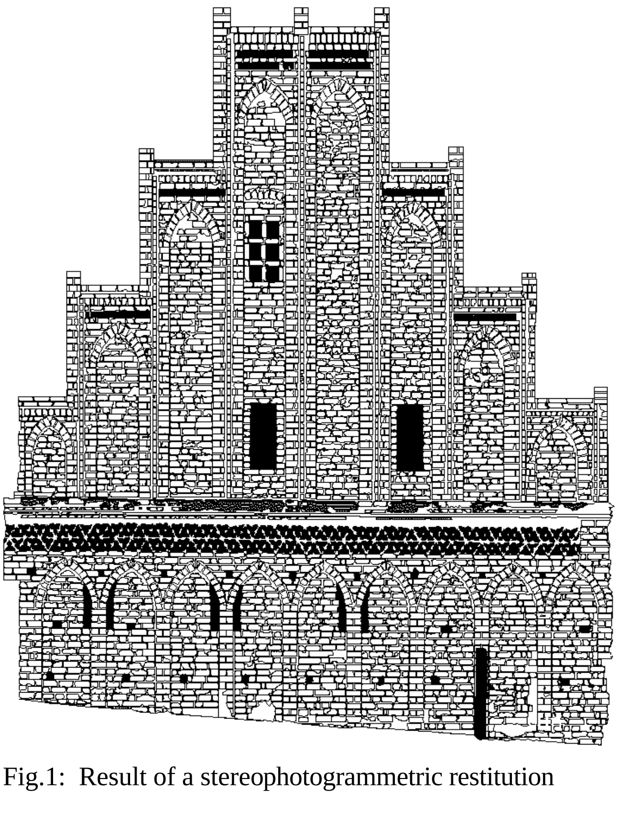

Fig.1: Result of a stereophotogrammetric restitution

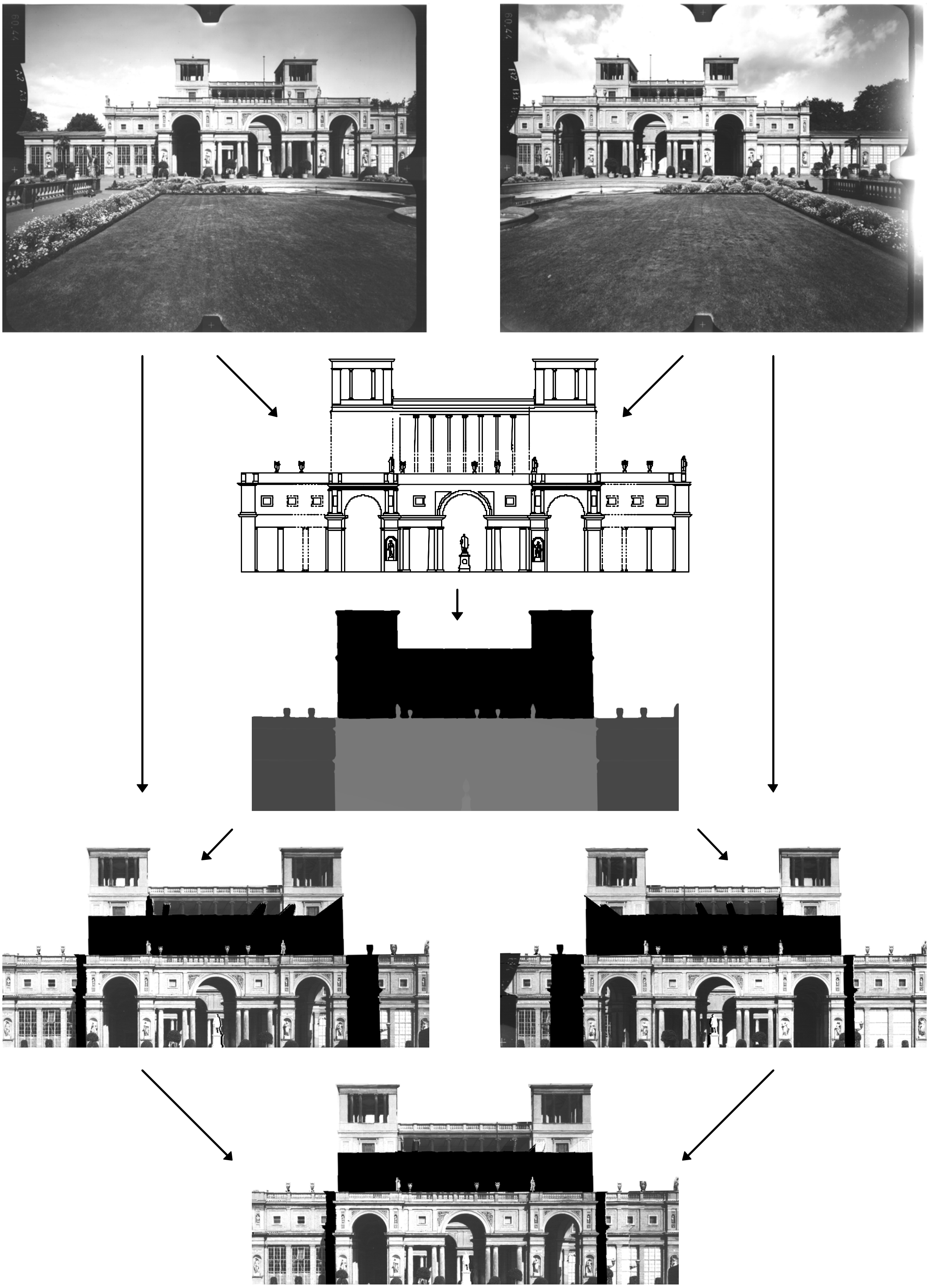

Fig. 2: Data flow for the generation of Digital Orthoimages

If a digitizer or screen is used for coordinate measurement without stereoscopic view, it is necessary to record the position of an object point in at least two images for the calculation of the three required object coordinates. In many cases it is difficult to measure the same features in two or more images because the are not sufficient definite points at the features. Only stereo systems enable the 3D measurement of curved lines without definite points (ALBERTZ & WIEDEMANN 1995). Some digital measurement programs support the measurement of corresponding points by displaying the already measured image rays in the following images.

2.4 Orthoimages

Orthoimages combine the geometric properties of plans with the contents of images by rectification. If the surface of the object is plain, this may be done by a rectification process based on a planar projective transformation.

In the other cases, a differential rectification is necessary to derive digital orthoimages. The data flow for the generation of digital orthoimages is presented in Fig.2. A photogrammetric restitution delivers data for a 3D CAD model. A Digital Surface Model can be derived from this data by calculating the maximum distances of the objects surface over a projection plane. This maximum distances are displayed in gray values. Using such a Digital Surface Model and a digital image, a digital orthoimage may be derived. Black areas in the orthoimages are occluded areas in the input image (WIEDEMANN 1996). If more than one image is used, the orthoimages can be combined to an image mosaic with fewer occluded areas.

2.5 Usage of Data Acquired by Photogrammetry

The most common photogrammetric products are vectorial representations, like plans or CAD models. They can be produced by the vertical projection of the 3D data model on a projection plain. Today in many cases the 3D data model is delivered as 3D CAD model to the commissioner. This 3D CAD data may be used as input data for a Virtual Reality Model. Using the geometry of a restitution process, digital orthoimages may provide data for texture mapping replacing generic textures by real pictures of the surfaces.

Whereas most of today's Virtual Reality models are a product of the subjective fantasy of the modeler. Models based on photogrammetric data are a virtual representation of the reality and the product of an objective deduction process. Though they are well suited as environment for the presentation of planed new buildings.

3. Digital Techniques for Automation

The aim of the developments in digital photogrammetry are

- release the operator from simple routine work, that he can concentrate on high level interpretation work
- accelerate the restitution process
- providing similar features on a computer as available only on expensive photogrammetric hardware
- architects and civil engineers should be able to do the photogrammetric restitution

There are a few fields of development, where a progress can be anticipated inthe next years.

3.1 Identification of Features

Some features in the images, which always look similar, may be automatically extracted. One of the already introduced image processing techniques in photogrammetry is the automatic measurement of fiducial marks or reseau crosses. This measurements are necessary for the reconstruction of the interior orientation of the pictures. This is relatively simple, because the pictures of the searched features look similar, independent from the background. The reseau crosses are usually darker than the background and have a size which is only a function of the image resolution. Fiducial marks have their own background.

In the design process of most buildings some geometric constrains like straight horizontal and vertical edges, symmetries and repetition of elements have been used. In the real objects this constrains are not exactly represented, but offer excellent initial values and may be used for prediction.

Whereas the already presented approaches use low and mid level image processing techniques only high level image processing will offer the opportunity to recognize objects in the images, like stones, windows, doors or others. This not yet available, because this require an enormous knowledge base and sophisticated object recognition techniques.

3.2 Edge and Line Detection

There are a lot of image processing techniques to extract edges and lines from digital imagery. But most of them generate a lot of fragments and interrupted edges. There is many additional work to do, to remove fragments and to join polygons. Fig. 3 shows a fine example of an edge detection in a digital image to extract the shape of natural stones (RODEHORST 1997).

If an a priori knowledge about the shape of the linear feature to extract is introduced, better results can be anticipated. Straight or regularly curved lines and edges may be completed behind occlusions. If further parameters, geometric, radiometric or topological, of the linear features are introduced, they may be used for the recognition of corresponding features in different images.

If a CAD model of the object already exists, this can be projected into the digital image and this information can support the extraction process by predicting the location of edges (STREILEIN & HIRSCHBERG 1995).

3.3 Corresponding Points

Fig.3: Automatically extracted stones

In photogrammetry it is necessary to identify the pictures of one object point in the different images. If a point is defined in a first image, the corresponding point in at least one further image has to be found to calculate 3D coordinates. During the last two decades a few well suited techniques for the measurement of corresponding points have been developed (HAHN & KIEFNER 1994).

The are two basic strategies for this purpose. The first, called feature based matching, is to identify interest points by appropriate operators and searching for pairs of corresponding interest points. The other approach, the image based matching, compares the contend of the image matrix around the start points and searches for the location with the maximum correlation or minimum differences in the gray values.

One of the major problems are the requirements for good initial values. If the surface of the object is nearly planar, they can be calculated by simple techniques like image pyramids. If the surface of the object is not plain, but contains large differences in the object distances and discontinuities there will be insufficient initial values. Solutions for this problems are semi-automatic approaches. Here it is necessary to support the matching process by a human operator who provides an initial point and a maximum parallax value. Using this technique the matching will stop at the borders of touched surface. An other possible solution is the use of more geometric or radiometric parameters and topological relationships, especially for the assignment of the corresponding interest points in the feature based approach.

4. Conclusions

According to the enormous stock of exiting buildings the importance of building conservation will grow. This will lead to additional requirements for 3D data for planing and documentation of the existing buildings.

Today's photogrammetry is well suited to generate computer models of existing buildings. If the objects are very complex, it is the most economic technique. But with further developments in digital photogrammetry, it will also become a fast and economic in the survey of more simple objects, will be possible on simple hardware and require a reduced amount of interactive work.

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