ARCHITECTURAL PHOTOGRAMMETRY AND PICTURE PROCESSING FOR ACQUISITION AND DOCUMENTATION OF A BRAZILIAN TOWN ENSEMBLE

S. Landes, H.-P. Bähr and K. Ringle
Institute for Photogrammetry and Remote Sensing
University of Karlsruhe
Germany
landes@ipf.bau-verm.uni-karlsruhe.de

Commission V, Working Group 4

KEY WORDS: Architecture, Cultural Heritage, Urban, Acquisition, Digitization, Archiving, Close Range

ABSTRACT

In need of surveying and documenting the architectural heritage of extended town ensembles, quick, accurate and not too expensive methods of image acquisition, analysis and representation have to be developed and integrated in urban information systems. For this aim modern digital image processing methods have to be applied. This goal is achieved by two sequential steps. In a first stage, it is necessary to build up archives of terrestrial photogrammetric images for documenting the facades of the buildings. From this archives the corresponding orthophotos are generated, and they have also to be integrated in these archives. In a second stage, additional information is necessary to create an urban information system. This additional information has to be combined with the data archives to obtain a suitable representation.

1 MOTIVATION

The inherent real problem to architectural photogrammetry doesn't refer to special cameras, equipment etc., but to the enormous number of objects which have to be documented and surveyed in the next few years. It has been shown, that this process has to be accelerated by a factor of 250 to be fulfilled (Waldhäusl, 1992) and that only digital photogrammetry can deal with this problem.

Having priority of being documented this task not only includes world heritage sites (Dallas and Carbonnell, 1992), but also includes the common urban environment.

These conditions cause the development of pragmatic photogrammetric solutions; the solutions have to be quick, accurate, not too expensive and easy to use. They should

- yield a terrestrial photogrammetric documentation of facades in broad urban areas
- include the possibility of an integration into
  - modern planning tools
  - urban information systems
  - geotechnical cadastres
  - GIS
- and they should cope with large amounts of data.

Therefore, the work can divided into several stages to reach this goal.

2 OUTLINE OF THE WORK

In a first step it is necessary to build up archives for terrestrial photogrammetric images documenting the facades of buildings. The corresponding orthophotos are generated and also have to be integrated in these archives. In a second stage, additional information, which will be described in section 2.4, is necessary to create an urban information system. This additional information has to be combined with the data archives to obtain a suitable representation.

2.1 Image Acquisition

To build up archives for terrestrial photogrammetric images a camera is needed. Here a *Pentax PAMS 645* camera is used for the process of image acquisition (Figure 1).

Figure 1: Pentax PAMS 645 camera

This camera has been chosen because of several features. The PAMS 645 is a microprocessor controlled metric camera with a picture size of $49.4 \times 39.6 mm^2$.

For photogrammetric use there are fiducial marks located in the four corners. In opposition to several other metric cameras the PAMS 645 has no Réseau which may cover information in the image and leads to unexpected artefacts after digital image rectification. For the lack of a Réseau the PAMS 645 is equipped with a vacuum back which keeps the film flat during exposure. There is also distortion data supplied with each camera. The PAMS 645 is used with a $45mm$ f/2.8 lens with a fixed focus of $8m$ for long-range photogrammetry and uses exclusively 220 roll films. Finally, the camera is easy to handle, which is another important point.

2.2 Digitizing

Another important task of digital photogrammetry is to produce digital images. There are several ways to do this. Therefore the authors examine two different kinds of digitizing.

The first one is divided into two steps: (a) to develop the images and (b) to digitize the resulting slides with slide scanner *MicroTek ScanMaker 45t*.

The second one is to use *Kodak's Pro Photo CD* service.

Digitizing with MicroTek ScanMaker 45t The ScanMaker 45t is a scanner for positive and negative slides up to a size of $121 \times 121 mm^2$. The company MicroTek specifies for the ScanMaker 45t an optical resolution of $1000 \times 2000 dpi$ and a maximum resolution of $2000 \times 2000 dpi$ because of interpolation. The colour-depth for one pixel and channel is 12*bit* and is converted to 24*bit* per pixel for all three channels R,G and B. The scanner is equipped with a SCSI-interface and can be driven with a *PC* or *APPLE* Macintosh.

Digitizing with Kodak's Pro Photo CD Eastman Kodak Company offers different kinds of their Photo CD (Gonsey, 1995). One is the so called "KODAK DIGITAL SCIENCE Photo CD Master Disc", which is used for images from 35*mm* film only. The possible resolutions are from Base/16 to 16 Base (Table 1).

The other Photo CD is the "KODAK DIGITAL SCIENCE Pro Photo CD Master Disc". This Pro Photo CD is used to store images from 35*mm*, 120, and 4×5 film, which may be digitized by a KODAK Professional PCD Film Scanner 4045. A Pro Photo CD Master Disc may hold as few as 25 pictures because each picture can optionally contain six resolutions: Base/16 to 64 Base (Table 1). Therefore films can be scanned at 6144×4096*pixel* resolution, depending on the image format.

Name	Resolution *(pixels)*	File Size *(MB)*	Purpose
Base/16	128×192	0.07	Index print of image
Base/4	256×384	0.28	rotated image on television
Base	512×768	1.13	TV or computer monitor display
4 Base	1024×1536	4.50	High-definition television display (HDTV)
16 Base	2048×3072	18.00	highest resolution on a Photo CD Master Disc
64 Base	4096×6144	72.00	only on a Pro Photo CD Master Disc

Table 1: Resolutions of Kodak's Photo CDs

In the authors' project the Pro Photo CD has to be used because of the special image format of the Pentax camera (Section 2.1). This format can't be handled with the Photo CD.

Comparison To estimate the two different kinds of digitizing, the geometrical quality was examined (Heinz, 1996). Therefore the coordinates of control-points on the film were measured. This was done with the *Zeiss PSK 2* comparator. And also the picture-coordinates in the corresponding digitized images were measured. To describe the distortions, mathematical functions were used, to do a transformation from the picture coordinate-system in the slide to the coordinate-system in the digitized image. The figures 2 and 3 show the resulting residuals – using a plane similarity transformation by overdetermination (Helmert transformation) – with:

$$
\begin{aligned}
x' &= a_0 + a_1 x - a_2 y \\
y' &= b_0 + b_1 x + b_2 y
\end{aligned}
\qquad (1)
$$

were (x', y') are the coordinates in the digitized image.

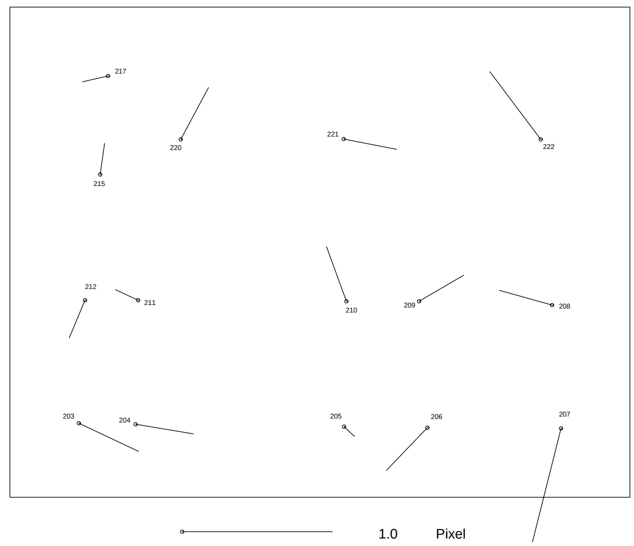

Figure 2: Residuals of Helmert transformation from slide-coordinates to the digitized image-coordinates on *Pro Photo CD*.

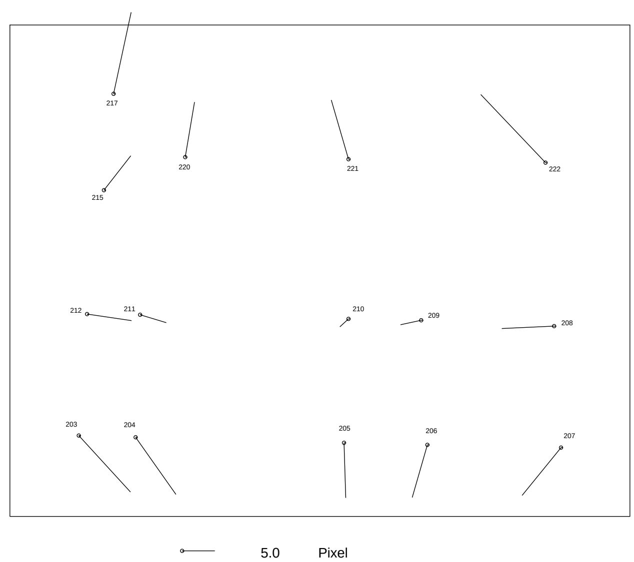

Figure 3: Residuals of Helmert transformation from slide-coordinates to the *ScanMaker 45t* digitized image-coordinates.

In Figure 3 the systematics and the size of the residuals indicate that the slide scanner produces results, which are not as good as in Pro Photo CD image. But other comparisons – done with plane affine transformation or 2nd order polynomal – show that the differences are not as much significant as with the Helmert-transformation. This is because the Helmert-transformation is not sensitive to different scales in x- and y-direction (Baumann, 1985). And this might be caused by the two different resolutions of the ScanMaker 45t. Such systematics can't be seen the images of the Pro Photo CD.

A visual comparison of the images maintains this results. Figure 4 shows an artificial control-point, which is part of an image produced from a slide by Kodak's Pro Photo CD service. Figure 5 shows the same detail in the same slide digitized with ScanMaker 45t.

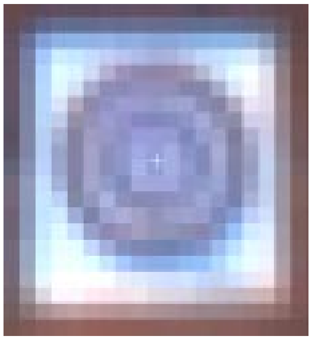

Figure 4: Image with artificial control-point produced by *Kodak's Pro Photo CD* service.

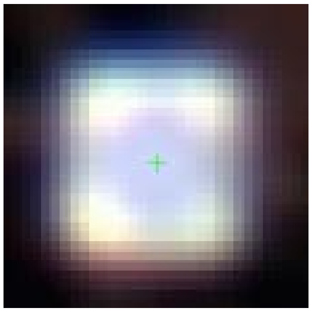

Figure 5: Image with artificial control-point digitized with *ScanMaker 45t*.

Also Figure 6 and 7 allow a visual comparison of a natural control-point.

But another important fact are the costs of a digitized image especially for large amounts of images. It has to be considered if it is less expensive to buy a scanner than to pay for the images of a Pro Photo CD. At the moment the costs of the *MicroTek ScanMaker 45t* compared with the Pro Photo CD service are amortized after 200 pictures. And Kodak can't guarantee how an individual service provider maintains the equipment and handles the original film.

It would be good to reduce the afford of developing and digitizing by using a CCD-camera. Therefore it would be a better solution for rapid processing to get a CCD-camera with a sufficient accuracy in geometry and resolution and with a suitable price.

The digital image is the base for all further steps like radiometric and geometric image analysis and correction, bundle block adjustment and it is also a good way to store the image data without the danger of fading colours. This is why digital photogrammetry has to be used, especially on the background of large amounts of data.

Figure 6: Image with natural control-point produced by *Kodak's Pro Photo CD* service.

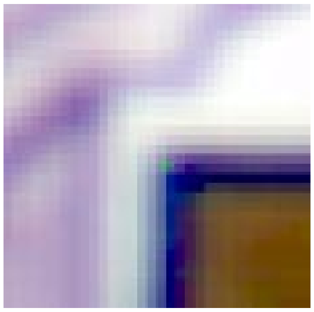

Figure 7: Image with natural control-point digitized with *ScanMaker 45t*.

2.3 Image Rectification

One field of activity in photogrammetry is to produce orthophotos of given facades. This can be achieved by a differential rectification of an image. But this requires the knowledge of the 3-dimensional model of a facade.

Under the assumption that a facade of a building is plane – what is sometimes very cruel and oversimplifying, but on plane buildings and facades a good approximation – a simple projective transformation of a plane can be used. The errors, produced by parts of the facade which are not in this plane, or by discontinuities, can be reduced by a part-wise rectification (Pallaske et al., 1992). For this approach the facade has to be subdivided into small pieces.

If the facades are too big for one single photo, or the rectification is done piece by piece, the resulting images have to be joined together by mosaicing (Heinz, 1996). This has been done using control-points to determine the coefficients for a projective transformation (Figure 8). In this task care and attention has to be paid to the equalization of the brightness and colour differences inside and inbetween single images.

2.4 Additional Information

In a second stage it is necessary to gain additional information for the creation of an urban information system.

This additional information consists of geo-referenced alphanumerical and graphical data.

Alphanumerical data consists of informations about special objects like buildings (age of the building, number of residents, date of last restoration, etc.), where as graphical data denotes images of objects, resulting orthophotos, representation of 3-dimensional models, etc.).

Archiving and representing alphanumerical data is a com-

Figure 8: Mosaicing of a plane facade consisting of four images rectified and joined together.

mon task for existing data base management systems. Georeferencing these data should be a standard application of a GIS (Rodcay, 1995).

Acquisition, handling and representing of a 2-dimensional or 3-dimensional graphical data is more complex. This information can be obtained from generated orthophotos – that have pictorial and geometric aspects – from maps, aerial images, stereo analysis and surveying. The additional information has to be combined with the data archives to obtain a suitable representation for documenting cultural heritage. The main and probably most difficult task consists of generating a 3-dimensional model of a given scene. As producing an orthophoto, it depends highly on the accuracy and the desired details to satisfy the requirements. Models gained almost automatically via aerial photos (Haala, 1995) or close-range methods (Grau, 1995) could be the solution.

With the 3-dimensional modelling the main part of the work is done. A simple representation of the data can be achieved by using CAD-software and raytracers, which are able to combine the models with orthophotos by mapping the photos on generated surfaces. But the integration into an urban information system is quite more sophisticated (Förstner, 1995).

3 CONCLUSION

The entire set of all this information and data mentioned above leads to extensive data archives. These archives must comply manifold requirements:

- The possibility of an integration into modern planing tools like urban information systems and GIS.
- The possibility of updating data to document changes.
- The easy handling of data enabling an access for different institutions and people.
- The possibility of data exchange with various existing systems.

If multiple people – with different demands – should have access to these information systems, or should offer data for this systems (like different state authorities), it is necessary to have a distributed structure (Koschel et al., 1996). In such a heterogeneous, distributed system architecture it should not matter which kind of special computer system is used and where these systems are located.

In the authors' project this demands are leading to several specifications. Therefore the documentation has to consider the integration in technical information systems like the *cadastro geotécnico* and to extend the *Inventário Nacional de Bems Imóveis - Proteção de Conjuntos* which is built up by the *Instituto Brasiliero de Patrimonio Cultural*.

Only if these described demands are satisfied, the data archives are able to fulfil the task of documenting cultural heritage.

REFERENCES

Baumann, E. (1985). *Vermessungskunde*. Dümmler, Bonn.

Bru, R. and Bahr, H.-B. (1999). *Segi*, volume 1. Wichmann.

Dallas, R. and Carbonnell, M. (1992). World heritage sides – photogrammetric records. In *International Archives of Photogrammetry and Remote Sensing*, volume XXIX, pages 419–426, Washington. ISPRS.

Förstner, W. (1995). GIS - the third dimension. In *IUSM WG on GIS/LIS Workshop "Current Status and Challenges of Geoinformation Systems"*, Hannover.

Gonsey, M. (1995). *Official Photo CD Handbook*. Verbum Books, San Francisco.

Grau, O. (1995). Ein Szeneninterpretationssystem zur Modellierung dreidimensionaler Körper. In *17.DAGM-Symposium Mustererkennung*, pages 244–251, Bielefeld.

Haala, N. (1995). *Photogrammetric Week '95*, chapter 3D Building reconstruction using linear egde segments, pages 19–28. Wichmann Verlag.

Heinz, D. (1996). *Untersuchungen zum Herstellen von farbigen Photoplänen auf digitalem Wege*. Diploma Thesis, IPF, University of Karlsruhe.

Koschel, A., Kramer, R., Nikolai, R., Hagg, W., and Wiesel, J. (1996). A federation architecture for an environmental information system incorporating GIS, the World Wide Web, and CORBA. In *Proceedings Third International Conference/Workshop on Integrating GIS and Environmental Modeling*, Santa Fe, New Mexico, USA. NCGIA.

Pallaske, R., Marten, W., and Mauelhagen, L. (1992). Digital orthophoto-system for architecture representation. In *International Archives of Photogrammetry and Remote Sensing*, volume XXIX, pages 67–73, Washington. ISPRS.

Rodcay, G. K. (1995). *GIS World Sourcebook 1996*.

Waldhäusl, P. (1992). Defining the future of architectural photogrammetry. In *International Archives of Photogrammetry and Remote Sensing*, volume XXIX, pages 767–770, Washington. ISPRS.