

## RECONSTRUCTION OF HISTORICAL BUILDINGS BASED ON IMAGES FROM THE MEYDENBAUER ARCHIVES

Albert WIEDEMANN, Matthias HEMMLEB, Jörg ALBERTZ

Technical University of Berlin, Germany  
Department for Photogrammetry and Cartography  
[albert@fpk.tu-berlin.de](mailto:albert@fpk.tu-berlin.de),  
[matti@fpk.tu-berlin.de](mailto:matti@fpk.tu-berlin.de),  
[albertz@fpk.tu-berlin.de](mailto:albertz@fpk.tu-berlin.de)

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### ABSTRACT

The reconstruction of destroyed buildings is discussed in the public. One of the major questions to mention is, whether sufficient information is available for this purpose. Photogrammetry may contribute to determine this information by using historical images, especially from the Meydenbauer Archive. A lot of details and sometimes the whole buildings geometry can be reconstructed. This may be used for architectural research, to publish information concerning the object or for a physical reconstruction. In this paper we present an overview of the used data sources, the orientation problems and some restitution techniques, by means of some destroyed buildings in the city center of Berlin.

### 1 INTRODUCTION

Many buildings in the city center of Berlin have been destroyed or suffered heavy damage during the Second World War, some have been pulled down later by the GDR government. Among these are important buildings like

- “Berliner Stadtschloss”, the former residence of the Prussian Kings and the German Emperor (built during centuries by Andreas Schlueter, Eosander and others),
- “Bauakademie”, the famous school for architects and also the former residence of the “Messbildanstalt”, the first architectural photogrammetric institution (built by Karl Friedrich Schinkel 1832-1835).

These and other buildings formed an ensemble which dominated the historical center of Berlin. Since the reunification of Germany, there is a continuous discussion about the reconstruction of the facades of these buildings in order to revitalize the historical city center. For this purpose detailed documentation of the facades must be made available. Modern photogrammetric techniques based on historical images can provide this information.

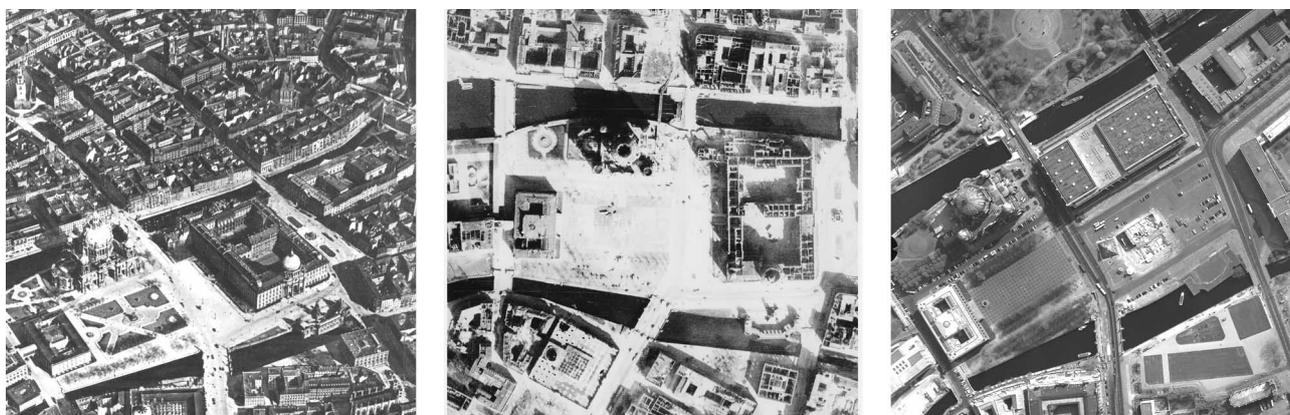


Figure 1: The site in an aerial image of the 1920s, with the Stadtschloss in the center (left). The heavily destroyed buildings in an aerial image of 1945 with the square-shaped Bauakademie at bottom right (middle). The scene in 1997 (right).

## 2 DATA RESEARCH

The first step is the search for data. This is of central importance in order to determine the type and amount of data available, the requirements for data processing and also to predict the level of detail which might be derived by photogrammetric approaches.

### 2.1 The Meydenbauer Archive

A major data source are the historical metric images, that have been acquired for the documentation of the cultural heritage by the former “Messbildanstalt” under the guidance of Albrecht Meydenbauer. The archives of this institution, known as the Meydenbauer Archives, are today under the care of the “Landesamt für Denkmalpflege” of the state of Brandenburg. These archives comprise about 20.000 negative glass plates, with a size of up to 40 cm × 40 cm, having been acquired between 1885 and 1920. In these images about 2.000 buildings in Prussia and at other places have been documented. About 40 photographs show the exterior and courtyard facades of the former “Stadtschloss”, and 8 photographs the facades of the “Bauakademie”. These historical images are the basis for the photogrammetric reconstruction of the facades.

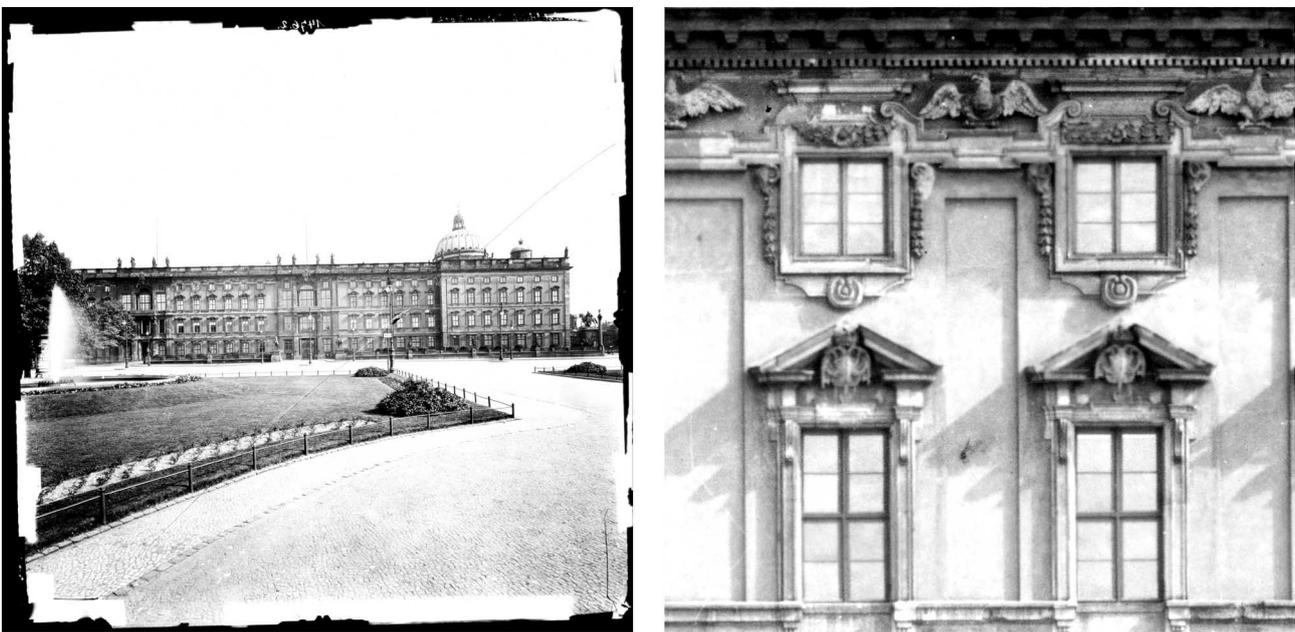


Figure 2: An original Meydenbauer image of the Stadtschloss (left) and an enlarged detail of the same image (right).

Unfortunately information about the interior and exterior orientation of the images is not available any more. These data got lost in the ups and downs of the archives during and after the Second World War. Furthermore, each photo may have an independent interior orientation, because the Meydenbauer cameras were designed in such a way that the lens could be shifted vertically, and also the cameras were mechanically not as stable as modern metric cameras. Furthermore in many cases the fiducial marks have been destroyed on the original glass plates during the past. Thus modern photogrammetric approaches must be applied, which are either independent of orientation data, or which determine the orientation parameters during the photogrammetric procedures.

Meydenbauer images have a very good image quality and deliver a high resolution, like the one shown in Fig. 2 in a very much reduced format. As one can see in this example, not all Meydenbauer images are well suited for calibration purposes. There is a lack of depth in the object, because this is limited to a small region in the central part of the image. Also a crack in the glass plate causes problems, it requires the use of two sets of interior orientation parameters for high quality approaches. In general there is an other major type of Meydenbauer images, acquired in a more diagonal direction across the corners of the buildings. These images are much better suited for orientation purposes.

### 2.2 Other Images

For the reconstruction of the “Bauakademie” six additional images from other sources, like the Berlin city archive or the federal archive “Bundesarchiv” in Koblenz could be used. They are of different size between 13 cm × 18 cm and

21 cm × 30 cm. The use of additional images has been necessary in order to complete a surrounding block of images around the object. As usual in such cases no information regarding technical parameters of the cameras was available.

The integration of additional images has to be considered carefully. Each image increases the amount of data to be determined during the orientation process. If the additional image is not well suited it may add undeterminable unknowns to the bundle adjustment. On the other hand it may improve the redundancy and the geometric stability of the image bundle block. As most images are acquired without a tripod, tilt angles along all axes must be considered. This allows the determination of vanishing points and the application of simple methods to calculate approximate values for the orientation parameters.

### 2.3 Historical Plans and Maps

The availability of historical plans of the destroyed buildings is varying very much. A lot of detailed plans are available for the “Stadtschloss”. However they are very inhomogeneous in level of detail and in scale. In some cases unknown historical measuring units are applied. Barely no plans are available showing the whole building. Some plans, like the 1:100 plans generated under great time pressure before the “Stadtschloss” has been pulled down in 1950, contain a considerable number of mistakes.

One major data source are the documents of the historical cadastral surveys. The site around “Stadtschloss” and “Bauakademie” was surveyed during 1880. The drawings with some metric data are available, and they allow partly a new adjustment in order to fit the historical measures into the modern survey network, making use of control points identified in the historical plans and in the present situation as well. Through this approach horizontal distances can be derived with a higher reliability than vertical distances.

### 2.4 Fundaments

Based on such information provided by a local survey attorney the corners of the “Bauakademie” have been calculated and staked out. The excavations based on this stake out delivered parts of the fundaments of the building. In Fig. 3 we see a historical plan of the basement, rectified according to the four calculated corners of the building. The results of a survey of the visible fundaments have been superimposed. According to experienced archeologists it is possible to determine the position of the former building from the fundament only with a maximum accuracy of a few decimeters, because the fundament and the building may differ.

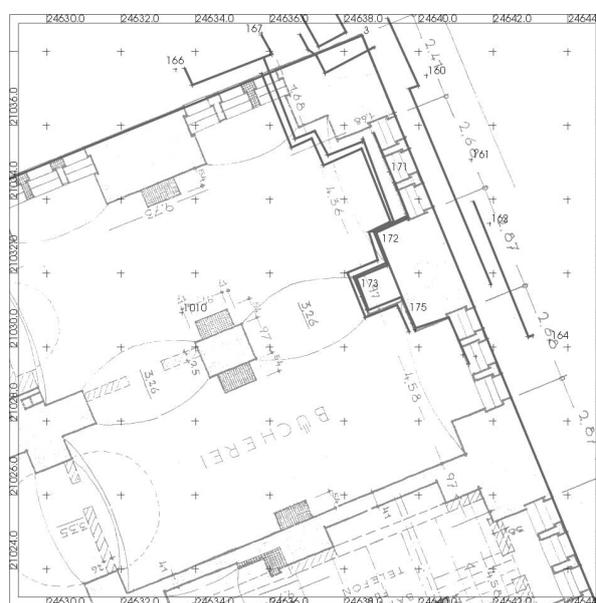


Figure 3: A historical basement plan of the Bauakademie rectified to the calculated building corners and superimposed by the survey of the excavated fundaments.

## 3 IMAGE ORIENTATION

Concerning the exterior orientation, we know from Meydenbauer's textbook, that it was his principle to set the image plane exactly vertical and to make  $Kappa$  to zero (Meydenbauer 1912). This fact was used for a simplified spatial resection, which delivers good approximate values for the orientation parameters. An other method for the definition of approximate values is to calculate the bundle adjustment with a reduced set of unknowns.

Though most of the images do not have a determined image coordinate system or some parameters of the interior orientation are flexible (due to the possibility to shift the lenses of the Meydenbauer cameras vertically), an individual set of interior orientation parameters for each image has to be calculated during a bundle adjustment together with the data of the exterior orientation. Because of the high correlation existing between the data of the interior and the exterior orientation the data set is badly conditioned. In order to avoid singularities additional control information has to be integrated.

### 3.1 Measurement of image coordinates

Due to the large format of the Meydenbauer images, no suitable comparators are available for the measurement of image coordinates. Thus, the original glass plates have been copied to geometrically stable photo material and scanned immediately after, by means of a large format scanner, with a resolution of about 1000 dpi. The measurement of image coordinates has been performed interactively in the digital data.

### 3.2 Control information

The measurement of a sufficient number of control points – as required for exact reference – is very difficult, because many buildings near the objects in the city center of Berlin are destroyed or have not been reconstructed exactly. The following sources for control points have been available:

- Elevated points on towers which have been used as remote targets for the triangulation. They have been listed in historical documents concerning the Prussian geodetic triangulation. Their coordinates in ancient systems had to be transformed into the actual coordinate system.
- Further points have been geodetically surveyed on objects, which have not been changed during the time between image acquisition and today. A higher amount of such points is available along the quay of the Spree channel just in front of the “Stadtschloss” and the “Bauakademie”.
- Additional points have been calculated using the historical plans, the survey of the fundamentals etc..

Due to the inhomogeneity of these data the accuracy and the reliability of each control point coordinate has to be evaluated individually. In general the control information is rare and must be considered insufficient, especially under the circumstances that we have to calibrate the individual camera parameters of the images involved. In order to improve the geometric stability of the block, the following additional control information can be integrated:

- Coordinate differences in the object, e.g. describing the fact, that points of the buildings have the same elevation.
- Horizontal and vertical distances between points, thus introducing additional scale information.
- Known orientation angles of the Meydenbauer images.

Such types of information and the related accuracies may be introduced in a careful way in order to avoid network deformations.

### 3.3 Tie Points

The majority of information introduced into the bundle adjustment is formed by the tie point coordinates. Along the facades of the “Stadtschloss” at nearly each window one tie point has been defined. A limitation for the introduction of tie points may be set by the capacity of the bundle adjustment software applied.

### 3.4 Bundle Adjustment Software

A suitable software package for the bundle adjustment of historical images has to fulfill a lot of special requirements. These special requirements are:

- The program has to allow the calculation of a great number of images and cameras in one process.
- The program must be able to treat each individual parameter of the interior and exterior orientation either as fixed, as observed or as unknown.
- The program has to accept the coordinates of control points, that have been measured in one image only.
- The program has to accept additional control information, such coordinate differences, distances etc.
- The program has to provide detailed statistical data to each observation introduced and also for each calculated unknown.
- The program should to be robust, reliable and fast.

Because no available software package fulfilled all these requirements a special system was developed for this purpose, based on Hell (1979) and Wester-Ebbinghaus (1981). This software package has been applied to the “Bauakademie” and the “Stadtschloss” as well.

## 4 RESTITUTION

Architects need different types of data for the derivation of detailed plans for the reconstruction of buildings. Generally views, cross-sections, ground plans or complete 3D CAD models are required. Different photogrammetric techniques may be used to provide these products.



Figure 4: Rectification result of the “Bauakademie”, based on geometric information provided in historical data (rectification scale 1:50)

#### 4.1 Rectification

For the generation of metric image plans of destroyed buildings photogrammetric rectification of historical images may be applied. The fundamental approach is to rectify planar surfaces, making use at least four control points per surface. These control points may either be derived from historical data provided by architectural researchers, or they are defined photogrammetrically through bundle adjustment. In many cases, the object surface may be divided into separate planes which can be rectified in individual processes. The results can be merged into single image plans providing an enormous amount of information for the further activities. The rectification of historical images is described in detail by Hemmleb (1999). The Fig. 4 and 5 show examples of this approach applied to the “Bauakademie” and the “Stadtschloss”.

#### 4.2 3D Restitution by Spatial Intersection

Whereas rectifications are well suited to generate facade plans, there are further requirements to be fulfilled in order to provide the information for drawing cross-sections. For this purpose also depth information for each facade is necessary. The adjusted tie points resulting from the bundle block adjustment form the geometric reference for following procedures. Further points may be measured in two or more separate images and calculated afterwards by ray intersection, making use of the orientation results of the bundle adjustment. In principle this seems to be a simple task, however in reality some practical problems come up. Due to different image scales, geometric and radiometric image resolution, points of view, illumination conditions etc. it is often very difficult to identify the same object point in two different images. The accuracy of the resulting point coordinates depends on the accuracy of the poorer one of the used pairs of image coordinates and the ray intersection conditions.



Figure 5: A Meydenbauer image of the “Stadtschloss”, rectified to control points as determined by a bundle block adjustment, superimposed by a 2m grid.

### 4.3 3D by Pseudo-Stereo Restitution

In many cases we find some features in a facade more or less duplicated and in a regular geometric arrangement can be assumed. In such cases pseudo-stereoscopy may be used for 3D restitution. For this approach only one image and its orientation parameters are necessary (Kager 1984). The principle is sketched in Fig. 6. In the traditional stereo model the region around pillar D and E may be processed.

Now a virtual image is introduced with new orientation parameters. Whereas the rotations are the same as for the real image, the projection center can be calculated by adding a shift vector to the real projection center. This shift vector corresponds to the “repetition cycle” of the object features. In the example the vector of any point on pillar A to the corresponding point on pillar C is used as the shift vector and thus is introduced as the photogrammetric base  $b$ , thus making stereophotogrammetric restitution possible.

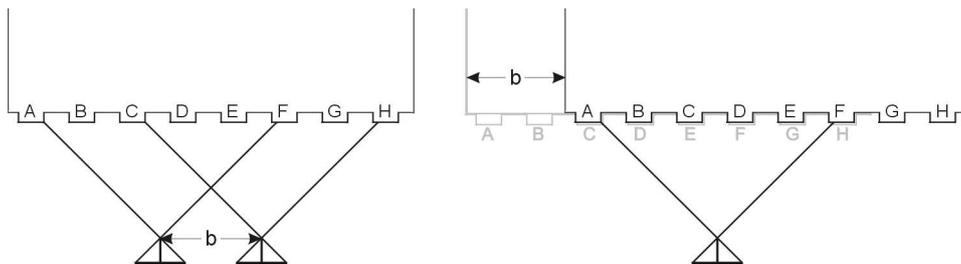


Figure 6: Principle of traditional stereo restitution (left) and pseudo-stereo restitution (right)

This principle works only with really identical object features. Small variations or object damages can cause gross errors. On the other hand, even shadows of outstanding parts of the object may be applied, because the solar illumination can be considered as parallel. The pseudo-stereo restitution may be a useful technique to acquire 3D data if no other method is applicable. However, it is obvious that this approach must be handled carefully because of the assumptions made. Fig. 7 gives an example for “identical” object features. There are some differences in the details, especially some damages at this window corner (left). These differences prohibit the use of automatic measurement tools.

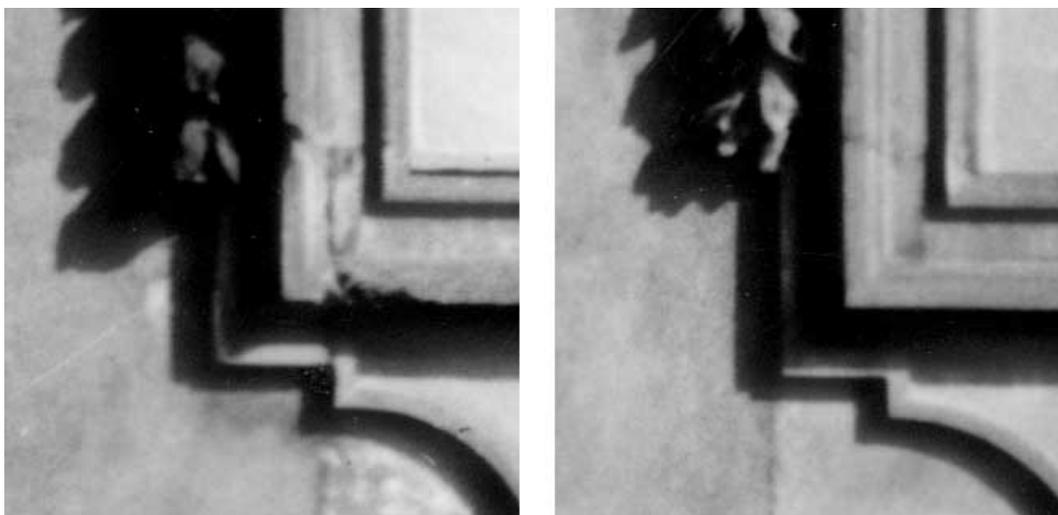


Figure 7: A  $320 \times 320$  pixel clip in a Meydenbauer image (left), the corresponding pseudo-stereo clip in the same image (right).

### 4.4 Indirect 3D Information

In some cases the required data to extract 3D information directly is not available. Additional techniques have to be considered. One approach is to determine the angle between the solar illumination and the normal to the facade. Using this angle, depth differences on the facade may be derived from the lengths of shadows. This technique may be used to determine single depth values at the facade.

## 5 CONCLUSIONS

The acquisition of data for the reconstruction of historical buildings requires the combined application of a wide variety of photogrammetric techniques. Traditional techniques have to be adapted to the special properties of this type of objects and must be used with care. Especially the problem of badly conditioned orientation problems, resulting from the unknown interior orientation, requires further research activities. On the other hand, a lot of valuable data have already been delivered to architects. No other data source is such an objective document as a historical photograph. In many cases just no other data sources are available. A corner of the former "Bauakademie" growing up during Summer 2000 is based on data provided by photogrammetric restitutions of Meydenbauer images.

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