

DIGITAL RECTIFICATION OF HISTORICAL IMAGES

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ABSTRACT

In the paper several methods for the rectification of historical images, with and without reference points, will be discussed. An example will be given for each case. At least there will be shown, how rectified historical images help to visualise the authentic state of historical monuments in a three-dimensional way.

1. INTRODUCTION

Historical images often are the only remaining documents of buildings and monuments, which were changed or destroyed in the past. Photogrammetric methods allow the evaluation of the existing photographs and the reproduction of plans of the facade and of horizontal intersections. These plans are valuable material for the work of architects and monument conservators in case of the reconstruction of historical monuments.

If the building, or at least a part of it, still exists, the scale reference can be calculated by reference points measured afterwards. In case of a destruction of the object, the reference information sometimes is given by still existing buildings in the neighbourhood. Otherwise, a true scale evaluation depends on still existing calibration data of the camera or information about the viewpoint. If additional rules were kept during the photography, these permit, under certain conditions, a scaled evaluation. This is the case, for instance, with many photographs of the archive of metric images of Meydenbauer. The success of a photogrammetric evaluation also depends on the number of pictures of an object, ideally taken with the same camera.

The object of this study is the evaluation of single images in form of a digital rectification. If the reference area is a cylinder, an image unwrapping can be applied. The results can also be used for the generation of 3D-photomodels, which represent the historical state of the object. As far as there exist metric images of the concerned buildings, this should be used for a single image evaluation because of their high quality and their photogrammetric properties. For this study historical metric images of the Archive of Metric Images of the Brandenburg Regional Department of Monument Preservation (Meßbildarchiv des Brandenburgischen Landesamts für Denkmalpflege) were used. Therefore this archive shall be described shortly at first.

2. ALBRECHT MEYDENBAUER AND THE ARCHIVE OF METRIC IMAGES

Albrecht Meydenbauer (1834-1921) is considered to be the founder of architectural photogrammetry (Schwidersky, 1971). Beside his considerations about the measuring principle by the reversal of the ray-tracing

during photographs, he constructed suitable metric cameras himself. His most important aim was the foundation of a German archive of monuments, where the cultural heritage could be kept in form of metric images and documentation being ready for a photogrammetric evaluation. Partly he achieved this aim in 1885 with the foundation of the Royal Prussian Institution of Metric Images in Berlin.

After an eventful history 20,000 large format glass plates with metric images remained, as a heart of Meydenbauer's archive of metric images, in the possession of the Brandenburg Regional Department of Monument Preservation (Koppe, 1996). Since the foundation of the Institution of Metric Images in 1885 until the thirties of this century, the images of a size of up to 40x40 cm were taken, under consideration of a special configuration, with high quality cameras, especially constructed for this purpose. The largest part of the collection contains monumental buildings of the former Prussian. But there are also numerous photographs of architectural sights in the whole of Germany and partly in foreign countries.

Unfortunately, all of the documentation about the cameras as well as the cameras themselves were lost in the Second World War. Thus there do not exist any calibration data, although the photographs are metric images. This circumstance, which complicates photogrammetric evaluation considerably, leads to the fact, that either the cameras have to be calibrated afterwards with the help of the images, or, for photogrammetric processing, methods are chosen, which either include a calibration or do not need any.

Lately examinations concerning an afterwards calibration of the Meydenbauer-cameras were carried out (Li, 1996). Until now, only single results for certain photographs could be presented, which do not allow general statements concerning the calibration parameters of the cameras. Therefore, it was not possible to take into account data of the interior orientation for the metric images used in the bounds of this study.

Thus, for evaluation, it is necessary to strive for a photogrammetric method, which does not demand knowledge of the interior orientation. In case of the building still being at disposal for the measuring of reference points, a digital projective rectification or an image unwrapping shall be applied on the metric images. The results can be

overlaid with the actual photogrammetric evaluations. These methods will be explained in the following chapter. For the rectification of metric images of buildings which do not exist any more, in chapter 4 an evaluation approach will be presented, which takes into account Meydenbauer's special configurations and combines these with digital rectification.

3. DIGITAL RECTIFICATION AND UNWRAPPING OF STILL EXISTING BUILDINGS

Is the building preserved, geodetic reference information is measured on the still existing facade and subsequently used in order to rectify the metric image geometrically and in true scale. It has to be considered that the reference points can be well identified in the historical image as well as on the building, and that their situation does not have changed during time. This mostly includes door- and window-settings, but not the doors or windows themselves.

In order to obtain a geometrically rectified image in true scale from a historical metric image, the pattern has to be digitised with a scanner at first (Fig.1). As pattern serves the reproduction of the metric images, which is provided by the archive of metric images as a service. This can be digitised with a high value flat bed scanner. It has to be ensured that the scanner resolution corresponds to the desired scale of the rectification. Thus, our example has been scanned with three different resolution levels (Tab.1). The values of the image size refer to a reproduction in the format 19x19 cm. The specifications of the maximum image scale assume a length of facade of 40 m (as the Naumburg town hall) and a resolution of 300 dpi, which is sufficient for instance for digital printing or exposing.

Scanner-resolution	Image size	Image size (greyscale)	Max. scale of rectification
[dpi]	[Pixel]	[MB]	
300	2244	5	1:200
600	4488	20	1:100
1200	8976	80	1:50

Table 1: Scan resolution and maximum rectification scale

For image rectification the program EDDI-2D, which is a development of Fokus GmbH, was applied. The digital rectification is based on a projective transformation. Since more than four reference points were used, the calculation of the coefficients was carried out with an adjustment and a statistic evaluation. This processing has a significant meaning especially for the rectification of historical metric images, because with the help of the statistic characteristics (residuals, redundancies and a presumed gross errors) it is possible to discover errors in the identification of the reference points. This method allows the recognition and elimination of reference point errors, which are caused by minor structural changes (for instance by the restoration of the building).

The result of the digital rectification, a geometrically rectified metric image (Fig.2), from which the measurements of the facade and architectonic details can be taken in a desired scale, was exposed and is thus available for further work in photographic quality. On the basis of the rectified metric image for instance further plans in form of vector graphics can be produced, which can be preserved in an archive or which can be used for restoration or reconstruction. If desired, the rectified metric image can also be provided and delivered digitally.

In order to contribute to the high demands on the quality of the rectification of historic metric images, a bicubic interpolation approach was chosen for the image resampling, since, despite the necessarily high computational performance, it delivers the best results. Only with the application of such efficient algorithms in combination with a high scan resolution, metric images, which show sufficient detail resolution even with large scales, can be calculated.



Fig.1: Town Hall in Naumburg, reproduction from Meydenbauer image (1906)



Fig.2: Rectified image of the Town Hall (original scale 1:50)



Fig.3: Church St.Cyriakus in Gernrode, reproduction from Meydenbauer image (1907)

If the reference area is a cylinder, an image unwrapping can be applied. We used this method for the evaluation of a historical image of the apse of the church St. Cyriakus in Gernrode (Fig.3). In this case a parametric approach has to be chosen (Hemmler / Wiedemann, 1996). Because of the organ galleries left and right, only the middle part of the historical image could be used for the unwrapping (Fig.4). For restorational purposes the present state has also been evaluated and overlaid with the unwrapping of the historical image (Fig.5). An accuracy between 1 and 2 cm was achieved for this example.

4. DIGITAL RECTIFICATION OF DESTROYED BUILDINGS

A significant part of the buildings photographed by Meydenbauer has been destroyed during or after the war. In this case it has to be checked, if there still exist reference point coordinates from former measurements or if the information can be taken from historic plans. Sometimes historical building plans or building measurements exist. But the measures taken from these plans have to be used with care. It has to be considered that errors in these plans have immediate effects on the accuracy of the rectification.

Another possibility for the acquisition of reference point coordinates is yielded if several historic metric images of



Fig.4: Unwrapping of the middle part of the image (original scale 1:20)



Fig.5: Overlay of historical and present state's unwrapping (detail, original scale 1:20)

the building are available. Then, in the best of cases, the photographs can be oriented in an image network and the coordinates of single points can be determined. Such a bundle adjustment with self calibration is rather costly concerning the effort and can only be applied with success with a sufficient number of photographs and a suitable configuration. Meydenbauer took his photographs with a certain configuration which allowed an evaluation according to his own rules. In many cases this configuration is not sufficient for a bundle adjustment with self calibration. In some cases, amateur photographs can be used in addition for a bundle adjustment. In the following example an insufficient number of photographs with a suitable configuration was available, so the reference point coordinates could not be calculated in the described manner.

In order to make the rectification of a metric image of Meydenbauer possible despite this fact, it suggests itself to study the geometric conditions which are implied by keeping the special photographic configuration by Meydenbauer. Meydenbauer followed the subsequent rules with most of his photographs:

1. The photograph is taken with a levelled camera, that means that the swing angle and the inclination angle are zero.
2. The building is photographed from a corner.
3. A vertical shift of the objective is used instead of the camera inclination in order to cover higher buildings as well.

For a graphic single image evaluation Meydenbauer took advantage of some geometric conditions most of the buildings are subjected to:

4. The building has rectangular corners in the plan.
5. On the building there exist vertical and horizontal edges.

Under this preconditions Meydenbauer deduced evaluation rules which allow a graphic evaluation of a facade from merely one image (Meydenbauer, 1912). For this purpose the focal length and the object distance were provided by the Institution of Metric Images. While the focal length can be calculated approximately by Meydenbauer's method as well as by other methods (Ethrog, 1984, Novak, 1986) from the image, the knowledge of the object distance is required for a true scale rectification. Because this information is not available several horizontal and vertical lines on the building have to be known instead (Finsterwalder, 1991).

With the means of digital analytical geometry, the constructive orders Meydenbauer gives for a graphic evaluation can be used for the calculation of the rectification parameters too. On this basis, a rectification program has been developed which only needs the

measures of one horizontal and one vertical line as an input. Furthermore the desired scale and the resolution of the rectified images have to be set. For the calculation of the geometry of the images two pairs of horizontal and vertical lines have to be chosen and measured in the image. After the calculation of the essential geometric elements of the image (image horizon and main vertical, control of the inclination) the transformation of the image coordinates can be carried out according to Meydenbauer's approach.

The situation of the resulting pixel in the original image is calculated, which means that an indirect rectification approach is applied. The exact grey value of the pixel is determined by means of a suitable resampling method. For highest image quality demands, it is possible to choose a bicubic interpolation.

As already explained, the measures of a horizontal and a vertical line on the object are preconditions for a true scale rectification. If these measures can not be deduced from old plans or structural historic details, a rectification is still possible but the scale reference is lost.



Fig.6: Kommandantur in Berlin, reproduction from Meydenbauer image (1911)



Fig.7 Rectified image of the Kommandantur (original scale 1:50)

In the used example (Fig.6), a horizontal line could be taken from old documents. Because no heights were available, a vertical was set arbitrarily at first. Thus the result of the rectification was true scale along the facade but not concerning the height. From an architectural detail (arc over the window) a correcting factor for the height was subsequently calculated. The entire height was corrected with this factor. In this way a geometrically accurate and in true scale rectified metric image could be produced (Fig.7). It has to be considered that the accuracy depends on given measures of the horizontal and the vertical line. Concerning the example, this means the accuracy of situation depends on the accuracy of the specifications of the historic structural measurement, the height accuracy, in this case, on the correctness of the used structure of the facade.

5. USE OF RECTIFIED IMAGES IN 3D-PHOTOMODELS

Rectified historical images help to visualise the authentic state of historical monuments in a three-dimensional way. The easiest way to build and view a 3D-photomodel is the construction of a VRML-scene directly from the rectified images (Bölke, 1998). In this case a 3D-CAD-model has to be drawn up first. For higher quality demands, the resolution of VRML-scenes is not sufficient. If it is possible to calculate the camera viewpoint, an image of the present state of the surrounding area can be taken and laid over the historical image (Fig.8).



Fig.8 3D-Visualisation of the Kommandantur in present surrounding area

But this is only a two-dimensional way. For the reconstruction of a high resolution 3D-model, first a CAD-model is necessary. The data for that model can be determined for instance by Photogrammetric methods. If the building was destroyed, a lavish construction on the basis of historical plans is necessary. After that, the rectified images can be wrapped over the 3D-model with the help of a 3D-rendering software. Fig.10 shows the result of such a work. The 3D-photomodel of the town hall in Halberstadt was derived from present and historical images and shows the building after a possible reconstruction. The texture of the historical building part was completely taken from historical photographs from Meydenbauer from the year 1896. The figure is an image from a digital animation, which lets you walk around the historical building.

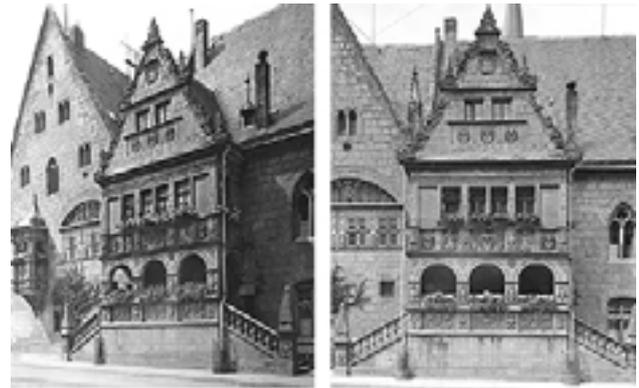


Fig.9: Two historical images of the Town Hall in Halberstadt (1896 and 1912)



Fig.10: 3D-photomodel of the Town Hall in Halberstadt

6. CONCLUSIONS AND FURTHER WORK

Within this study it has been shown, how historic metric images can be rectified. If the concerned building is destroyed and no information on the orientation data of the camera is available, a rectification is still possible. In this case, the combination of modern image processing methods with the analytic realisation of Meydenbauer's geometric evaluation rules allows the determination of

mathematically accurate solutions. The high geometric and photographic quality of Meydenbauer's metric images, which can be transferred in this manner to rectified metric images and facade plans basing on these, is of great advantage.

The introduced methods remain limited on the evaluation of plain facades at first. Especially with more complicatedly structured buildings these methods cannot be applied. The further work on and the analytic realisation of Meydenbauer's ideas certainly let us expect, even in these cases, the possibility of a photogrammetric image evaluation.

If you are interested in the work of CIPA Task Group 2 „Single Images in Conservation“ or if you want to see more examples please look at the TG2 Internet-homepage (http://info.uibk.ac.at/sci-org/cipa/tg2_1.html) or at the Internet-homepage of the Fokus GmbH Leipzig (<http://home.t-online.de/home/Fokus-GmbH>).

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