

# DISCUSSION OF TWO PHOTOGRAMMETRIC TECHNIQUES COMBINED FOR DOCUMENTATION OF DEFENSIONSKASERNE IN MINDEN WITH REFERENCE TO ARCHITECTURAL HERITAGE CONSERVATION

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**KEY WORDS:** combination, measurement, rectification; architectural heritage conservation, close range photogrammetry; multi-image measurement system, Defensionskaserne in Minden.

### ABSTRACT:

This paper aims to present the process of an architectural photogrammetry application that has combined two existing techniques; digital image rectification and monoscopic multi-image measurement systems. The case considered, which is an early 19th century Prussian monument, is Defensionskaserne in Minden, Germany. This architectural object may be defined as a prism with only one richly ornamented surface. It is the 100 m long East elevation that is mainly composed of a series of sub-planes. These sub-planes can be abstracted into rectangles at different depths.

The orthogonal composition of the facade has been considered suitable for single image rectification and ortho-imaging. The peculiar longness of the facade has necessitated a three stepped bundling during the multi-image measurements. Scaled handling of textures via rectification is an important tool that provides base for production of digital maps, which are indispensable parts of architectural conservation projects. Measurements of architectural elements, structural and material characteristics, damages, alterations, intervention decisions, etc. can be mapped on rectified surfaces. The problem of hidden area in rectifications via perspective correction was solved in Photoshop after the processing in MSR by Rolleimetric. Photo 3D, which is an easy to work with software, was considered sufficient to derive data for the textured model.

Consequently, modelling of the monument at its present, past and future states is desired in conservation projects. The measuring system of CDW from Rolleimetric has provided accurate results in handling overlapping photographs taken from different angles of this long object. 3D data was exported to CAD system for modelling.

Therefore, these combined techniques of photogrammetry have provided the visual base necessary for the development of an architectural heritage conservation project.

## 1. INTRODUCTION

This study focuses on the recording of the Defensionskaserne in Minden. The aim is to present how two different photogrammetric techniques were combined in the documentation of the building. These techniques are multi-image measurement and single image rectification. The methodology of this paper is describing and evaluating the application process of the two photogrammetric techniques combined. The strategies developed and criteria taken into consideration are introduced. Validity of these combined techniques in architectural heritage conservation is pointed out. Multi-image measurement technique is efficient in the definition of a building geometry. Defining building geometry includes the identification of size and form of an architectural object or object piece. The east elevation of Defensionskaserne is documented with multi-image measurement technique. On the other hand, single image rectification is efficient in determining the texture of an elevation. For the application of this technique, the geometry of the object should be known. So; at the second stage of the study, the texture of Defensionskaserne was mapped using single image rectification technique. The geometric data gathered through the application of multi-image measurement technique was used in the production of 3D model in CAD environment. The 3D model was covered with the texture map produced with single image rectification technique. The map was presented also as an ortho-image. The production of the 3D model is discussed by Prof.Dr.Günter Pomaska in this conference.

## 2. IDENTIFICATION OF DEFENSIONSKASERNE AS AN ARCHITECTURAL OBJECT

The Defensionskaserne is known as the earliest building belonging to Prussian Classicism in Minden (Figure 1). The building, which has been functioning as Prussian Museum in the recent years, had been constructed for defense purposes between 1827 and 1829. It has a rectangular plan of 98 by 16.6 meters. It is nearly 14 meters in height and composed of basement, ground, first and roof floors. The roof floor is additional. The east facade facing the old courtyard is richly decorated, while the other three facing the exterior possess windows designed specially for shooting and lack such decoration (Westfalishen Amt, 1999).



Figure 1. View of the entrance of Defensionskaserne, Minden

### 3. FIELD SURVEY

In all building surveys, 3d object information is reduced to a minimum of points. From those points, a data structure with predefined geometrical elements can be derived. In this research, point coordinates were derived through total station measurements and multi-image photogrammetry. Total station measurements have supplied control point information. Multi-image technique has been applied while taking metric images. This has provided ease in selecting camera positions. In addition to these two surveys, digital images were taken for producing the texture of the building model. The process of the field survey is explained in the below under two headings: measurement of control points and image acquisition.

#### 3.1 Measurement of Control Points

All elevations were surveyed with total station. It was decided to measure minimum six evenly distributed points for every 33 by 14 meters. In other words, the long elevations were divided into three measurement areas and the short ones were considered as single measurement areas. Then, a polygon was inserted around the building (Figure 2). The control points on the elevations were connected to the polygon through a series of measurements. x, y and z values for each selected point were measured. All this measurement process included the facade area up to the entablature zone. The recessed roof portion was eliminated.

#### 3.2 Image Acquisition

In this step, criteria for selecting metric and digital cameras, and taking photographs were developed.

**3.2.1 Camera Selection:** A comparison of image formats and resolution after film-scanning presents that **medium format metric cameras** are the best ones suitable for building recording (Pomaska, 1998). Image formats in the range of 60mm x 60mm are known as medium format cameras. Such cameras provide metric solutions using a reseau. The widest known metric camera for close range applications is the Rolleiflex 6008 metric. It is a reseau camera with 121x121 crosses; mesh distance 5mm. This camera is the ideal solution for photogrammetry in cultural heritage recording (Pomaska, 2001). On the other hand, **digital cameras** are time saving devices for detailing the building models produced on the basis of surveys with metric cameras (Grussenmeyer, et al, 2002). **Digital cameras** are still in a rapid development process. Today, digital cameras known as SLR (Kodak Blue Plus Color Full Frame) are of importance for architectural photogrammetry (Pomaska, 2001).

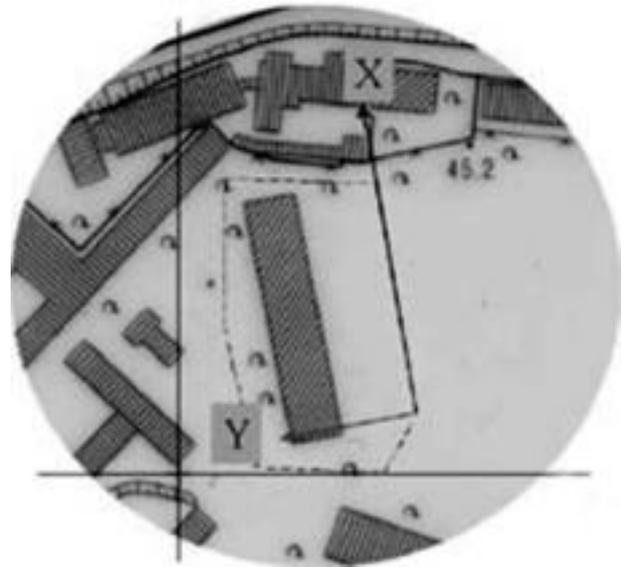


Figure 2. The polygone and the coordinate system established around Defensionskaserne.

In the case of Defensionskaserne, Rolleiflex 6006 metric camera and Kodak DCS 290 are used, respectively. They are not the state of art at present, but they were the ones available in hand and they are sufficient for the job. Kodak 400 ASA film was used. With Rolleiflex 6006, metric recording of the building was carried out. Then, the model produced on the basis of the data collected with Rolleiflex 6006 is textured by the help of digital images taken with Kodak DCS 290.

**3.2.2 Development of a Strategy for Taking Photographs:** The strategy for taking metric and digital images were developed separately. For metric images, it is known that **multi-image technique** is easy to handle on site. Camera stations can be selected without restrictions. Total station measurements supply control point information in a unique coordinate system. Complex buildings can be recorded with several separated image bundles.

It was decided to survey only the decorated east elevation of Defensionskaserne in detail. This means multi-image technique was applied only here. As explained for the control point measurements (see section 3.1), this long elevation of nearly 100m was divided into three parts named as left, middle and right. It is known that bundling all the images together should be preferred for the success of the adjustment. However, the division of the long facade into three parts has some practical outcomes. It becomes possible to work on every part separately. This means the opportunity of different people working on different parts. At the same time, it becomes easier to make the bundle adjustment since the number of images is decreased.

The position and direction of middle format cameras were so organized that the facade whole was covered (Figure 3). It was important to shoot two images for each building component to be measured. A third image was preferred to provide control information. While shooting these images that cover up the same area to be measured, correct definition of the intersection angle between the shooting directions gains importance. That means the intersection angle should neither be very acute nor obtuse, but it should be around ninety degrees. This angle selection does not only goes for xy plane, but also for zy plane. At the end of this survey, **close up images at human scale** and

**close up top images** are obtained. The camera was lifted with a tripod to provide top images. However, the recessed portion of the top floor and the roof could not be well documented since lift-support and aerial photogrammetry were necessary for these work. Apart from close ups, overviews were taken. **Overview images** are not for measuring, but they cover the façade in a few photographs and help one to orient himself within the image set.

Apart from multi-image technique, single image rectification is selected to be used for the photogrammetric plotting of the details. For this process, the **digital camera** was used. Since these images were for texture mapping and orthophoto production, it was important to shoot them with minimum perspective possible. Within this frame, unit areas between every two pilasters (6,5 x 14 m) were documented in a single photo taken from the ground level.

#### 4. PRODUCTION OF PHOTOGRAMMETRIC MODEL

In order to produce the photogrammetric model; first, the metric images were digitized on a desktop scanner. Then, these images were evaluated with an image evaluation software.

##### 4.1 Scanning

Photogrammetric evaluation in desktop environment requires images in digital format. Films shot with reseau metric cameras are best suitable for scanning because of the possibility of controlling image deformation caused by the scanning process. A wide range of high quality image scanners with high optical resolution, good geometric quality and color depth with 14 bit for each color is available. In short, large film formats with a reseau in combination with desktop scanners with high resolution provide good results (Pomaska, 2001).

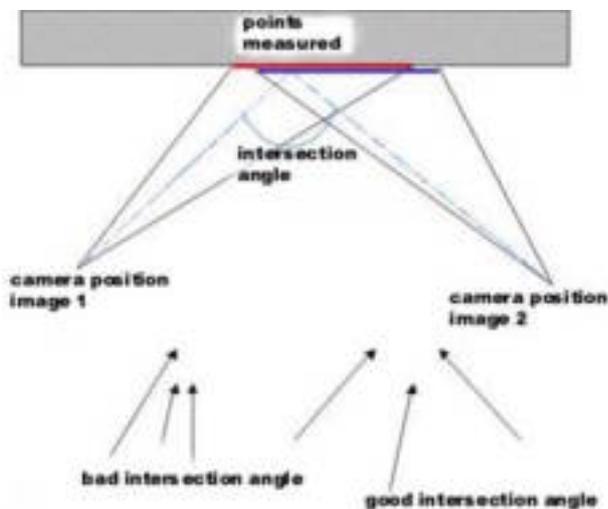


Figure 3. Principle of taking metric images

In this study, films shot with Rolleiflex 6006 metric reseau camera were scanned on AGFA Duo Scan T 2500. With this scanner, a resolution of 2500 dpi can be reached. The object size in regular images was approximately 15 x 15m. This corresponded an image size of 60 x 60mm. Therefore, the image scale was calculated as  $1/250$  ( $15\ 000 / 60 = 250$ ). According to the scanning theorem (Luhmann, 2000), 5mm should be taken, if 10mm is the aimed object resolution. Then, the result of the calculation  $15\ 000\text{mm}$  (object size) divided by 5mm (object resolution) is 3000. This is the number of pixels. The end-

product of the scanning process will be 3000 by 3000 pixels in size. This is around 1000 dpi. For getting a unique image resolution, the object resolution was selected with 0.005m. A surface of 15x15m is then given with a resolution of 3000x3000 pixel. On the other hand, the production of good colours in the scanned images requires the calculation of a profile for the scanner. Here, scanning was carried out in RGB colours. For the improvement of the images via the image processing program Photoshop, gamma correction of 1.5 and sharpening was made. Image files were named considering film numbers and image numbers, and saved as bitmaps.

##### 4.2 Evaluation of Images

There are various software for evaluating metric images. In this research, CDW (Close Range Digital Workstation) was used for the evaluation of metric images. This software provides aid in image refinement. Correction of photo coordinates is known as image refinement. Image deformation results from different sources. These are lens distortion and geometric deformations such as lack of film flatness or orthogonality (Atkinson, 1996). CDW handles the correction of lens distortion and geometric deformations. At the same time, the software measures image coordinates (Pomaska, 2001).

In this study, library of images for left, middle and right parts (see section 3.2.2) was developed. Scanned images were saved in their correct folders. Evaluation of each library (part) was carried out separately; then, the results were combined. The following process was repeated for each set in CDW environment:

1. The system fixing table was filled in. From the control points, measured with a total station, seven values for defining the degrees of freedom for a coordinate system were selected and entered in the system fixing table.
2. Camera data was introduced: 6050 middle format, reseau 6006, focal length: 51.24, XH: -0.25, YH: 0.16, rO: 20, angle unit: GON.
3. Images were oriented. During this process, the reseau crosses were utilised. The crosses at the four corners of the central cross were checked in. This gave way to an automatic selection of the rest of the crosses. If more than 50% of the crosses are oriented automatically, the transformation is considered as sufficiently accurate. In turn, the image file is saved.
4. Image coordinates were measured. Images documenting the same sub-section of the building surface were grouped together. At least two images viewing the same area with a different perspective is necessary for measurements (see section 3.2.2). Then, 'measure image coordinates' was chosen on the toolbar. Six matching points that are observed on the images of the sub-section worked on are marked. For example, left top corner of window A is marked in the images viewing it. The six points should be distributed evenly on the selected elevation portion. In addition, these points should not belong to the shadowy and hidden areas.
5. Object coordinates and camera positions are calculated. Theoretically, this process is composed of a series of resections followed by intersections

(Pomaska, 2002). Calculation is clicked on the toolbar. Image files are selected one by one. First, single image orientations are made. Then, single image orientations are made. Then, two image files are clicked simultaneously for multi image orientation. This is followed by multi-image orientation of three, four, ... files. For each group, results are displayed. If there are problematic points, they are detected and calculation is repeated.

6. Images are measured. This includes the definition of three dimensional points and polylines on the elevation surfaces. In other words, three dimensional points and three dimensional polylines that have key importance for the definition of the elevation surface are measured. This process includes the clicking of the same point or line on all related images in sequence. After the selection of a point on the first image, "epipolar lines" help the identification of the same point on the other two images. Then, compute command is chosen. According to the decided scale of the end-drawing, the limit of delta values that is to be accepted at the end of computation is decided on. In this project, 2 cm has been taken as the limit. This means the acceptance of measurement mistakes upto 0.5 mm in 1 to 50 scale (Figure 4).
7. Measured points and polylines are transformed to CAD environment. "DXF transfer" on the toolbar is clicked. A dialogue box opens. The extension of the source file is selected as ".POO", and that of target file is selected as ".DXF". "3D Interface" is checked. Finally, "preview and transfer" is clicked. Then, autocad program is turned on. The folder with DXF extension is opened. Three dimensional view is clicked under the view option. Coordinates of similar points such as corners of column bases are compared with each other to detect problems. If the values are very different from each other, then there is a problem in the transformation. It should be repeated. Since the east facade of Defensionskaserne is worked under three sub-parts, the transformation should be carried out for each part separately. This necessitates the transformation of a single part first. Then, the autocad file including the transferred data is saved with a different name. All data except the information about coordinate system and rotation are erased. The transformed data related with the second part is copied here. The first part is also copied. The process is repeated for the third part.

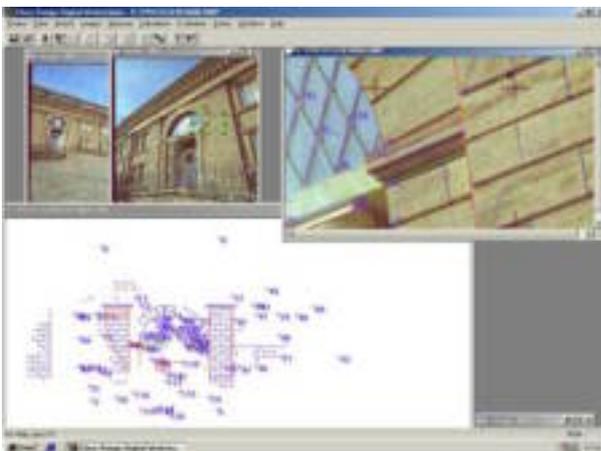


Figure 4. Measurement of 3D points and polylines.

## 5. PRODUCTION OF 3D MODEL

The strategy was to visualise the monument at its present state. Therefore, a problem of visual reality was faced with. 3D model was created in autocad environment on the basis of the photogrammetric survey. This 3D model was processed in various ways so as to produce textured model, etc.

## 6. IMAGE RECTIFICATION

Image processing procedures for warping an electronic image on the basis of the geometric principles so that the perspective is controlled and an orthogonal image is achieved at the end are known in photogrammetry as rectifications. By the help of rectification, a lot of details can be mapped in a very fast way (Pomaska, 1998). While applying the rectification technique, the following points should be considered: A single tilted photo and four control points are enough to rectify a scaled image. But it is better to take photographs of building elevations as much perpendicular as possible to the elevations. Evaluating only the central part of the image also increases the accuracy of the result. Another important point is the organization of image series. Images taken from a single building elevation should define different planes of the elevation. In other words, a special rectification is necessary for every plane at different depths. It is impossible to rectify an object surface that is not a flat plane (Grussenmeyer, et al, 2002). Series of rectified images of a building surface can be assembled in two basic ways. These are ortho-imaging and texture mapping.

Rectified images are brought together in an image processing software to produce ortho-images (ortho-photos). Ortho-image of a building elevation is a combined photo of the elevation without any perspective. If rectified images are assembled so as to cover up a simplified 3D model of a building, then a textured 3D model is produced. Model simplification is found necessary since it is difficult to prepare a separate rectification for every building element. This simplification involves the definition of some basic geometric planes on the model surfaces. The rectification applications carried out in Defensionskaserne are explained in the below.

### 6.1 Ortho-imaging

In the study, Rolleimetric MSR and Photoshop are used for the process. The Rolleimetric MSR software package (<http://www.rolleimetric.de>) provides scaled representations of existing objects on the basis of rectified digital images. Images taken with medium format camera are used. The strategy was to produce an overview of the east elevation and a detail of the same elevation. For the overview, the elevation was abstracted to five basic planes whose depths varied. These planes are named as left corner, left wing, entrance, right wing and right corner. The architectural elements such as pilasters, pilaster bases, window sills, etc. obviously present varieties in their depths. But these are considered as the same for the rectification of the overview. Depending on these decisions, the metric images were reduced in size using Photoshop and saved as PSD files. Then, coordinates of the corners of the planes were introduced to MSR by clicking data-data editor-plane editor on the toolbar.

Here, camera data were also entered. Then, measure – plane points is selected. The corners of the planes were marked one by

one. It is important to note that the rectification area can be chosen larger than the defined plane. The desired number of pixels per unit length of the end-product are marked in the equalisation settings. In this study, 1 pixel is taken as 0.01 m. Finally, the rectified images are saved as BMP file. A series of sub-pieces of the rectification can be saved to provide ease in latter colleague work in photoshop. These rectified images are opened in photoshop and perspective correction is made. The image size is re-determined according to the desired scale at the end. In this project, the scale is determined as 1 / 200. Then, the ratio of the present image size and the measured distance in rectified photoshop image is proportioned with the ratio of the new image size and the measured distance in autocad model. The total size of the overview ortho-photo is calculated as around 8000 pixels x 700 pixels.

For the detail ortho-photo of the left corner (1 / 25 scale), two images were used. The two pilasters, wall piece with window openings, three different bases and the flat piece at the bottom of the entablature were regarded as separate planes. The above described process was repeated (Figure 6).

## 6.2 Production of Textured 3D Model

In Defensionskaserne, Photo 3D (software for 3D model with texture from photo) was used for rectification process. Image library of the digital camera was sufficient for the work. As stated in section 3.2.2, each digital image covered an area between two pilasters (6,5 x 14m). 'File' on the toolbar was clicked. An image was loaded by clicking 'add photo'. Then, calibration option was selected. Two axes were decided to be used in the calibration. Therefore, the y axis was hidden.

Two sets of parallel lines making up the borders of the top and bottom sides of the wall piece with openings, and exterior sides of the two columns were marked by pulling around the calibration lines to these defined positions. Then, model option was clicked on the toolbar. A cursor was initialised again by clicking the "init" button on the toolbar. This cursor was stretched and moved to one of the planes to be rectified. Then, rectangle option was clicked on the toolbar to indicate that the plane definition can be saved. The initialisation process was repeated for al the planes selected for rectification. Finally, texture on the toolbar was clicked to illustrate the areas desired to be used in texture mapping; these are the interiors of the defined rectangles (Figure 5). Finally, the file is exported as VRML 2.0 document to a folder and saved.

After the production of the textures, they are sticked on the 3D model in Autocad environment.

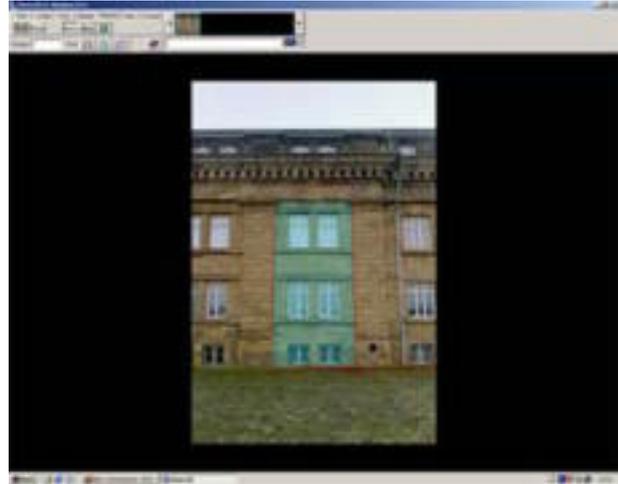


Figure 5. Selection of a plane for texture mapping.



Figure 6. Orthophoto of the east elevation's left corner.

## 7. CONCLUSION

The application of multi-image measurement and single image rectification techniques has provided the accurate documentation of the geometry and texture map of the east elevation of Defensionskaserne. Three parted working technique developed for the extraordinary long elevation has been successful during multi-image measurement. With the photogrammetric data, 3D textured model of the object has been produced.

The significance of this end-product from the view point of architectural heritage conservation is as follows: The 3D model documents accurately the object. This is an indispensable data for an architectural conservation project. The textured map is necessary for visualization of analytical information such as material types, structural problems, alterations, etc. Therefore, the combination of the two photogrammetric techniques has provided an accurate base for conservation studies.

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