

IMPLEMENTATION OF DIGITAL 3D-MODELS IN BUILDING SURVEYS BASED ON MULTI IMAGE PHOTOGRAMMETRY

Günter Pomaska, Prof. Dr.-Ing. Fachhochschule Bielefeld,
Fachbereich Architektur und Bauingenieurwesen, Germany

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ABSTRACT:

Hybrid measurement techniques for performing a digital 3D-model with respect to the building survey of an ancient castle are shown. An analytical model of the castle, including sufficient information for digital image rectification, is provided through multi image photogrammetry. Results of image rectifications are stored in a bitmap library for further orientation in the 3D-model. Common software tools are used for this process. The software packages RolleiMetric MR2 for the analytical multi image evaluation and RolleiMetric MSR for digital image rectification support the photogrammetric part. Adobe Photoshop is used for digital imaging. AutoCAD and AccuRender are the tools for manipulating the analytical and digital 3D-model.

Am Beispiel der Bauaufnahme einer Burgruine wird der Einsatz hybrider Meßverfahren zur Erstellung eines digitalen 3D-Modells bis hin zur Animation gezeigt. Mittels Mehrbildphotogrammetrie wird ein geometrisches Modell der Burg erstellt, das hinreichend Informationen zur digitalen Entzerrung der Fassadenaufnahmen beinhaltet. Ergebnisse der Entzerrung werden in einer Bitmap-Library gespeichert und im analytischen 3D-Modell orientiert. Hierbei werden die Möglichkeiten standardmäßiger Softwarewerkzeuge aufgezeigt. Neben den photogrammetrischen Programmen RolleiMetric MR2 zur analytischen Mehrbildauswertung und RolleiMetric MSR zur digitalen Einbildentzerrung werden Adobe Photoshop für die Bildbearbeitung, AutoCAD und AccuRender zur Bearbeitung des analytischen und digitalen Modells eingesetzt.

INTRODUCTION

Surveys for performing the as-built structure of a building are carried out for several purposes such as preservation and restoration or studies on the architectural history. A civil engineering project today demands the presentation of the surveying results as an analytical CAD-model which fulfils the requirements of further data processing for various tasks. Simulation and animation like walk throughs are highly accepted presentation techniques today. Finally the data base can be used for facility management applications.

A complete building survey includes recording of the facades as well as floor plans, section and height measurements. A combination of photogrammetric recording, electronic tacheometry and tape measurements is the appropriate technique.

SITE SURVEYING AND RECORDING

Electronic Tacheometry. Usually a geodetic network is necessary for recording the as-built structure of a construction. Setting out and control measurements



Figure 1: Part of the castle already renovated.

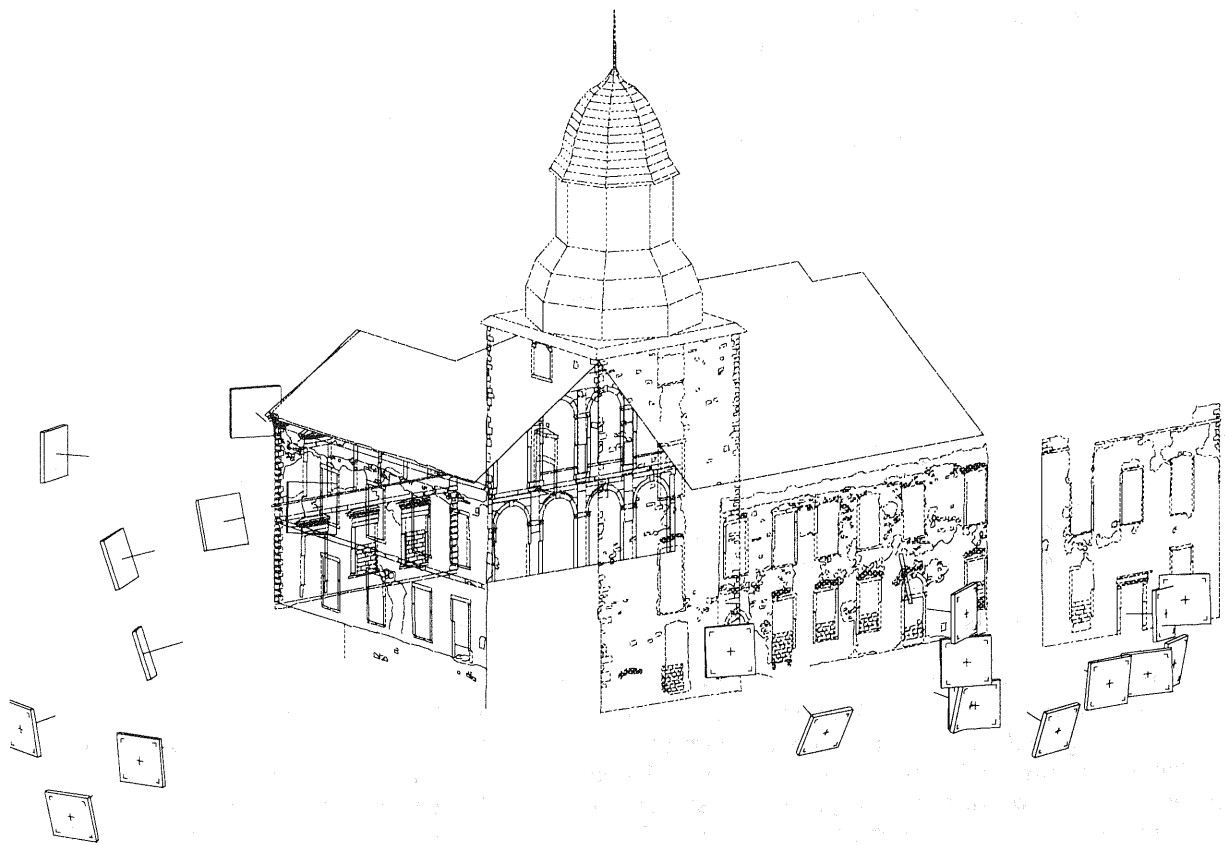


Figure 2 : Multi image evaluation of the 3D-model including photo positions and reconstruction of the roof.

are performed with respect to that network. Traverse surveys and control point measurements for the photogrammetric orientation is carried out simultaneously. Natural points, marked in polaroids, are quite good as control points. The effort for object signaling with artificial points is not acceptable. It is a good practice to adjust tape measurements for floor planes to the geodetic network as well. Therefore, control points for indoor surveying have to be defined in the different floors.

Multi Image Photogrammetry. The implementation of multi image photogrammetry reduces the effort in the on-site work for facade recording. Restitution of the image bundle results in a 3D-point network, including object points for the complete building. The datum of this network can be derived from a levelling or plumbing line and some spatial scales or is given by the local network.

The equipment used for the a.m. method is a medium format metric camera such as the Rolleiflex 6006 metric. Evaluation of those photos is performed in paper enlargements on a digitizer or from the digital images presented in the frame buffer. Most common ways of getting digital images are scanning the negatives alternatively the positives or on-line

recording using a CCD camera. Every image is stored in a separate file written in a common standard format like TIF. A typical image bundle may consist of a large number of photos taken from some up to several hundred positions. The orientation process starts with approximate values for the photo positions and is finished by calculating the bundle adjustment, taking into consideration all measurements in the image and object space. Weights according to the accuracy of the observations have to be implemented. This best fit procedure provides object point coordinates including their accuracy and reliability.

Evaluating the details from the images results only in simply structured point and line information. This data material has to be converted into a complete 3D-structure. To fully benefit from the capacity of a CAD-system, a solid modeller has to be used. Often, a compromise must be accepted between the real measurement values and the architect's construction idea. Otherwise, it seems impossible to produce the complete 3D-data base.

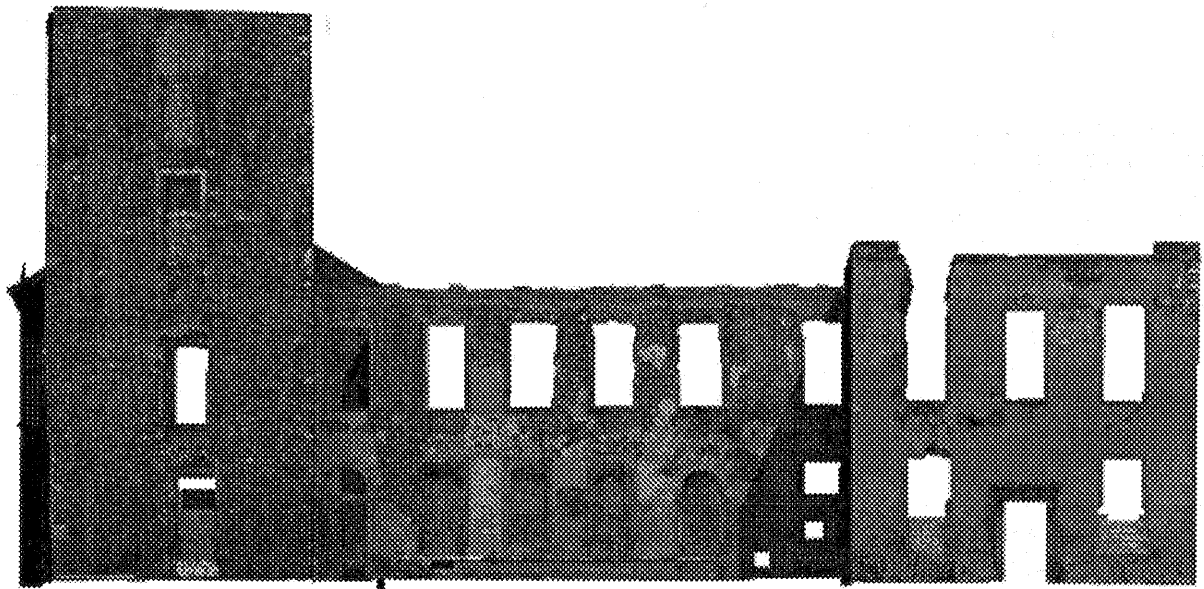


Figure 3 : Orthographic projection of the west facades of the castle

The analytical vector structure provides the geometrical frame for the digital model which may give pixel information for every point on an object's surface.

Figure 2 shows the facade drawings generated with the RolleiMetric MR2 program. Included are the photo position which are calculated by the photogrammetric orientation procedure. Reconstruction of the roof is shown in this stage as well.

DIGITAL IMAGE RECTIFICATION

Warping digital images is a process that defines a geometric relationship between each point in an input and output image. The mapping function for rectification is a perspective transformation based on the relationship between the image and the planar object. With a minimum set of four control points given in the image and on the object surface the eight degrees of freedom for a perspective transformation can be determined. Forward mapping consist of copying each input pixel onto the output image to positions determined by the mapping function. Inverse mapping projects each output coordinate into the input image. The value of the data sample at this point is copied onto the output pixel. Inverse mapping guarantees that all output pixels are computed. The output image in this way is generated by point sampling. With point sampling, entire intervalls

between samples are discarded. Interpolation is required. When large scale changes occur, aliasing artifacts such as jagged edges or moire patterns are evident. Antialiasing algorithms have to be implemented. Fast warping techniques are critical for the application. Scan line algorithms have reduced complexity and processing time.

The RolleiMetric MSR software rectifies images with respect to the a.m. theory taking into consideration interior orientation parameters of metric cameras. The control points are imported from the multi image evaluation results and represent a 3D-surface. Maximum distance from the average plane is shown. Due to the overdetermined calculation of the transformation parameters quality control of the rectification is given by the residuals. The output image represents a surface on the object with a predefined pixel distance. The offset of the pixel coordinate system is stored in user coordinates in a separate file. This information yields to user coordinates for every pixel and is useful for further processing such as scaling , clipping or merging image data.

Acquisition of Digital Images. Digital image acquisition is provided by use of a digital camera, slide scanning or desktop scanning. Resolutions of digital cameras are often insufficient. Handling of high resolution equipment is not convenient on site.

Therefore film scanning is recommended for architectural applications. 35 mm slide scanners are coming with 2700 dpi resolution. The Kodak photo CD provides a base resolution of 512 * 768 pixel which is available on the disc in 4 and 16 times resolution as well.

Table 1 shows calculation samples for different scan resolutions using a 35 mm slide scanner. An image scale of 1 : 200 is estimated. Scale 1:200 on a 35 mm format is an object size of approx. 8 meters. The image size is theoretically calculated without compression. If a photo is scanned with a 600 dpi resolution, the image size results in 1.3 Mbytes with a pixel size of 0.04 mm. Transferred to the object, a gray value for every 8 mm is given in the object. If the image is enlarged five times the appropriate resolution for a desktop scanner is presented in table 2.

ScanRes [dpi]	Size RGB 24 bit	Size Gray 8 bit	Pixelsize [mm]	Object [mm]
2700	26	9	0.01	2
1200	5.2	1.8	0.02	4
600	1.3	0.4	0.04	8
300	0.3	0.1	0.08	16

Table 1 : Scan resolution and image size using a film scanner for 35 mm formats.

ScanRes [dpi]	Size RGB 24 bit	Size Gray 8 bit	Pixelsize [mm]	Object [mm]
600	37	12	0.04	2
120	1,5	0,5	0.2	8

Table 2: Scan resolution for a desktop scanner using a five times enlarged print.

Comparing both tables infers that it is not necessary to use always the maximum scan size. Scanning the enlarged print with the desktop scanner using a scan resolution of 120 dpi delivers gray values for every centimeter of the object.

A laser printer with 600 dpi resolution has in fact a graphic resolution of 75 dpi. The reason for this reduction is the 8 x 8 dither matrix. Assuming a 1:50 scaled print for a 10 meter facade requires under those circumstances 0,02 m object resolution.

The values presented in table 3 are calculated according to a Kodak photo CD. The base resolution is 518 x 712 pixel and available on the disc as a four times and 16 times base resolution.

ScanRes [dpi]	Size RGB 24 bit	Size Gray 8 bit	Pixelsize [mm]	Object [mm]
512x768	1,2	0,4	0,05	10
1024x1536	4,7	1,5	0,02	4
2048x3072	18,8	6	0,01	2

Table 3 : File size in MByte and pixel size according to a Kodak photo CD. Assumed image scale 1:200.

Digital Imaging. Mapping of a building's facades involves the acquisition of multi image sets. The photos were taken from flexible positions under different light conditions. Geometric transformations are based on a unique coordinate system. Spatial relationship and scale is sufficient. Brightness and contrast varies. Using digital imaging software not only provides color transformations. Altering the image content is one of the fascinating aspects of digital imaging.

Image-editing programs provide selection tools for isolating image areas. One can create oval, rectangular or free form selection, appearing as a series of blinking lines on the screen. These areas can be used as masks. Painting, color correction, brightness and contrast editing is performed in those marked areas.

Photogrammetric images are prepared for the rectification by cutting out the areas without interest. Planes not sharing the rectification surfaces are eliminated as well. This preprocessing results in data reduction and is convenient for continuous handling.

To achieve homogeneous brightness and contrast in an image that consists of several separate rectified areas like a mosaic adjusting tonal control is necessary. Adobe Photoshop provides in its image menu the submenus "map" and "adjust". Selecting the "equalize"-function from the map menu redistributes the brightness values of the pixels so that they more evenly represent the entire range of brightness levels. The levels dialog box allows brightness, contrast and gamma adjustment. That command displays a histogram of the image and allows correction by moving sliders. Since one can read the color information of the image pixels or average value of a 5x5 pixel square some objective criteria is given for brightness and contrast changes. Figure 3 is a sample for a digital facade rectification with 4 different photos. Some image content manipulation was performed to remove hiding objects.

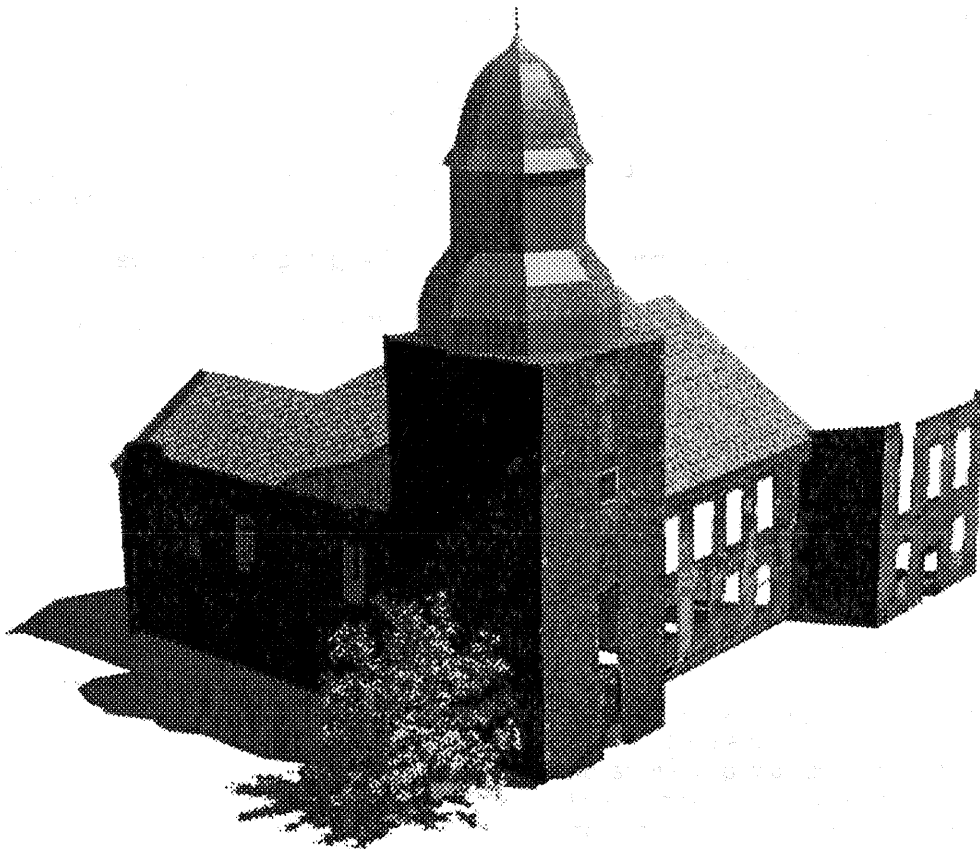


Figure 4 : Rendering sample of the digital 3D-model

RENDERING WITH BITMAPS

Photorealistic rendering is based upon assigning materials to the entities of a CAD-model. In addition to the material model, a light model has to be designed. Materials are bitmap patterns which are repeated like tiles in columns and rows until the entity boundary is completely covered. So called bitmap decals are not tiled. They consist of a single instance of the image. A bitmap decal has to be scaled correctly to fit the planar mapping projection. If the source of the bitmap does not deliver the appropriate scale, a scale factor in x- and y-direction can be defined. Calculation can be performed from the pixel information delivered by the digital imaging software compared with the dimensions from the drawing editor. Orientation of the bitmaps has to be defined through an origin point, the direction of the x-axis and a point in the x-y-plane. Excluded color options allow masking from the bitmaps. The effect is, that the background is visible through those masking areas. In the present sample the software package AccuRender is used.

Materials and their structure can be assigned to surfaces and objects. Light modelling and defining environmental elements such as sky and clouds, background or groundplanes are amongst the features available. The complete software functionality is available directly in the drawing editor.

Figure 3 shows an orthographic projection of the west facade of the castle. Note that the dark areas resulting from the light source, which here is the sun.

Environment, landscaping and animation. The realistic environment includes elements without part of the original AutoCAD drawing but should nevertheless be contained in the rendered image. These elements include background and ground plane as well as light settings, fog and haze and depth cue.

Is a model shown in a perspective view a background should be imagined as an infinity globe around the model and the ground as an infinitive surface underneath.

On the globe colors, clouds and bit maps are

projected, which can set the model into a realistic or even surrealistic surrounding. Ground can be covered by different materials. Fog and haze could simulate the effect of normal haze in the background up to real fog. Colors of haze correspond to background color. Vegetation acts as normal 3D-objects, producing shadows and being reflected.

Some ideas what can be done are shown in figure 4. Simulation of the projected roof is included. Shingles were assigned to the roof's surface. This model is prepared for an animation. Viewpoint animation or sunlight animation is possible. A viewpoint animation is known as a "walk through". Along a defined path are the frames calculated. The frame sequence is stored in a FLIC-file and can be animated with every animation player. The sunlight animation calculates a frame sequence from a fixed viewpoint under changing light conditions.

SUMMARY

A procedure for setting up a digital model of a civil engineering object is described. Bitmaps are derived from photogrammetric images using rectification parameters. They are calculated from point information existing in the vector model compared with the corresponding points in the image. Rectifying includes image deformation corrections resulting from digitizing and lens distortion. The output provides a scaled bitmap with 2D-pixel information. These bitmaps are related to their 3D-surfaces stored in the CAD-model. Common CAD-programs or rendering utilities allow scaling and orientation of bitmaps according to the existing spatial vector information. Adding pixel information to the vector data allows photorealistic presentation, animation and printing of scaled digital images from which geometric information can be derived.

Apart from photogrammetric evaluation, also image processing is necessary for getting homogeneous brightness and contrast or masking. Masking is important for contour and content correction as well as combination of separate photos. Software products such as Adobe Photoshop are recommended to carry out the image processing.

It is the aim of this paper to describe a procedure for receiving a complete 3D-digital object model from multi image photogrammetry. Photogrammetric functions are supported by standard software packages for CAD modelling, rendering and digital imaging

First results and experiences are presented with the recording of an ancient castle named Hundisburg located in Germany.

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