

# Desktop - Photogrammetry and its Link to Web Publishing

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**Abstract:** Dimensional analysis from images seems to be a field for experts involved with special knowledge and equipped with high performance tools. Since softcopy workstations replaced the analytical plotters it is not the case further on. Photogrammetry has moved to the desktop and is incorporated into CAD or image processing software. Recording is provided amongst others with digital cameras of the shelf.

Requirements to recording and documentation of archaeological sites have reached a high standard. Results have to be published not only to researchers or experts. It is important to reach a wide community for generating interest and education in history. The Internet provides this platform. Photogrammetry can be an efficient tool for on site recording as well as for exciting documentation.

This contribution focuses to some aspects of digital photogrammetry particular camera handling, recording and evaluation methods and the products one can receive from photogrammetry.

## 1 Photogrammetric Image Acquisition

Photogrammetry is defined as recording, measurement and interpretation of 3D-objects from images with non-contact recording systems. The major application of photogrammetry is mapping from aerial photos. Non-topographic photogrammetry or close-range photogrammetry covers applications in archaeology, architecture, forensic science and industrial metrology. To produce true scale drawings from images the exposure arrangement has to be reconstructed first. Photo positions and camera parameters must be known before a detailed evaluation can be performed. Accuracy results beside other conditions from image scale and image measurement accuracy. The former analogue and analytical plotters are replaced by „softcopy workstations“ today. Close-Range applications benefit from utilizing standard cameras for metric applications. A sensor supplies from a surface of 2/3 of an inch millions of pixel including colour information. The Workstation can be a notebook computer.

Figure 1 displays a „Meydenbauer camera“ from 1890 designed for terrestrial applications. The image format of this camera is 30cm x 30cm, carrier for the film emulsion was glass. Another example for photogrammetric equipment is given in figure 2. The Stereoplanigraph C8 from Zeiss Germany produced 1967, connected directly to a drawing table. Driving the floating mark in the photogrammetric model was recorded directly in true scale line drawings. Today the results are presented as 3D-CAD models, orthophotos, hierarchical polygon models, high-density point clouds or models in Web-formats.

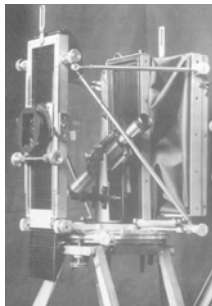


Figure 1: Meydenbauer camera built 1890 for terrestrial photogrammetry

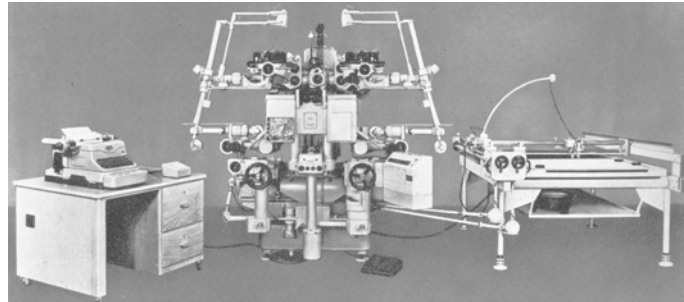


Figure 2: Stereoplanigraph C8 from Zeiss Germany, built 1967

## 1.1 Image Refinement

Many photogrammetric evaluation methods are based upon a central projection model. A point is projected by a straight line through the projection centre (camera lens) onto the image plane. Deviations from this model can be parameterised. Without covering the details some remarks about co-ordinate systems, camera calibration and image refinement are necessary here. The location of a 3D-object is referenced in an object co-ordinate system. Image measurements, which supply after some computations the object point, are taken in an image co-ordinate system. A reference to the image co-ordinate system is given by the camera's format frame (not good), by fiducial marks (better) or by réseau (best) that is a grid plate in front of the film surface. Digital cameras include the reference in the pixel positions. The difference between the origin of the image co-ordinate system and the reference system is given by the principle point position.

Image deformations result from insufficient film flatness and radial and tangential lens distortion, which cause from variations in angular magnification and misalignment of lens components. Film flatness can be controlled and numerically corrected using a réseau-camera. Camera calibration by means of bundle adjustment provides the model correction parameters. Particular if wide-angle lenses are used a transformation to the principle point and radial lens distortion correction is necessary. The process is known as image refinement. Radial lens distortion can be simply detected by observing straight lines of the object shown as curves in the image. A stereoscopic image pair of a plane surface gives an example. Without image refinement, the plane is presented as a curved surface. Image processing programs enable subtraction of two images. The difference between a distorted image and the according refined image illustrates the influence of distortion as well.

Strategies for camera calibrations should not discuss here. Figure 3 is an image of a plain calibration field, taken with a 2-megapixel camera. The radial lens distortion curve of this camera is shown in figure 4. The amount of distortion in the image corner is about 40 microns. Please note that this value in object space increases with the factor of the image scale.

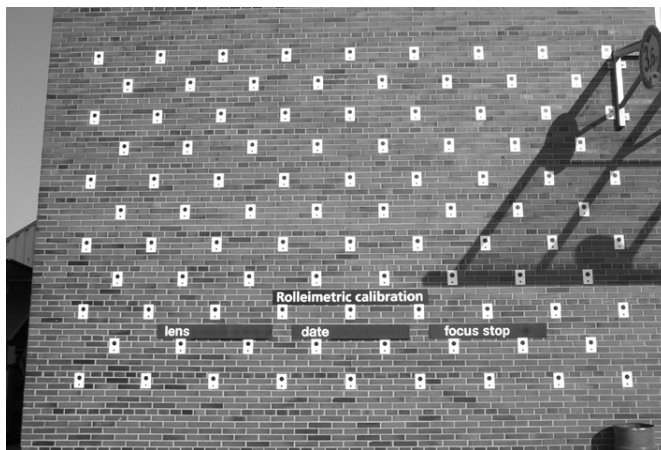


Figure 3: Calibration wall for camera field calibration, Rolleimetric calibration, Braunschweig

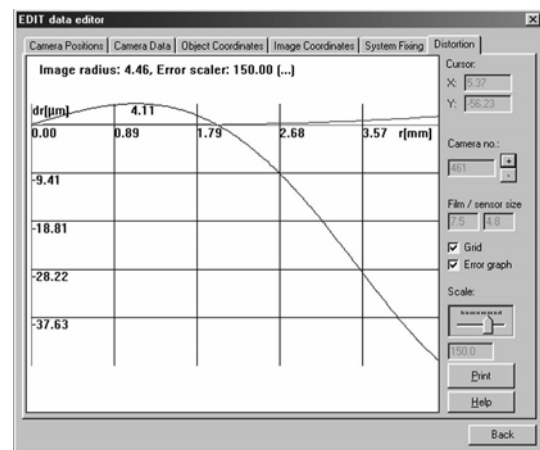


Figure 4: Lens distortion of a CCD camera with an 8 mm lens.

One mega pixel camera, which corresponds to the metric requirements, is the Rollei d7 metric, see [2]. The calibration parameters are stored in the digital image. The original image data is protected in the raw data format that cannot be manipulated. Image refinement is processed in advance of the photogrammetric evaluation.

## 1.2 Object resolution

The discussion of image resolution using digital cameras and in case of film scanning as well should be directed to object resolution. What object area should be covered by one pixel? The image scale is given by comparison of object size with the according image size. Full format photographing an object of 50-metre extension with a medium format camera supplies an image scale of 1:830. For a 35mm camera this would be 1:1400, a 2/3 inch CCD displays the object with a scale of 1:2950.

Here is an example from the point of view of accuracy calculated only by the thumb rule that the object accuracy is derived from the image measurement accuracy multiplied by image scale. Measurements from images should deliver an object accuracy of 1 cm. The sensor used is sized 2/3 of an inch with a resolution of 1800 pixel. Pixel size is approx. 10 microns, equal to the estimated measurement accuracy. Image scale should be 1:1000 that means an object size of approx. 16 metres could be imaged. But do not forget the scanning theorem that the scanning frequency has to be at least twice as the local frequency. Desktop Scanners with film adapter units are equipped with optical resolutions of 1200 ppi and therefore usable for formats from 35 mm to medium format and larger. 35mm film scanner supply resolutions up to 2700 ppi optical.

To summarize: A medium format camera in combination with a desktop scanner supplies the same image resolution as a digital camera of the shelf. A disadvantage of the digital camera is the small format. To fulfil high accuracy requirements, a réseau camera provides best results. Every photogrammetric evaluation software package needs a camera description file including, focal length of lens, principle point position, lens distortion parameters, image format width and height, shape and position of reference for image co-ordinate system.

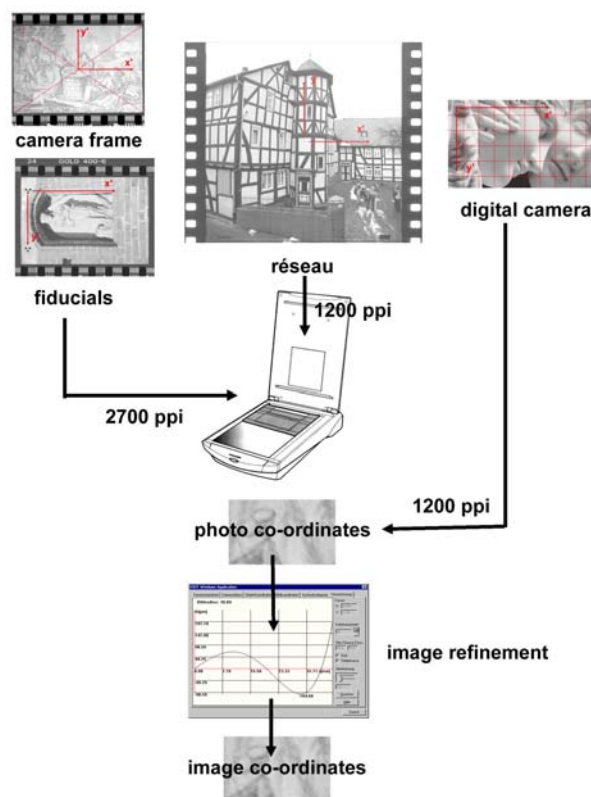


Figure 5: References to the image co-ordinate system. Format frame, fiducials as recommended by EOS Systems, réseau image and digital image.

## 2 Photogrammetric recording and evaluation strategies

The number of photos taken and the method used for object reconstruction can classify photogrammetric methods. Single image methods require some object information. Two photos taken as a stereo pair represent a model for evaluation based on parallax measurements. Several models are combined by adjustment. Multiple images enable point computation by intersection and over determination.

### 2.1 Single image rectification

Single image methods need additional information about the object shape. If the object shape is a plane surface, using the relationship between object plane and image plane can perform rectification. The perspective projection parameters can be calculated by four given control points in the object plane. Relative positions of these points in the image must be measured. Architectural applications can benefit from parallel lines in the object. Two orthogonal located pairs of parallel lines have to be marked in the image. The geometric condition will be restituted after rectification. Results of image rectifications are high-resolution image maps. Image rectification in this way works without metric camera modifications and unknown focal length.

### 2.2 Multi Image Potogrammetry

Multi image photogrammetry works with convergent exposure arrangements. Object co-ordinates are computed by intersection methods. An object is completely covered by an image bundle. The photo positions have to be calculated by best-fit algorithms. Multi image photogrammetry supplies geometric object information with high accuracy and reliability. Interactive detailed evaluation enables production of high quality large-scale line drawings. There are no limitations to camera positions. Multi image photogrammetry needs at minimum 2 photos; applications with several hundreds of images are known. Figure 6 shows the principle of multi image photogrammetry.

### 2.3 Stereoscopic Photogrammetry

A stereoscopic image pair corresponds to the human viewing system. Reconstruction of the object is given via disparity or parallax measurements. Using a stereoscopic viewing systems enables visual evaluation by driving a floating mark in the stereoscopic model. Automatic object reconstruction is possible by means of correlation. In this case monoscopic viewing is sufficient, systems are called “one-eye stereo systems” and represent a major advantage of digital photogrammetry.

### 2.4 Orthophoto

Particular the digital orthophoto is an example for automatic image evaluation. A digital surface model is calculated automatically. Photos are resampled from perspective view to orthogonal projection taking into consideration of the predefined surface.

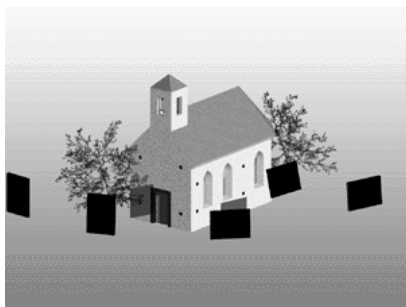


Figure 6: Exposure arrangement for multi image photogrammetry



Figure 7: Stereoscopic recording simultaneously with two cameras

Numerous software packages for PC-workstations like RolleiMetric CDW, RolleiMetric MSR, Elcovision 10, Photomodeler, Photo3D and others are available for object reconstruction from photos. Conventional photogrammetric products are line drawings, CAD-Models, point-clouds, image maps and orthophotos. With the ongoing development of Web technologies the demand to new products like image objects, panoramas, digital 3D-models for interactive navigation increases. Hierarchical polygon models replace model descriptions by contour lines. Texture mapping became more popular. In the following chapter some methods of image based documentation and the according Web publishing techniques are introduced.

### 3 Web Publishing

#### 3.1 3D-Models and Texture Mapping

With the definition of VRML virtual modeling language a standard for interactive inspection of 3D worlds is designed. For increasing the reality imagination, the geometric model is covered with texture. A texture is a 2D bitmap. Every 3D corner point of a surface of the geometric model is connected with a 2D point in one of the texture files. Current photogrammetric software packages include geometric modeling and texture extraction from photos. Since not all applications require the high accuracy low end products like Photo3D provide solutions to get a VRML model from standard 35 mm photos or digital cameras. Figure 8 displays a sample. On the left is the original photo, in the middle a scaled image map of the facades. On the right a screenshot of a VRML view.

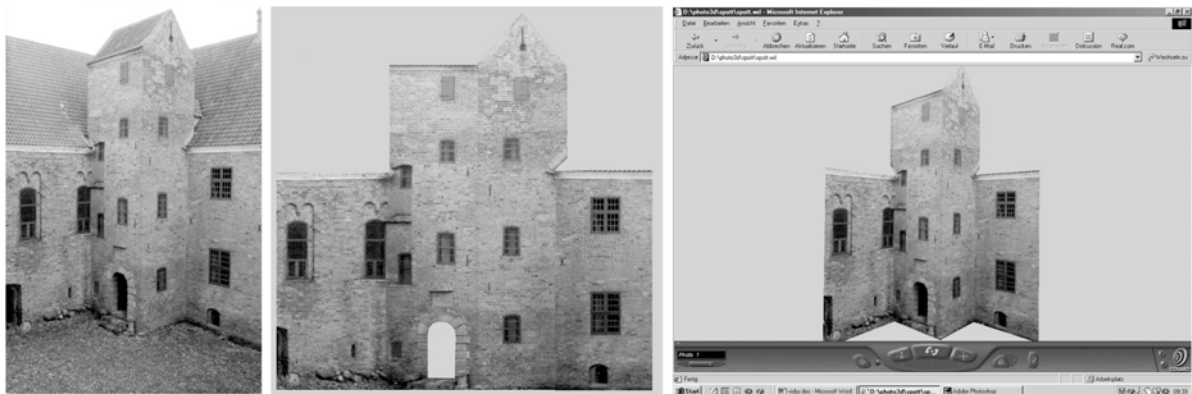


Figure 8: From a single 35mm photo, to a scaled rectified facade map and a VRML-model with PHOTO3D software for the PC.

#### 3.2 Orthophoto and DTM

Monoplotting from stereo pairs by means of correlation seems to be one of the major advantages of digital photogrammetry. Under this circumstance a digital orthophoto is the appropriate solution for automated mapping. The geometric shape of the object surface is automatically detected. The orthophoto in plane view provides a true scale image map. An example is given in figure 9. A DTM and the orthophoto mosaic resulted from a low altitude image flight. Some buildings of particular interest are presented in a 3D structure. All the data was converted in a VRML format. The buildings are connected by a link to other URLs. Detailed Information will display after a mouse click.



Figure 9: Orthophoto, DTM and buildings of particular interest in a VRML-File with links to detailed description.

### 3.3 Panoramas

There are several methods existing to shot a panorama. The conventional method crops the image to a long format. When the negative is printed it looks like a long narrow panorama but the field of view is still unchanged. The APS cameras today provide such an imagination.

Field of views up to 180 degree can be photographed with a swing-lens camera. The lens is mounted in a rotating cylinder while the film plane is curved. During exposure the lens rotates and paints the image through a slit onto the film.

The rotational method needs a camera that can rotate about 360 degree while the film turns synchronously opposite to the camera rotation. This technique is still very popular. An advantage is, that moving objects can be recorded without any problems. While taking street scenes with the segmented method, people or cars can occur several times in different positions.

A series of images taken with a rotating exposure direction and displaying the photos next to another is the oldest method to show a wide field of view. The advantage of digital image technology makes the segmented method very popular today. Taking the photos with a digital camera enables an automated process to display scenes for interactive viewing. Stitching software processes the single pictures to a cylinder, sphere or cube. The most precise panorama consists of evenly spaced photos using a tripod. A special panoramic head assures that the camera rotates on a level plane around the centre of the lens. A number of 12 photos using a wide-angle lens of 35 mm in portrait format can be sufficient for outdoor scenes.

Publication via the Internet enables free selection of the viewing direction and the distance to the object by zooming in and out. Plug-ins or Java applets are required. Panoramas on Web pages can be linked to other sources by putting "hot spots" into the images.



Figure 10: Panorama of the inner court of the Convento Sao Francisco in Recife / Brazil. The curved lines will be straightened while viewing in a Web browser using a plug-in or applet. This panorama was taken free hand. Therefore it is not so precise as it should be.

### 3.4 Image Objects

Taking a series of images from a fixed camera position while the object is rotating on a turntable provides photos for an image object. An image object can interactively inspected by selecting the rotation and the distance to the object. Processing those images can be done with QuickTime or MGI Picture Object Modeler. The software enables image selection, image adjustment and storage in different data formats like .avi or \*.fpx. The latter is a hierarchical image format, designed for distribution of high-resolution images. The Web server must be equipped with the according software to support the format. Figure 11 demonstrates the production of spin photo objects, here in stereo mode. Two digital cameras are computer controlled. Photos are taken in a time interval; the object rotates on the turntable in steps of 15 degrees for example. The software mentioned above supports masking as well, so that the environment can be corrected digital.



Figure 11: Computer controlled recording of image objects. Here a stereo arrangement with the object on a turntable.

### 3.5 Stereoscopic Images

The usage of stereoscopic images covers a wide range of applications of computer visualization. Those can be entertainment, medical and forensic applications, topographic mapping or architecture. In all cases stereoscopic displayed data is far more effective for visualization than a flat presentation. Monoplotting from stereo pairs by means of correlation seems to be one of the major advantages of digital photogrammetry. Displaying the results in stereo with standard equipment on a PC-Workstation is one step more for a better acceptance of photogrammetry. Image separation is realized by spatial separation (cyber head), temporal separation (shutter glasses) or filtering (red/green anaglyphs).

Stereoscopic image pairs can be stored in one image file. Side by side is the basic arrangement of a stereo pair according to the position of the human eyes. From the two free viewing modes parallel and cross-eyed, parallel is limited to very small images. Therefore cross-eyed is the default mode of a JPS stereo pair. JPS is in fact a JPEG format, which allows specific stereo software to handle those images. For example a Web browser plug-in from Vrex Corp. interprets that format and converts it to the viewing mode available.

According to BMP or PNG (portable network graphics) the stereo formats BMS and PNS exist. While BMS has no direct form of compression, PNS is a no-loss form of compression. Using the JPS format, a moderate amount of compression is recommended, since a major loss of stereo quality will occur while reducing image information.

Figure 12 demonstrates the use of the Java applet stereoscope. The stereo image will be calculated upon request client sided. The server provides the left and right image. Alternatives for image separation can be selected from the applet menu.

Image pairs can be photographed by using a stereo bar as shown in figure 11. For artefacts a desktop scanner provides high quality images. Computer models must be rendered from different viewpoints.

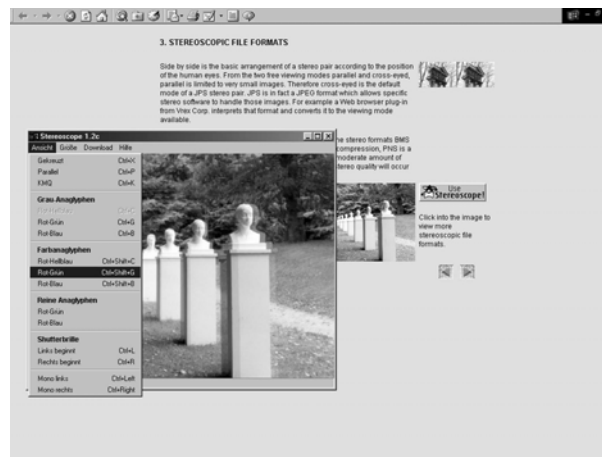


Figure 12: Web page including stereoscopic images to be viewed with stereoscope, a Java applet from Andreas Petersik, see [1], [4].

## Conclusion:

In addition to the conventional photogrammetric products like line drawings or contour line plotting new techniques and data formats for recording and documentation of 3d objects from images are developed. Image objects, VRML-models and hierarchical polygon models with texture mapping are distributed via the Internet. New data formats and plug-ins for Web browsers are introduced for sufficient transfer speed, image quality and interactive presentations.

The paper is available in pdf and HTML-format at [www.imagefact.de](http://www.imagefact.de), images and examples are given there in colour and with the above-mentioned interactive facilities.

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