INTEGRATION OF DIGITAL IMAGE ANALYSIS FOR AUTOMATED MEASUREMENTS INTO A PHOTOGRAMMETRIC STEREO EVALUATION SYSTEM

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Commission V, WG 2

KEY WORDS: Stereoscopic Documentation, Architecture, Matching, Digital Surface Model, Scanner

ABSTRACT:

The purpose of the introduced project is to achieve a combination of photogrammetric measurement techniques and procedures of digital image analysis in one stereoscopic evaluation system, which can be used in architectural surveying, building preservation and archaeology. Digital stereoscopic examination allows users an estimation of the spatial dimension and the surface texture of objects. The integration of automated image analysis techniques simplifies the stereoscopic measurement procedure and offers an increase in accuracy. Due to the substantial similarities of stereoscopic image pairs, correlation techniques provide measurements of subpixel precision for corresponding image points. Already within the process of image orientation this technique allows the use of natural unmarked tie points. Separate signalized control points are no longer necessary. The stereoscopic measurement process itself is simplified by an automated correlation-based depth determination for manual single point measurements. An adapted expansion algorithm for the same process even offers the possibility to measure profiles and object surfaces automatically. Additionally an included interface for the integration of tacheometric measurements and laser scanner point clouds allows a combined object evaluation. Digital surface models (DSM) can be created by triangulation and edited within the stereo model. In combination with the high resolution image material of the stereo evaluation, high-quality unwrappings, ortho images and 3D models can be generated. Taking various approaches for camera modelling into consideration, analogue and digital amateur cameras as well as panoramic cameras, can be used for stereoscopic recording in addition to the common metrical cameras.

1. INTRODUCTION

Photogrammetric techniques are still important for object documentation in the fields of architectural surveying, building preservation, and archaeology. Compared with discrete measurement techniques, like hand measuremts or tacheometry, they offer a continuous, high-resolution rendition of the visible object surface and allow photogrammetric evaluation also at a later date. While image rectification of plane objects is a simple but approved technique for cultural heritage documentation, in many cases the handling of higher level photogrammetric methods for spatial object analysis is too complex for its users. Stereophotogrammetric recordings allow three-dimensional documentation and evaluation of uneven objects and freeform object surfaces. Spatial perception at stereoscopic viewing gives users information about condition, quality, and structure of surfaces. The integration of automated image analysis techniques in one user-friendly stereo evaluation software can simplify the stereoscopic measurement procedure and open up this technology for a wider user area.

The use of stereophotogrammetry and image analysis for building history and archaeology is one research focus at the chair of surveying at the BTU Cottbus. The introduced workings are based upon a long-term cooperation with fokus GmbH Leipzig and the joint research project "Integriertes 3-D Panoramamesssystem" for combined photogrammetric evaluation of digital panoramic images and laser scanner data between TU Dresden, KST Pirna, and fokus GmbH Leipzig.

2. IMAGE CORRELATION TECHNIQUES

The process of depth measurement is often difficult for untrained users and may produce wrong results at manual stereoscopic evaluation. Due to the substantial similarities of stereoscopic image pairs, correlation techniques are well suitable for integration into a stereo evaluation system. First an automated depth measuring function using image correlation was implemented for an easily positioning of the floating mark on the object surface. According to the Vertical Line Locus procedure (Cogan & Hunter, 1984) a straight line orthogonal to the current projection plane is defined. For discrete points with a defined interval Δh along this line, image coordinates for the left and right image will be calculated. The intersection point between the line and object surface can be obtained from the image coordinates with the maximum similarity between the surrounding image matrices using the normalized cross-correlation coefficient for a one-pixel accuracy approach. (a.o. Piechel, 1991). A sub-pixel localisation will be calculated afterwards with least squares matching (LSM) (Ackermann, 1984, Foerstner, 1982, Gruen, 1996) for a geometric and radiometric transformation between both image patches. LSM is the most accurate image matching technique and offers an improved accuracy also for images with larger perspective differences. Moreover the adjustment calculation of LSM affords statistical estimation on the obtained inner accuracy.

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3. IMAGE ORIENTATION

Image orientation is organized in a three-step procedure starting on inner orientation for the used cameras, relative orientation between both images and absolute orientation of the model coordinate system. Different approaches for camera modeling allow the use of digital and analog non-metric cameras as well as digital panoramic cameras. The parameters of inner orientation should be previously determined by a camera calibration based on a reference pointfield. On suitable object geometry approximated values for inner orientation can be determined by space resection adjustment separately for each image.

The measuring of homologous image coordinates for relative orientation is supported by the integrated correlation techniques. So, natural unmarked tie points can be used to consider an ideal point location within the object space (Fig. 1). Image points with sufficient texture information will be defined in one image. Initially, the search area for the corresponding image points has to be specified by the user. After the first calculation of relative orientation parameters, the search area for the correlation process can be automatically limited to the corresponding epipolar band.
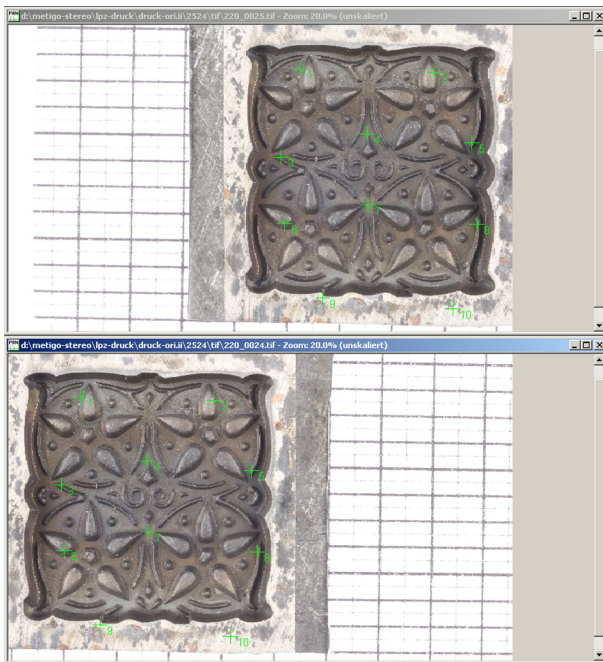

Figure 1. Relative image orientation using correlation techniques for matching of unmarked object points, (Printing plate, size: 2 cm x 2 cm, Canon D20, c_k 100 mm, CCD 3504 x 2336 pixels)

The model coordinate system of relative orientation can be transformed with passpoints into object space or simply scaled with a known object distance. Using a calibrated stereo bar as object distance for scaling (Fig. 2), no other reference information will be needed in the object space and so, full-scale reconstructions of non-reachable objects can be easily generated. Additionally, single image orientation is possible by space resection adjustment. Signalled reference points for an absolute orientation or space resection can be automatically measured with sub-pixel accuracy using centroid calculation for circular targets or adapted methods for cross-shaped patterns (Luhmann, 1986).

Figur 2. Simple camera bar for stereoscopic exposures with defined base distances of 30 cm and 60 cm

The orientation of panoramic images will be calculated by an adapted space resection (Schneider, 2003). With known parameters of inner and outer orientation central perspective images can be generated for specified regions by a tangential image projection. Input data for stereoscopic evaluation are corrected stereo image pairs with parallel camera axes (Fig. 3). Stereo image pairs can also be assembled direct from tangential image projections by relative / absolute orientation process.

Figure 3. Stereoscopic view of a panoramic image pair (Dresden Trinitatis church, EYESCAN M3D, c_k 35 mm. RGB CCD-line with 10.000 pixels)

4. PHOTOGRAMMETRIC IMAGE ACQUISITION

Digital SLR cameras offer good lens quality, a sufficient geometric stability and the high image resolution is comparable to analog medium format cameras. Also large format metric or non-metric cameras can be used for image recording. Several studies have shown the suitability of compact digital zoom cameras for photogrammetric purposes on principle (Hastedt, Luhmann, Tecklenburg, 2004), but the use for an exact stereo evaluation is not recommended.

According to stereometric cameras like Zeiss SMK with a calibrated stereo base, a defined distance between both camera

positions can be realised with a simple base bar (Fig. 2). This configuration allows the use of just one camera for both exposures according to the advanced normal case of stereophotogrammetry. Scaling of the stereoscopic model system is possible with the known base distance, so that no additional object information is needed. This procedure allows fast and easy stereophotogrammetric documentation of architectural fragments and archaeological findings on site with possibilities for full-scale three-dimensional evaluation at a later time.

With the help of object scale-bars or a reference frame (Fig. 4) with given 3D coordinates within the object space it is possible to transform different stereo views into one uniform object system.

Figure 4. Reference frame for stereo model orientation, (Corinthian capitel, object height 80 cm, Rollei 6006 metric, c_k 80 mm, scan 2500 dpi)

5. AUTOMATED STEREO MEASUREMENTS

Similar image structures can be automaticaly determined with image matching algorithms. The first step is the calculation of approximated values for the best location of a reference image patch (template) within a predefined area of the search image using normalised cross-correlation coefficient. A sub-pixel localisation follows using least squares matching. Object coordinates are computed from the matched image coordinates with forward intersection using the parameters of inner and outer orientation.

The generation of 3D point clouds for the processed object surface will be done by applying expansion algorithms on the matching procedure starting from a given object point. The increment for the template translation within the reference image and the size of search area within the stereo partner can be defined by the user, dependent on image resolution and object structure. Furthermore the user can restrict the evaluation area within the stereo model interactivley.

Horizontal and vertical profile evaluations of objects (Fig. 6) can be generated similar to surface determination using expansion algorithms for image matching. A profile line for the automated measurements can be defined by a given elevation for horizontal sections or an aligned perpendicular coordinate system for vertical sections.
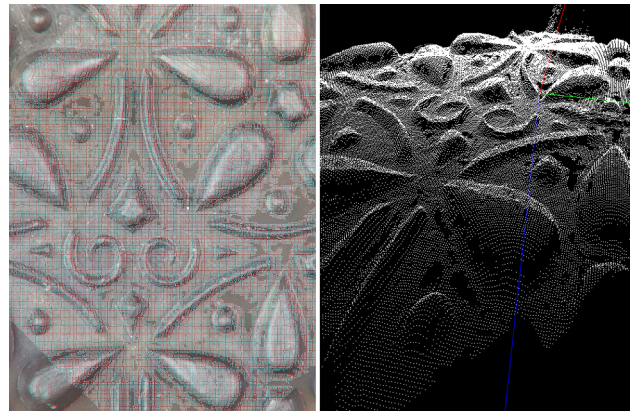

Figure 5. Matched points of a printing plate (see Fig. 1) in the stereoscopic image display (left) and 3D view of the created point cloud (right)

It is also possible to import 3D laser scanner data into a profile, given in STL format or over a user defined ASCII interface. With a coordinate filter only points within a defined tolerance range to the profile plane will be used.

With a special separation algorithm it is possible to arrange discrete points into objects or to eliminate outliers (Scheller & Schneider, 2006). The automated measured points of a profile line can be reduced and adjusted for the creation of simple vector geometries using smoothing algorithms (Bienert, 2006). A DXF interface allows the export of profile drawings to CAD systems.
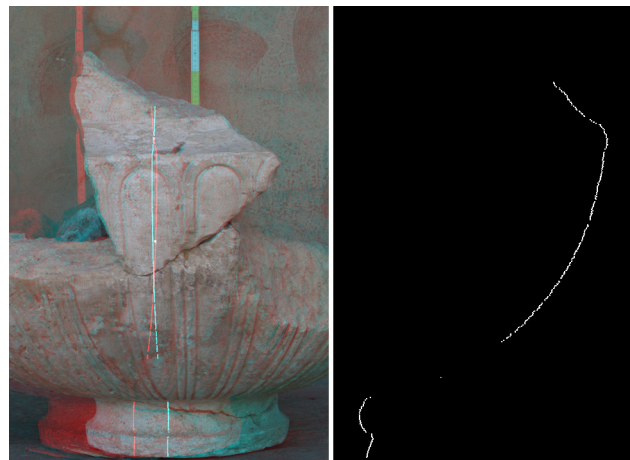

Figure 6. Automatic measured vertical profile in stereo view (left) and matched points in the profile plain (right) (Fragment of a Kratér, max. diameter 60 cm, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)

6. DSM TRIANGULATION

Digital surface models can be generated from matched object points and laser scanner data using the Ball Pivoting Algorithm (Bernardini, 1999). The algorithm is comparable with a ball rolling over the point cloud surface. The radius of the ball has to be larg enough, so that it don´t fall through the point cloud surface. Starting at a triangle, the ball pivots around the axis between two points until it touches another point, forming another triangle. Thus, the ball rolls over point cloud surface until no new triangles can be found. Because of irregular

interspaces between matched or scanned points, it is not possible to triangulate the whole point cloud with just one ball radius. Therefore an adapted algorithm was implemented using several ball radii for such irregular point clouds (Vetter, 2005).
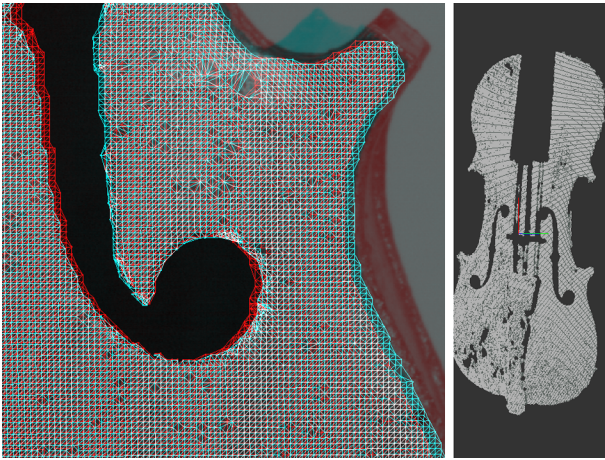

Figure 7. Triangulated object surface of an ancient violin (Object size 30 cm x 60 cm, Pentagon Scan 5000N, c_k 60 mm, trilinear CCD-line with 8.192 pixels)

7. TEXTURING OF POINT CLOUDS AND DSM

Several approaches for the texturing of point clouds and triangulated digital surface models were implemented within the presented software. With collinearity equations the color of 3D point clouds can be determined from image information either of oriented stereo or single images (Fig. 8 and Fig. 9). Furthermore distance dependant point coloration can be determined related to a coordinate plane or the laser scanner standpoint.

For triangle texturing using stereoscopic image information the following criteria have to take into consideration:

- intersection of an image ray with the DSM
- alignment of the directions between triangle normal and camera axes
- consideration of triangle neighbourhood

To eliminate image failures and covered object areas the user has the possibility to define areas within the selected images.

8. CONCLUSIONS

The integration of image matching techniques into a stereo evaluation system for close range photogrammetry affords a spatial collection and evaluation of objects especially in the fields of architecture, archaeology, and preservation. The presented system considers the special needs of architectural photogrammetry and allows the use of analog and digital amteur cameras as well as digital panoramic cameras. A simple technique for stereo image acquisition together with first automations in relative image orientation using correlation techniques allows a fast preparation of stereoscopic models without advanced photogrammetric knowledge. The automated stereoscopic measurement procedures offer high accuracy for photogrammetric point determination and simplifie the three-dimensional object reconstruction.

The describted functions were implemented within the software metigo *STEREO* of the fokus GmbH Leipzig.
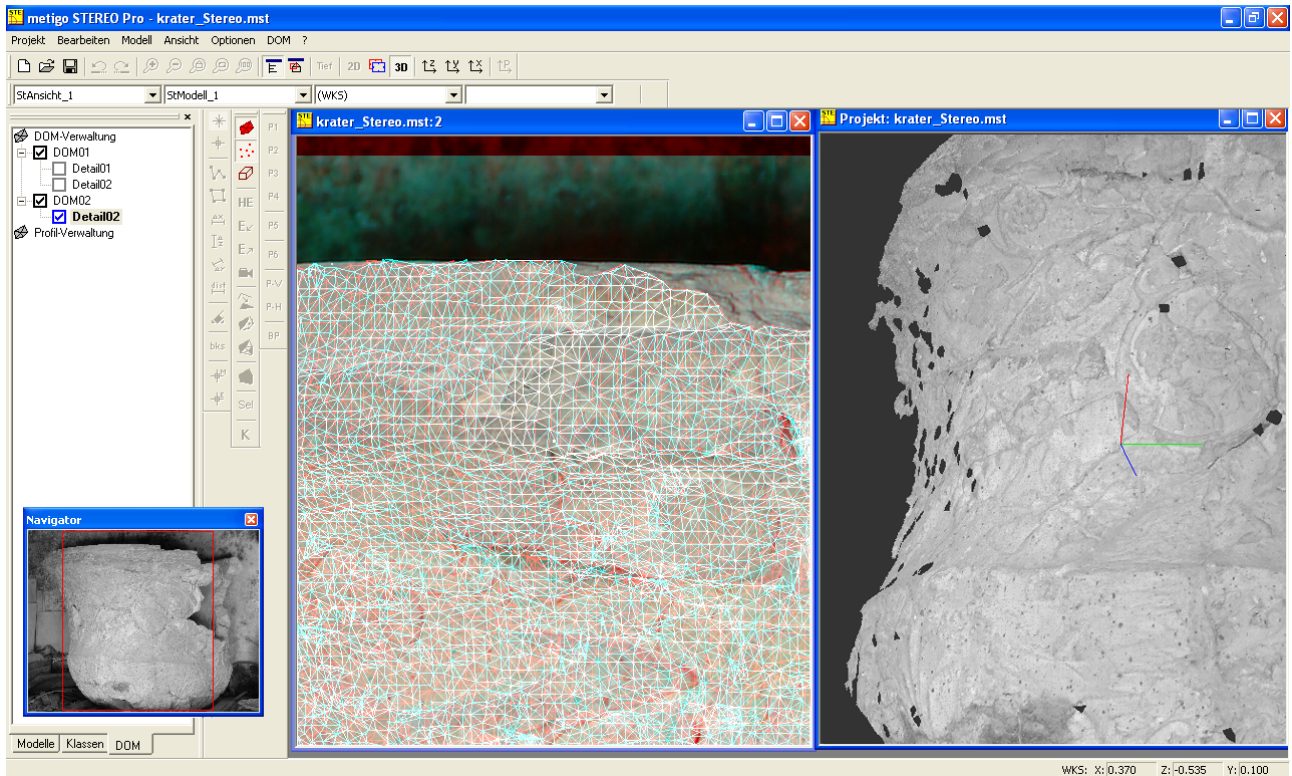
Figure 8. Evaluation with metigo STEREO: stereoscopic view with overlaid triangulation (left) and textured 3D model of a Kratér (diameter 1 m, height 1m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)
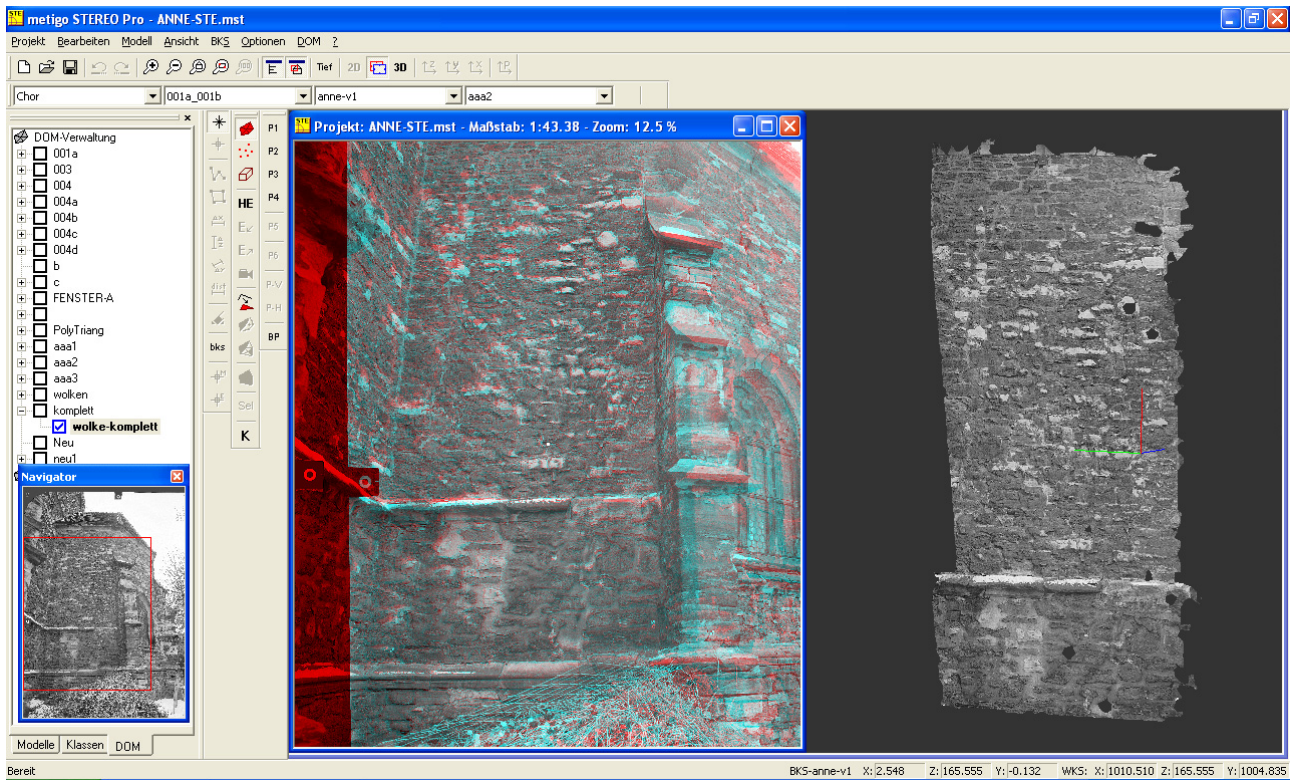

Figure 9. Evaluation with metigo STEREO: stereoscopic view (left) and textured 3D model of church St. Annen, Eisleben (facade height 8 m, Zeiss UMK 13 x 18 cm², c_k 100 mm, scan 2500 dpi)

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