GENERATION OF DIGITAL SURFACE MODELS FOR ARCHITECTURAL APPLICATIONS WITH ARCHIMEDES3D

Rüdiger Tauch and Albert Wiedemann *

FPK Ingenieur GmbH, Feurigstr. 54, D-10827 Berlin, Germany – { R.Tauch, A.Wiedemann}@fpk.de

Commission V, Working Group V/4

KEY WORDS: Surveying, Digital Photogrammetry, Architecture, Digital Surface Model, Orthoimage

ABSTRACT:

Orthoimages are well suited for architectural documentation. The most challenging part of their generation is the determination of the Digital Surface Model (DSM). There are some different techniques available to acquire the information requested to generate a DSM. In this paper we describe how a motorized and reflectorless total station, controlled by the software package Archimedes3D can be used to determine the necessary information. Besides the total station, only a mobile computer and a digital camera are required to acquire the data for the differential rectification. The lower data rate of a total station compared to laser scanners can be compensated by maintaining intelligent control of the measurement process.

KURZFASSUNG:

Orthophotos eignen sich für die Dokumentation von Fassaden. Dabei ist der aufwändigste Teil die Bereitstellung des Digitalen Oberflächenmodells. Es gibt unterschiedliche Techniken die erforderlichen Daten zu erfassen. In diesem Aufsatz wird beschrieben, wie dies mit einer motorisierten, reflektorlos messenden Totalstation unter Steuerung durch das Programm Archimedes3D erfolgt. Neben der Totaltstation wird nur ein mobiler Computer und eine Digitale Kamera benötigt um die für das Orthophoto erforderlichen Daten zu erfassen. Die geringere Messgeschwindigkeit der Totalstation wird durch einen intelligenten Messprozess kompensiert.

1. MOTIVATION

Archimedes3D is a system for the integration of different measurement types in the field of architectural documentation. One of the core products is the Digital Orthoimage, a product combining the geometry of a plan with the information density of a photo (Hemmleb & Wiedemann 1997, Dequal & Lingua 2002). Archimedes3D is a modular tool box. One of the tools is FASED (Façade Digital Surface Model Editor), a tool to combine geodetic and photogrammetric data, laser scanner point clouds and/or manual measurements in an integrated environment to provide the necessary Digital Surface Model (DSM, depth map) for the generation of true orthoimages of façades.

Data can be introduced in the form of single points, profiles, point clouds or CAD models. suited than a triangle network: Most of the edges of the object are parallel to the vertical and horizontal grid lines of the DSM and most faces are rectangular. Due to the different planar façade elements of the common objects surface, a triangle network would consist of very different sized coplanar and perpendicular triangles.

The DSM describes the orthogonal height of the façade points above an analytical surface, usually a vertical plain. For architectural applications a rectangular grid seems to be better Thresholds for the optimized triangulation are difficult to find. In a regular grid, you only have to determine a suitable grid width for the DSM, based on the resolution for the proposed orthoimage. If the available input data have already a sufficient point density, e.g. based on laser scanner data, only the closing of occluded gaps remains as a challenging tasks (Wehr & Wiedemann 1999). Bot all laser scanner systems provide the required data in a sufficient quality and density (Böhler et al., 2003) Some gaps might be closed by an image based 3D acquisition (Schouteden 2002) – but special problems of

Fig. 1: Measurement equipment for FAMES

* Corresponding author.

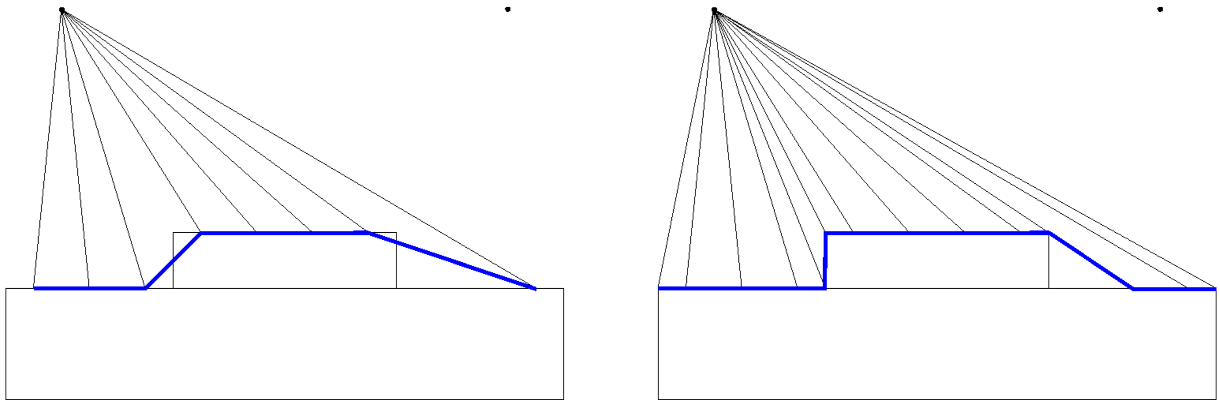

Fig. 2: Semi-automatic profile measurement from the first station. First run (left), automatic densification (right)

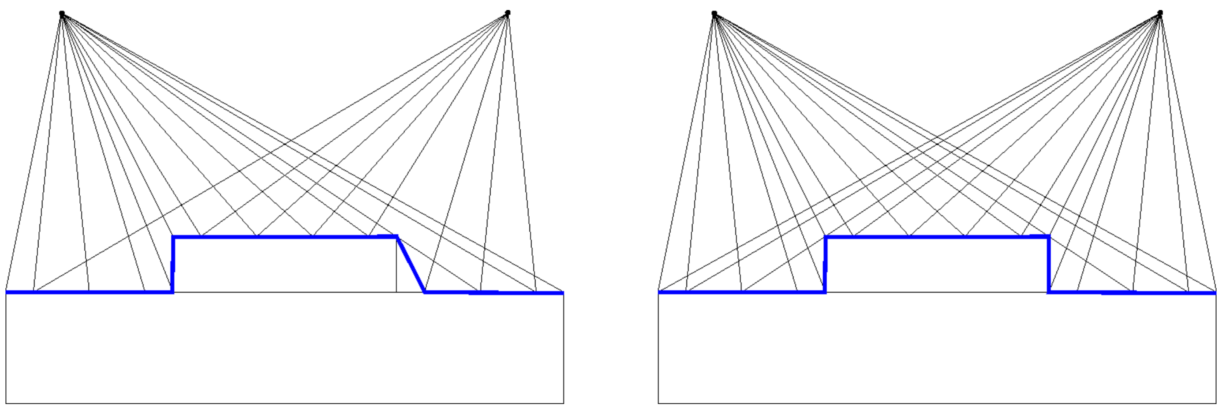

Fig. 3: Completing the profile from a second station

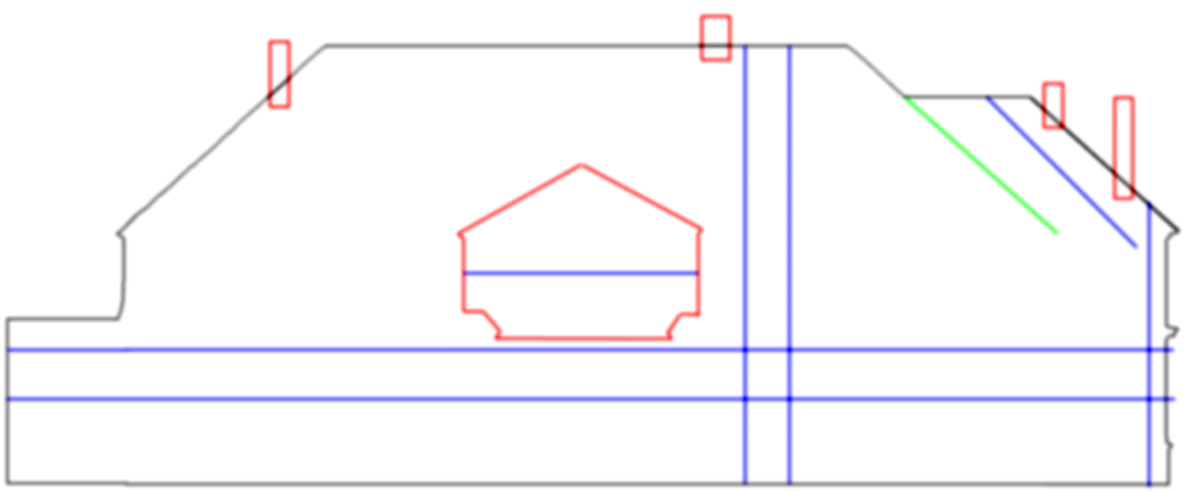

Fig. 4: Profile measurements, additional measurements of individual features and measurements of the surrounding polygon

matching techniques in architectural applications are well known (e.g. low texture, identical features, surface discontinuities).

A further approach is to derive the DSM from an existing 3D CAD model. This CAD model has to consist of closed faces (B-rep) and has to represent a high level of details (Wiedemann 1996). To derive a 3D face model from punctual measurements can be a time consuming and challenging task. If such a 3D CAD model already exists, a generation of a orthoimage is usually not necessary anymore.

2. MEASUREMENTS

A lot of interactive editing or a very intelligent interpolation is necessary to create a DSM with the required point density when only a limited amount of input data is available. On the other hand, knowledge about the object can be considered: planarity of surfaces, continuity of curvature, symmetries, identities and other knowledge can be used by an operator in a semi-automatic process to create the DSM. This is provided by the measurement program FAMES (Façade Measurements) and the interpolation and editing tool FASED.

FAMES allows the semi automatic measurement of profiles. Only a few of these profiles are necessary for the generation of DSM if the façade is regularly structured and organized in window axes and partially identical floor levels. Some profiles may be duplicated, due to their identity.

This semi automatic profile measurement is done with a motorized and reflectorless working total station (tested with Leica TCRA 1100 series) under control of a mobile computer (Fig. 1). The semi automatic process (Juretzko 2002) cares for the correct leveling during the measurement of horizontal profiles and the control of the correct location for vertical profiles. In the first run points are measured in a predefined metric or angular distance. In a second step an automatic process locates significant depth jumps in the profiles (Fig. 2). From a second station the occluded parts of the profiles may be filled if they are visible from this new point of view (Fig. 3).

Even regularly structured façades need some additional measurements of polygons around individual features (e.g. chimneys, balconies, protrudes) and a façade surrounding polygon (Fig. 4).

3. DERIVATION OF DSM FROM PROFILES

With FASED the façade area is divided into rectangular fields with the edges at the non static positions of the profiles and the assumption of a continuous curvature in the fields. In the first step the fields touched by a profile are filled with the corresponding height value. In a second step all adjacent fields are filled step by step based on similarity to already filled fields and other knowledge about the façade. Finally the additional measurements of individual features are added by deriving their height from their surrounding polygons.

The generation of the DSM is done under supervision of the operator. Helpful is also a wide mashed raster (e.g. 1 m grid width) measured over the façade to confirm the DSM derived from the profiles, to solve ambiguities and to detect irregularities and deformations in the façade.

The DSM is stored as a regular raster grid in a sufficient grid width, usually as 8 or 16 bit image file (e.g. TIFF). This offers the opportunity to visualize and edit the DTM with a wide variety of software tools. The result of this semi-automatic process is a DSM to fulfill the requirements for the generation of high quality true orthoimages for architectural applications.

4. PRODUCTS

The quality of the DSM can be checked by doing differential rectifications of images from different points of view. The differences in the orthoimages result from differences in the DSM, errors in the orientation process or obstacles in the foreground. The bundle block adjustment (e.g. with the Archimedes3D tool IMBUN) provides quality control data for the orientation data. Differences between the orthoimages from different points of view indicate areas that require special attention. The erroneous parts of the DSM can be located, delimited and improved – using knowledge about the façade, or additional measurements at the site or in the available image.

Archimedes3D also provides tools to generate different types of documentation requested in heritage documentation: image mosaics (with MOSAIC) or 2D or 3D line drawings (Fig. 5) by mono or 3D plotting (with IMDIS). Under consideration of the DSM the 2D CAD data acquired by plotting in one image can be extended to 3D data. The rectified images and mosaics can also used directly for geometric correct further 2D analysis (Lerma 2002).

5. CONCLUSION AND OUTLOOK

Archimedes3D allows the documentation of architectural

Fig. 5: Digital Surface Model (left), Digital Orthoimage (center) and derived CAD data (right)

objects at reasonable cost without special and expensive hardware, just using a total station and a digital camera. It is not designed for very complicated objects, but for objects with low and mid level of details and scales. For these objects image and line based products in 2D and partially 3D are generated. Some work has to be invested to care for features which are not limited by straight horizontal or vertical lines. Image analysis tools might contribute to solve this problems. For more details and latest news see the Archimedes3D homepage at www.archimedes3d.com.

6. ACKNOWLEDGEMENT

We acknowledge the contribution of the "Investitionsförder-programm Berlin", represented by the Investitionsbank Berlin, who supported the development of Archimedes3D. Further we thank John Moré for his tremendous contributions and the students Axel Gotthardt and Alexander Lübeck for their engagement and contributions.

7. REFERENCES

Böhler, W. & M. Bordas Vincent & A. Marbs (2003): *Investigating Laser Scanner Accuracy.* Proc. of the XIX. CIPA Int. Symposium, Antalya, Turkey, Sep. 30 -Oct. 4, 2003. International Archives for Photogrammetry and Remote Sensing (IAPRS). Vol. XXXIV – 5/C15, pp. 696-701.

Dequal, S. & A. Lingua (2002): *True Orthophoto for Architectural Survey.* Proc. of the XVIII. CIPA Int. Symposium, Potsdam, Germany, Oct. 18.-21 2001. International Archives for Photogrammetry and Remote Sensing (IAPRS). Vol. XXXIV – 5/C7, pp. 269-276.

Hemmleb, M. & A. Wiedemann (1997): *Digital Rectification and Generation of Orthoimages in Architectural Photogrammetry*. Proc. of the CIPA Int. Symposium '97, Photogrammetry in Architecture, Archaeology and Urban Conservation, International Archives for Photogrammetry and Remote Sensing (IAPRS). Band XXXII, Part 5C1B, Göteborg, Schweden, 1.-3. Okt. 1997, pp. 261-267.

Juretzko, M. (2002): *The System TOTAL for Recording the Geometry and Image Data of Historic Buildings and Monuments.* Proc. of the XVIII. CIPA Int. Symposium, Potsdam, Germany, Oct. 18.-21 2001. International Archives for Photogrammetry and Remote Sensing (IAPRS). Vol. XXXIV – 5/C7, pp. 611-613.

Lerma, J. L. (2002): *Documentation and Recovery of Rupestrian Paintings: An Automatic Approach.* Proc. of the XVIII. CIPA Int. Symposium, Potsdam, Germany, Oct. 18.-21 2001. International Archives for Photogrammetry and Remote Sensing (IAPRS). Vol. XXXIV – 5/C7, pp. 377-380.

Schouteden, J., M. Pollefeys, M. Vergauwen & L. van Gool (2002): *Image-based 3D Acquisition Tool for Architectural Conservation* . Proc. of the XVIII. CIPA Int. Symposium, Potsdam, Germany, Oct. 18.-21 2001. International Archives for Photogrammetry and Remote Sensing (IAPRS). Vol. XXXIV – 5/C7, pp. 300-305.

Wehr, A. & A. Wiedemann (1999): Fusion of Photogrammetric and Laser Scanner Data Proc. of the CIPA Int. Symposium '99, *Int. Archives for Photogrammetry and Remote Sensing*, Vol. XXXIV, Part 5C1B, Olinda, Brazil, 3.-6. Okt. 1999, published on CD & on http://www.archimedes3d.com/

Wiedemann, A. (1996): Generation of Digital Orthoimages Using Digital Surface Models. International Archives for Photogrammetry and Remote Sensing (IAPRS) XXXI, Part 5, Vienna, pp. 605-609.