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A COMPARISON OF PHOTOGRAMMETRY SOFTWARE PACKAGES FOR THE DOCUMENTATION OF BUILDINGS

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Abstract:
Architectural photogrammetry has completely changed during the last decade due to the development of new digital cameras, new algorithms for data extraction and image processing, and new software packages. But, contrary to aerial photogrammetry mainly based on stereo-methods, there is no worldwide method for recording and restitution objects in terrestrial photogrammetry. Every object is different and the obstacles located in the field really influence the data acquisition method.
The carrying out of non-metric digital cameras and of several commercial software packages dedicated to digital architectural photogrammetry applications is attractive for many users including photogrammetrists (above all surveyors) and non-photogrammetrists (as architects, conservators, and archaeologists). In this paper, we discuss the characteristics, advantages and disadvantages of some commercial and academic software packages usable for building documentation and modeling.
We present also a project from CIPA (The ICOMOS & ISPRS Committee for Documentation of Cultural Heritage) proposed at the XVII CIPA Symposium in Olinda /Brazil. In this project called “A reference data set for digital close-range photogrammetry", the authors are interested in the comparison of different digital photogrammetry software capacities, used in 3D-object reconstruction. The available data contains a questionnaire and several digital photographs of the old city hall in Zurich (Switzerland). These photos have been taken with two low cost non-metric digital cameras FUJI DS300 and OLYMPUS C1400L. The most important questions of the questionnaire given with the dataset have been extracted in this paper to analyse the performances of digital architectural photogrammetry software packages. An example of 3D model of the Zurich City Hall is also presented at the end of the paper. The digital images and the control information for this CIPA project are available on the web at http://cipa.uibk.ac.at.

1. Introduction

Digital architectural photogrammetry evolves rapidly (due to new cameras, new software, new algorithms for data extraction and processing, etc.). Methods of data acquisition and processing in terrestrial photogrammetry are very different from aerial photogrammetry and the software packages in this last case are mainly dedicated to cartography and often not usable for modeling objects as buildings. Nevertheless, the carrying-out of non metric digital cameras and their use for documentation are of interest for many users as surveyors, architects, conservators and archaeologists, especially due the low cost of the commercial software packages (1000 to 3000 US$). The main features of some commercial and education software packages are given in the paper. The commercial software packages are 3D Builder, Canoma, Photo 3D, Dimension, PhotoModeler and ShapeCapture. The academic software packages are Orpheus 3.0, SolidFit, Façade, Tiphon and Arpenteur.
To go into more details, a project from CIPA (The ICOMOS & ISPRS Committee for Documentation of Cultural Heritage) is presented as well as an example of building modeling. The advantages and the disadvantages of the different packages are discussed and the most important points of the questionnaire associated to the CIPA project have been used to discuss the capabilities of software. An example of building modeling with Photomodeler is given at the end of the paper.

2. Commercial software packages for 3D measurements and 3D modeling

2.1. 3D Builder Pro

3D Builder Pro is a window-based application developed by 3D Construction Company. It covers a wide range of custom modeling situation and enables the user to work with one, two or more photos and to take textures directly from the original photos. 3D Builder is also equipped by a 3D Preview window, which shows an interactive, rendered and textured model. With this software, we can use different camera types and different image formats including Photo CD, TIFF, JPEG, BMP and Sun raster. The 3D generated model can be exported under many formats: DXF, VRML, and 3D Studio. It is also compatible with most other rendering packages. Additional information is given at http://aay.com/release.htm.

2.2. Canoma

Canoma (Meta Creations, 1999) is a software intended for creating photorealistic 3D models from illustrations (historical materials, artwork, hand drawn sketches, etc.), scanned or digital photographs. Based on image-assisted technique, it enables to attach 3D wireframe primitives and to render a 3D image by wrapping the 2D surfaces around these primitives. All of the 17 built-in wireframe templates are simple geometric such as planes, rectangles and polygons or basic architectural elements like arches and tables. The textures may be taken directly from the original photos. We can also mirror textures to fill in the invisible sides of object. Canoma uses many image formats such as : BMP, GIF and JPG and allows to export 2D (BMP, PSD, TIFF, etc) and 3D files (DXF, VRML, etc). Three formats of animation are available: QuickTime, Sequential BMP (PC) and Sequential PICT (Mac). Additional information is given at http://www.metacreations.com.

2.3. Photo3D

Photo 3D is a software that allows creating 3D models with textures from photos. Photo3D is developed to create these models from single and multiple images. The correction of lens distortions is possible and the created models can be examined in a preview mode. Relations between lines such as parallelism and orthogonality (geometric constraints) are used to determine the spatial relation between the camera and the object. This model, named the glass-painting model (which is theoretically equivalent to pinhole camera model), is used to calculate automatically the eye position and the direction of x, y, z-axis of real-world co-ordinate relative to image rectangle. Additional information is given at http://photo3D.com/eindex.html.

2.4. Dimension

This software is designed to be used to measure dimensions and build 3D models of photographed objects. It can use the scanned photos, digital photos, scanned illustrations, digitised video frames, etc. With this software, mono and multiple image modeling are possible. In fact, it is equipped with a special measurement toolbox which allows the determination of 3D information from single images. The accuracy of the resulting model depends on the image quality, the image scale and the number of available images. Only DXF format can be exported. It allows the communication between Dimension software package and CAD/CAM systems. We can notice that this software does not allow texture contribution. Additional information is given at:
http://www.kodak.com/US/en/government/specialImaging/products/dimension/dimension.shtml.

2.5. PhotoModeler

Photomodeler is a digital photogrammetry software used to extract 3D geometrical data and to reconstitute 3D models from 2D images. It is based on the measurement of the homologous points on a block of images carried out with one or more cameras. Version 3.0 of this software supports digital amateur cameras. Many solutions are proposed to realise the interior orientation (camera with fiducial marks and digital camera). With regard to the exterior orientation, it is done by using the control points. Other solutions are proposed, of which a scaling using a distance known in the object and the image, rotations, etc.
In any case, a self-calibration can be adopted during the calculation of the image block. The software has an algorithm of a free network adjustment, which can be used in the event of the absence of the control data. The graphical interface of the software is rigorous and interactive, where points, lines, surfaces (to generate D.S.M) and curved forms (not enough practical in version 3) measurements are possible. With this software, 3D realistic models can be realised where the original photos are used as textures. A 3D viewer is used to display in real time the points, the lines and the surfaces measured on the images. This viewer allows also displaying the cameras' position. In PhotoModeler we can export

text files (which contains the orientation parameters and the pixel co-ordinates of measured points), DXF files, VRML files and other formats.
The new version of this software PhotoModeler Pro 4.0 'Beta' tries to overcome the problems of the old versions and to improve the tools for the modeling of complex objects and the possibility to handle more single photo projects. Many features have been improved or added in this version as, curved elements, edges, geometrical constraints, etc. The data offered by the CIPA project (see §5) were treated by using PhotoModeler 3.1 and PhotoModeler 4. Additional information is given at http://photomodeler.com/.

2.6. ShapeCapture

Shape Capture is an image-based modeling software released by ShapeQuest. This software offers target and feature extraction, target and feature 3D co-ordinate measurement, full camera calibration, stereo matching and 3D modeling. It outputs, also, accuracy estimates for all measurements. Target extraction, matching and measurement are automatic. With ShapeCapture, we can export 3D co-ordinates and models under many 3D formats such as : VRML, DXF, Wavefront OBJ, MTL, STL, and XYZ. It allows also 3D modeling from single photo and from two or more photos. The single photo drawing features include parallel and perpendicular surfaces. During the modeling procedure, vertices joining is done automatically. The method of bundle adjustment is used to solve the exterior orientation problem. It should be noted that the software is equipped with the following features: image processing, edge detection, surface fitting, single image 3D, automatic point creation and measurement on known surfaces using either triangle or random point generation. Additional information is given at: http://www.shapequest.com.

2.7. Advantages and disadvantages

All these commercial software packages do not require professional competencies. In fact, they are interactive and easy to use by any one. They also allow reconstructing from one (mono-image modeling) or more scanned or digital images (or even illustrations) taken with metric, semi-metric, digital or non-metric cameras. Most of these software offer the possibility of lens distortion correction, digital image processing and camera calibration (as for example: Photo 3D and PhotoModeler). However, the packages generally act as black boxes and don't supply detailed information neither on the accuracy of calculated parameters of interior and exterior orientations, nor on the accuracy of the resulting 3D model. In fact, most of these approaches do not demonstrate high geometric accuracy. On the other hand, the visualisation tools are often well designed and easy to handle.

3. Academic software packages

3.1. Orpheus 3.0 **(**OR**IENT** PH**otogrammetric** E**ngineering** U**tilities** S**ystem)**

Orpheus is a software of digital photogrammetry developed at the Institute of Photogrammetry of the Vienna University of Technology. *ORPHEUS* is equipped of a (GUI) for the hybrid photogrammetric adjustment system ORIENT. Moreover, it can be used to take interactive measurements of points and/or lines in order to calculate the different types of orientation. ORPHEUS is well suited for aerial multi-image photogrammetry as well as for terrestrial photogrammetry applications. It can handle the images taken with digital cameras with unknown geometry. This software offers also many possibilities to calculate the photo orientation parameters. In order to determine the approximate values necessary to block calculation, the software proposes an automatic method and another interactive (graphical) one. Point and line measurements can be processed. Using these possibilities, we can generate wire-frame models. In this context, different colours can be distributed to the lines in order to distinguish the various semantic layers. In ORPHEUS, it is possible to export the orientation parameters, 3D DXF and VRML files. It has to be noted that this software is equipped with a powerful algorithm for image processing and allows image pyramids creation for the handling of large images.

3.2. SolidFit

SolidFit is an interactive software package for deriving three dimensional measurements and shapes from a single image of one or more regular objects. These information can be derived through measuring up regular features such as vanishing points. SolidFit reconstructs the locations of space points from their perspective projection in the image. In addition, geometric constraints can be imposed on the relative position of these points. Error in the points locations and measurements is estimated using error propagation theory. The resulting model can be visualised in 3D viewer or a CAD package. Additional information is given at http://www.cssip.edu.au/~vision/solidFit.htm.

3.3. Façade

Façade is a software that allows the modeling and rendering of the architecture by using a small number of photographs. The user can perform radial distortion correction on images and specify camera parameters. He can also mark features (points, edges, contours) in the image, constraint the components of the model and verify the model accuracy by projecting the model into the recovered cameras. The geometry of the model has a VRML file format. This model can be rendered and we can create animations using various forms of texture mapping including view-dependent texture mapping. It has to be noted that Façade software inspired the commercial product Canoma sold by MetaCreation Corporation. Additional information is given at: http://www.cs.berkeley.edu/~debevec/Research.).

3.4. Tiphon-Arpenteur

TIPHON and ARPENTEUR are two simple photogrammetric software packages dedicated to stereoplotting and modeling. The TIPHON software (in French "Traitement d'Images et PHOtogrammétrie Numérique") has been developed since 1996 by the Group “Photogrammetry and Geomatics” of the LERGEC Laboratory (Research laboratory in civil engineering) at Strasbourg [Grussenmeyer, et al., 1999]. Since 1998, in the frame of a joint project between the LERGEC and the GAMSAU (CNRS Research laboratory of the School of Architecture at Marseilles, France), the TIPHON software has been adapted to the Internet World to become platform-independent and available as an applet on the web by a simple internet browser. This new version called ARPENTEUR (ARchitectural PhotogrammEtry Network Tool for EdUcation and Research) is particularly dedicated to applications based on small format images [Grussenmeyer & Drap, 2000]. ARPENTEUR is a Web based tool since photogrammetric concepts are embedded in Web technology and Java™ programming language. Therefore it can be easily used from anywhere all over the world and with whatever operating system is used. Two servers located in Marseilles and Strasbourg are available to manage project data. Different solutions for the adjustment of the photogrammetric model are currently available as well as a measurement method based on image correlation. Examples are available for education and personal projects can be stored on the servers’ database. An overview of the different photogrammetric functions available in both packages is given in Figure 1.

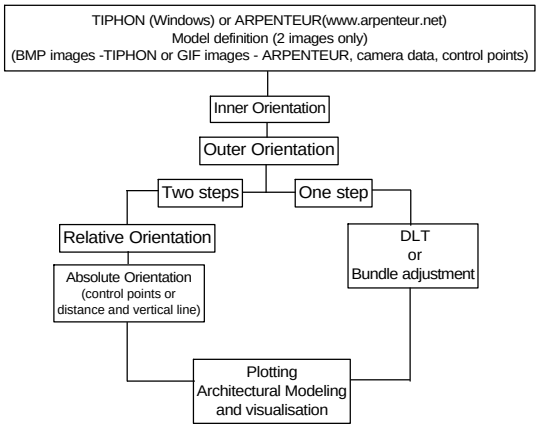

Figure 1. Overview of the current photogrammetric solutions available in TIPHON-ARPENTEUR

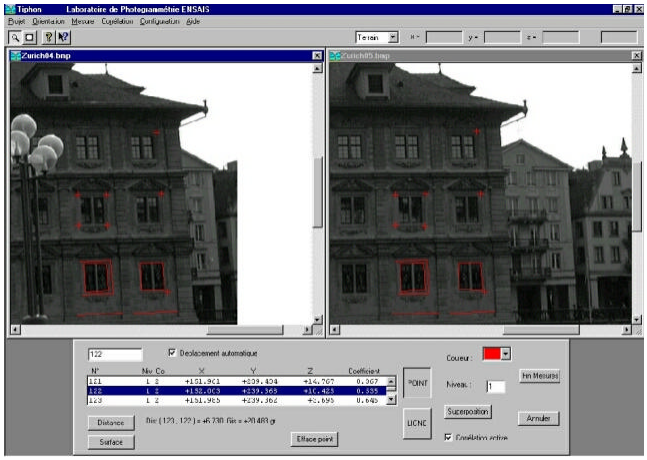

Figure 2. TIPHON’s stereoplotting module (from the CIPA project, see §5)

The design of both packages is based on the measurement of couples of images (close to the normal case or convergent images). Homologous points can be measured by correlation. Area correlation is used to determine the required sub-pixel position in the digital image. A release of TIPHON (in French) running on Windows’95/98 can be freely downloaded at http://photogeo.u-strasbg.fr .
ARPENTEUR is also freely accessible via the Internet by a simple browser like Netscape Communicator at www.arpenteur.net .

3.5. Advantages and disadvantages

All these non-commercial packages supply detailed information about all the steps of calculation and provide statistical testing of the calculated parameters. For the most of these software packages, standard deviation is used to evaluate the accuracy of the orientations’ (interior and exterior)

parameters and points co-ordinates computation. Regarding the interior and exterior orientations, many algorithms are proposed such as the affine, homographic transformation, DLT, graphical methods (used to compute the initial values of the exterior orientation parameters), manual absolute orientation, bundle adjustment, etc. These algorithms allow the precise computation of orientation parameters and 3D points co-ordinates, as well as the visual and numerical control of plotting. However, these software packages are strictly intended to photogrammetrists and require professional skills.

4. Indications to evaluate digital architectural photogrammetry software packages

The topics proposed by the CIPA questionnaire (CIPA, 1999) can be considered as key-ideas to answer the question "how can we analyse the capacities of a such digital architectural photogrammetry software packages?" In the next pages, the following topics will be discussed: interior orientation, measuring process, exterior orientation (one or two steps), reconstruction of the object, data export and Graphical User Interface.

4.1. Interior orientation

With regard to the interior orientation, the following questions are posed:

- Is the measurement of fiducial marks carried out manually, semi-automatically or automatically?
- How is the orientation of the digital photo (taken with digital cameras) done?
- Which are the algorithms used to compute the parameters of the interior orientation (affine transformation, homographic, etc.)?

As the semi automatic or automatic interior orientation depends on the quality of the digital image (image-based correlation is influenced by shadows, contrast, brightness, etc.) which is not always satisfactory, it is better if the software is equipped with different possibilities of measurement and computation.

4.2. Measuring process

Traditionally, the basic form of measurements in the software packages intended for digital architectural photogrammetry applications are points and lines measurements (or other 2D features) carried out on two or more photos (stereoscopic or multi-image photogrammetry). These measurements are carried out manually or semi-automatically. However, mono-image modeling and the modeling based on the geometrical primitives (cylinder, cone, sphere, etc.) can be attractive for many applications (architectural or industrial ones). The fact that such a software package is equipped with these possibilities is already an advantage.

4.3. Exterior orientation

4.3.1. Two-steps orientation

It is important to know how the relative orientation is carried out. Indeed, one of the greatest advantages of the use of digital photogrammetry is the possibility of automation of some or all tasks of measurement on the photo. Thus, it is necessary to know how the homologous points on two or several photographs are achieved: manually? semi automatically? or automatically?
With regard to the absolute orientation, the diversity of the control information (control points, vertical lines, distances, etc) is an important factor for the evaluation of such software.

4.3.2. One-step orientation

In the most of the available academic software packages, the method of bundle adjustment is used as a rigorous solution of the one-step orientation and/or self-calibration problems. Usually, the approximate values of the exterior orientation parameters (required for the rigorous iterative computation of these parameters) are determined by using a numerical (DLT method for example) or a graphical method (method used in ORPHEUS for instance). However, regarding the commercial software packages, the algorithms used to solve these problems are, in general, unknown.

4.4. Measurement methods

Since the complete 3D modeling requires a topological, geometrical and textural description of the imaged object, it is very important to know, which and how topology, geometry and texture can be measured and distributed by using such a software.

4.5. Graphical User Interface

The user interface is an essential element, in particular to evaluate software. So the answers of the following questions are important: is this interface well equipped (zoom, undo, redo, measurements tools, etc., ?). Are interactive measurements possible with enough flexibility?

4.6. Data Export

Since the form of the generated model varies from one application to another (VRML, DXF, 3D Studio, etc), it is necessary that the software can export the same model under several formats. It should be noted that the diversity of these formats and the simplicity or the complicity to handle the data and software are other significant points during the evaluation.

5. Example of 3D model: Zurich Old City Hall

At the XVII CIPA Symposium (The ICOMOS & ISPRS Committee for Documentation of Cultural Heritage) in Olinda /Brazil in 1999, a call of participation has been launched by A. Streilein, P. Grussenmeyer, & K. Hanke in a paper entitled "A reference data set for digital close-range photogrammetry". In this call, the authors have proposed to compare and test different software packages dedicated to photogrammetric building reconstruction and documentation. The principal terms of this comparison are: topology, consistency, accuracy and reliability. By using the data available at the CIPA web site (http://cipa.uibk.ac.at), we present in this part the 3D model of the Zurich Old City Hall carried out with PhotoModeler Pro3.1 and PhotoModeler Pro 4.0 'Beta' in Summer 2000. We also present a description of used data, used methods and the majors problems encountered during the modeling procedure. Finally, the 3D resulting model is presented under VRML format.

5.1. Data description and used methods

The modeled object is the old city hall of Zurich whose dimensions are approximately 35 x12x18 meters. Two low coast digital cameras (Fuji DS 300 and Olympus C1400L) have been used for the image acquisition of this object and 31 digital images (in TIFF and JPEG format) have been taken. The photos cover all the *façades* of the building. Cameras data are given in the dataset. Camera calibration was done by the authors of the dataset by using Camera Calibrator of PhotoModeler 3.1 software package. To define our model, we used only 18 digital images of the dataset and about 400 points were measured on the images (each point was at least measured on two images). Points and lines have been marked and referenced on all photos (figure 3). Tightness indication has been used to evaluate the accuracy of points and lines location. The calculation of 'interior and exterior orientations' parameters and the wireframe 3D model were carried out by using PhotoModeler 3.1.This Wireframe was completed by using PhotoModeler Pro 4.0 'Beta' in July 2000. The realistic aspect (figure 4) of the generated model was improved by creating surfaces and textures (the original photos have been used as textures). These photos have the advantage to be rectified and corrected of perspective distortions. However, shadows and some non-desired objects such as persons and electrical cables that appear in the photos have influenced the texture quality.

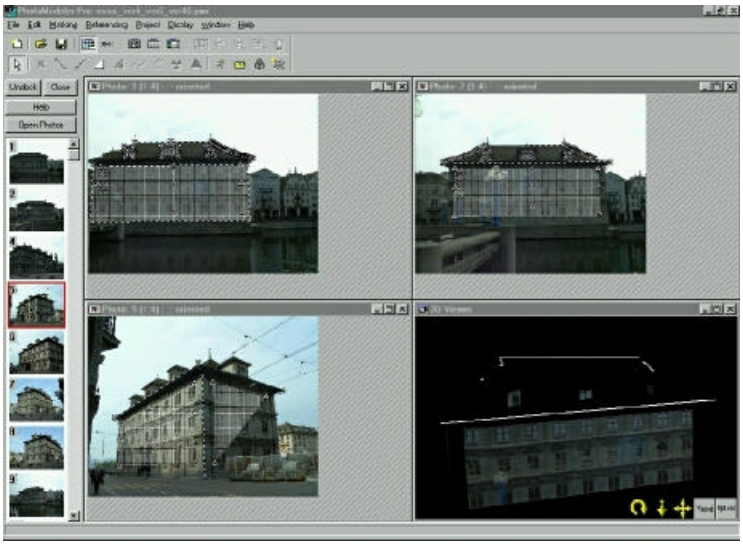

Figure 3. G.U.I of PhotoModeler 4.0 'Beta'

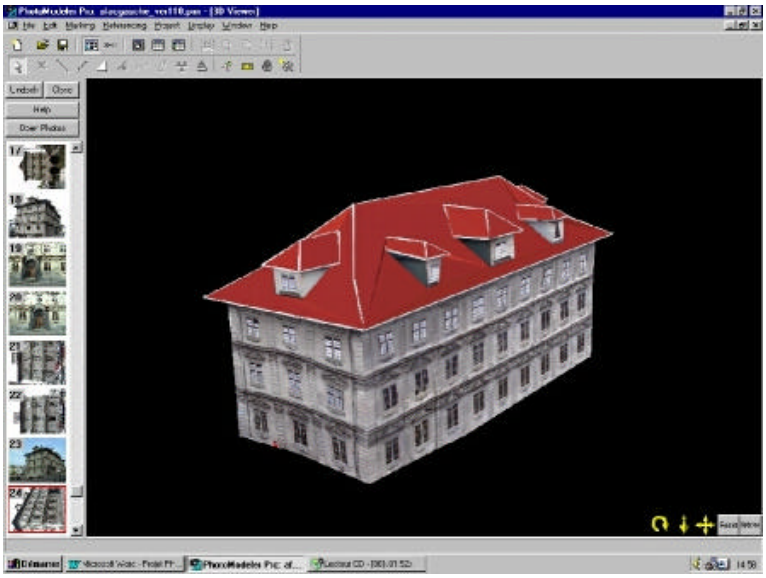

Figure 4. VRML model of the city hall of Zurich (3D viewer of PhotoModeler)

5.2. Major problems

Major problems noticed during the modeling process were:

- the linking of the different parts of the façades;
- the difficulties to reconstruct the backside of the building (no control points, no front view, only side views);
- the modeling of the three windows located on the roof is impossible at the backside.

The door of the building (back side) contains forms which are relatively complex and irregular. The modeling of these forms turns out to be difficult, specially, if we want to make 3D effect stand out with accuracy. An ideal representation requires that we concentrate to the building entrance only, by choosing a consequent number of points relative to every detail.

6. Conclusion and perspectives

The increasing use of digital close-range photogrammetry techniques for recording buildings and objects world-wide motivates the development of new tools for data acquisition and 3D modeling. In this paper, we have presented the main features of some (low cost) commercial and academic software packages and their ability to produce 3 dimensional data. In the previous paragraphs, we have noticed that the disadvantages of the commercial systems are often considered as advantages in the academic ones and vice-versa. We can imagine for the future a system which can overcome these disadvantages. It has to be accurate (does not act as a black box) and usable by any one. Several systems are able to use any kind of camera (metric or non-metric), to calibrate them by simple methods, to integer CAD systems and photogrammetric tools with several approaches, to present the models in powerful visualisation tools. The CIPA dataset of the Zurich Old City Hall is intended to go thoroughly into the software packages. The CIPA questionnaire has been used for establishing some key-ideas useful for the evaluation of such products. We invite you to take part in that project (http://cipa.uibk.ac.at). The results will be presented during the coming CIPA Symposium in Potsdam in September 2001 (http://www.fpk.tu-berlin.deCIPA2001).

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