THE ADVANTAGES OF DIGITAL APPROACH IN ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

This paper begins with main characteristics of Close Range Photogrammetry in comparison with Aerial Photogrammetry. Next, the paper present a short description of the evolution of photogrammetric methods and instruments, insisting upon the digital photogrammetry and digital image instruments utilization. The paper proceeds with a presentation of typical aspects of the digital photogrammetry exploitation in comparison with the analogical and the analytical methods. In the end, the paper focuses an the advantages of digital approach in architectural photogrammetry and presents some practical examples there to connected.

1. INTRODUCTION

As we all know, terrestrial photogrammetry is developed before aerial-photogrammetry, because the airplanes carrying photogrammetric cameras (sensors) appeard end world developed only in the early 20th century. We must also mention the fact that while the exterior orientation elements of aerial-photograms were still unknown, terrestrial photograms were taken over by fixed stations on the ground, having known coordinates and a known direction of axis of exposure. That is why the utilization of terrestrial photograms(the analogical type, but mainly the analytical type) presented evident advantages in comparison with the classical topographic restitution. As a matter of fact, the information contained in the photographic image is of utmost importance in architectural photogrammetry.

If at the beginning, the utilization of photogrammetry was restricted to the application of certain perspective graphic procedures, after the appearance of the stereocomparator (in 1901) a step was taken forward to certain simple numerical methods, especially in the normal case of terrestrial photograms acquisition. The subsequent evolution of photogrammetry was marked by the developmend of some analogical type apparatuses. Thus after the invention of the stereoautograph (in 1908) and it is development by the Carl Zeiss Jena company (in 1911), the stereoscopic exploitation of terrestrial photograms could expand both in topographic applications and in non-topographic ones. Later, some other types of apparatuses used exclusively in terrestrial photogrammetry were developed or which could be used for the utilization of terrestrial photograms as well. Then, the specialists attempted to modernize the stereo-restitution analogical apparatuses, by using some devices to record the measurements and by connection with computation devices (computer).

A completely new age was the shift to the analytical exploitation. We must mention that principles of analytical photogrammetry have been long known, but the mathematical developments remaind without any practical applicability as long as the computation means were primitive. In consequence, the analytical methods started to be efficient, operational as of the seventh decade of the last century. Similarly to the analogical photogrammetry, the analytical approach also uses conventional photograms (obtained in the same way and having the same characteristics). Corection of the image points position due to the influence of the main sources of systematic errors (emulsion support deformation, lens distortion) is performed much more easly by analytical means. Note can be also taken of the fact that, unlike the analogical classical methods, analytical exploitation is a point by point operation as in topography, but much more efficient especially when there is a large number of points (Turdeanu, 1997). Last but not least, we must point out that analytical photogrammetry represented the (absolutely necessary) passage to the digital photogrammetry whouse theoretical and methodological bases it actually represents.

2. THE SPECIFIC NOTE OF THE DIGITAL PHOTOGRAMMETRIC EXPLOITATION

The main characteristic of the digital photogrammetric exploitation is represented by the operation with images recorded by opto-electronical means. These images can be obtained in two ways: digitization of photographic images by scanning, respectively digital image direct acquisition by means of specific cameras. As for the precision, this is determined by the size of the pixel : the smaller the size of the pixel, the bigger the precision.

From a mathematical point of view, digital image processing has both an informatives aspect and a photogrammetric specific (based on the collinearity and coplanarity conditions). In principal the acquisition of this images is made by stereoscopic vision simulation, then the image analyses and structure recognition is performed. Photogrammetric measurement is largely performed automatically and photogram orientation as well as aerial-triangulation is made by analytical methods. Digital image stereorestitution is performed in an analytical way, with a possibility to present the result in graphic form as well. The main devices by which the results of digital photogrammetric system can be vizualised is a high precision plotting board using vectorial data.

The main characteristics of digital photogrammetric system are : such of system uses the computer in order to perform photogrammetric operations with digital image data; these operations are performed by image data sets, consisting of pixels having various shapes and sizes; the sensor can be a digital camera equipped with CCD or scanner moving along a linear zone of the CCD, the image date being transmitted in digital form by digital - analog conversion; if the date are derived from photographic images, they are obtained by high precision scanners (with linear or areal CCD) ; the main element of digital photogrammetric system is the digital photogrametric work station, which can carry-out manual, semi-automatic or

automatic operations; the final results can be vectorial maps, data regarding the digital terrain model (DTM) or digital ortho-images. The main elements of digital photogrammetric system are : devices for digital image data acquisition from various sensors; scanning technologies for the photographic image digitization; photogrammetric work-station and output devices.
On the other hand, the set of software programs is extremly important, as it has to permit a large range of processing. This programmes must carry-out the following functions (Lebel, 1994): image handling, mathematical model, coordinate processing, containing photogrammetric routines of interior and exterior orientation (relative and absolute), of aproximative value generation, of block adjustments; graphic modules for data acquisition regarding points, lines and symbols; GIS/CAD interface; digital elevation model (DEM), performing data acquisition, data verification, (network) sampling, outlining, visualization, editing; automation modules for image matching, line tracking, structure representation, image classification etc; the image rectification, creating nodale points based on a DEM sensor; image resampling, creating an ortho-image based on the linear digital image and on the nodale points; image processing, modifying the digital images (softcopy) to better correspond for the display on the screen or for the analyses. Another fact to be remarked is that in this programs system, the strictly photogrammetric elements appeare only in the second and the third module, most of the modules containing computer processing.
Compared to the analogical and analytical models, digital photogrammetry can be mainly characterized as follows (Zheng Yong – Jian, 1993) : initial input (initial observation) are extended from geometric values to (for instance) to image point coordinates; the output (the results), regard not only the geometric properties but also the physical properties of the image objects; the accomplishment of the "input-output" transformation aims at complete automation, unlike the traditional approaches which are based essentially on the action and intelligence of the operators in image measuring and interpretation; the field of application become larger and larger. Thus, digital photogrammetry greatly enlarges the product range offered by traditional photogrammetry of which we can mention : the simplified generation of DTM, digital maps and ortho-photomaps, GIS and LIS based on the photogrammetric data.
All these aspects led to an efficient utilization of the digital approach in architectural photogrammetry.

3. DIGITAL EXPLOITATION IN ARCHITECTURAL PHOTOGRAMMETRY

Compared with aerial photogrammetry, close-range photogrammetry and particularly the architectural photogrammetry is not limited to vertical photographs acqueried with special cameras.The methodology of terrestrial photogrammetry has changed significantly and various photographic acquisitions are widely in use (Kasser and Egels, 2002).
New technologies and techniques for data acquisition (CCD cameras, Photo-CD, photoscanners), for data processing (computer vision), for structuring and representation (CAD, simulation, animation, visualization) and for archiving, retrieval and analysis (spatial information systems) are leading to novel systems for processing methods and results representation.
The improvement of methods for surveying historical monuments and sites is an important contribution to the recording and perceptual monitoring of cultural heritage, to the preservation and restoration of any valuable architectural or other cultural monument, object or site, as a support to architectural, archaeological and other art-historical research.
As is previous shows digital image data may be acquired directly by a digital sensor, such as a CCD array camera, for architectural photogrammetric work. Alternatively, it may be acquired originally from a photograph and then scanned.
For the applications in architectural photogrammetry the use of cameras was for a long time determined by the use of expensive and specialized equipment (i.e. metric cameras). Depending on the restrictions due to the photogrammetric reconstruction process in former times, only the metric cameras with known and constant parameters of interior orientation could be used. Their images had to fulfil special cases for the image acquisition (e.g. stereo normal case).
Nowadays, more and more image acquisition systems based on digital sensors are developed and available at reasonable prices on the market. The main advantage of these camera systems is the possibility to acquire digital images and directly process them on a computer.
The classic, photographic cameras have their advantages in the unequalable quality of the film resolution and in the well-known acquisition technique. The process of analytical photogrammetry makes a benefit of the knowledge and rich experiences of the human operator. On the other hand, the pure digital data flow has not yet image acquisition devices comparable to film-based cameras. But, this procedure allows a productive processing of the data due to the potential of automation and the simultaneous use of images and graphics. Furthermore, it allows a closed and therefore fast and consistent flow of data, from the image acquisition to the presentation of the results. In addition, with the digitization of film, a solution is available that allows the benefits of the high-resolution film to be merged with the benefits of the digital image processing. But, the additional use of time for the separate process of digitization and the loss of quality during the scanning process are dis-advantages.
The digitization of photographic images offers a means to combine the advantages of film-based image acquisition (large image format, geometric and radiometric quality, established camera technique) with the advantages of digital image processing (archiving, semi-automatic and automatic measurement techniques, combination of raster and vector data).
The development of digital image acquisition systems is closely connected to the development of CCD sensors. The direct acquisition of digital images with a CCD sensor holds a number of advantages, which makes them interestings for photogrammetric applications. For example (Kasser and Egels, 2002):

- direct data flow with the potential of on-line processing;
- high potential for automation;
- good geometric characteristics;
- independent of the film development process;
- direct quality control of the acquired images;
- low-cost system components.

The quality of digital images directly influences the final result: the use of low-resolution digital cameras or low-priced scanners may be sufficient for digital 3D visual models, but not for a metric documentation. The systems may be used by photogrammetrists as well as by architects or other specialists in historic monument conservation, and run on simple PC-systems, that suffice for special taks in architectural photogrammetry.
According to the specific needs in architectural documentation, the different kinds of systems are based either on digital image rectification, or on monoscopic multi-image measurement or on stereoscopic image measurement (Fellbaum, 1992). Software of

such systems is advanced in such a way that mass restitution and modeling is possible, if digital images are provided in a well-arranged way.

To compare different systems, the following topics can be considered (CIPA, 1999):

- the handling of a system;
- the flow of data;
- the management of the project;
- the import and export of data (image formats, parameter of interior and exterior orientation, control information, CAD information);
- the interior orientation;
- the exterior orientation (one step or two steps);
- the reconstruction of the object;
- the derived results in terms of topology, consistency, accuracy and reliability;
- the amount of photogrammetric knowledge necessary to handle the system.

Many parts of architectural objects can be considered as plane. In this case, even if the photo is tilted with regard to the considered plane of the object, a unique perspective is enough to compute a rectified scaled image. We need at least four control points defined by their coordinates or distances in the object plane.

Basically, the major stages encountered in the rectification of photography are as follows (Bryan et al., 1999);

- site work (photography and control);
- scanning;
- rectification;
- mosaicking;
- retoucking;
- output;
- archive storage.

Photographs of the buildings facades should be taken the most perpendicular to reference planes and only the central part of the image should be considered for a better accuracy.

Photogrammetric multi-image systems are designed to handle two or more overlapping photographs taken from different angles of an object. In the past, these systems were used with analogue images enlarged and placed on digitizing tablets. Presently, the software usually processes image data from digital and analogue imaging sources (reseau, semi-metric or non-metric cameras). Monoscopic measurements are achieved separately on each image. These systems don't give the opportunity of conventional stereo-photogrammetry. For the point measurements and acquisition of the object geometry, systems can propose support:

- for the automatic reseau cross-measurement;
- for the measurement of homologous points through the representation of line information in the photogrammetric images and epipolar geometry.

The main contribution of digital images in architectural photogrammetry is the handling of textures. The raster files are transformed into object surfaces and digital image data is projected on to a three-dimensional object model. Some systems are combined with a module of digital orthorectification.

Digital stereoscopic measuring systems follow analytical stereoplotters, well known as the more expensive systems. Many plottings are still done on analytical stereoplotters for metric documentation but as the performance and ability of digital systems increase and allow mass restitution. As textures are increasingly required for 3D models, digital photographs and systems are getting more and more important.

The data of the computer internal representation, which is sorted according to a specific order ('data structure'), forms the basis for software applications. The data basis is not directly accessed, but via available model algorithms, which allow the performance of complex functions by transforming them into simple basic functions according to a defined algorithm. The representation of a real-world object in a computer-oriented model is a synthesis of data structure and algorithms.

In principle, 3D models can be subdivided into three independent classes: the wireframe model, the surface model and the solid model (Kasser and Egels, 2002). The division is based on the different computer internal representation schemes and is therefore also for the application areas of these models.

Wireframe models are defined by the vertices and the edges connecting these vertices. They fix the outlines of an object and allow a view through from any point of view. This is an advantage for simple objects, but reduces the readability of more complex objects. This representation is therefore often used for simple objects.

Surface models represent the object as an ordered set of surfaces in three-dimensional space. Surface models are mainly used for the generation of models, whose surfaces consist of analytical not easily describable faces having different curvatures in different directions.

Volumetric models represent three-dimensional objects by volumes. The data structure allows the use of Boolean operations as well as the calculation of volume, centre of gravity and surface area (Mäntylä, 1988). Surface modeling is the most demanding, but also the most calculation-intensive way of modeling. Solid models always represent the hierarchy of the object, in which the primitives and operations are defined.

Each of the classes mentioned above has its specific advantages and disadvantages. Depending on the task, the advantages and disadvantages are more or less important. Therefore, it is not possible to make a general statement, which of the classes is the best representation of real-world object.

Beside the 'pure' representations of object models often hybrid models, are utilized. Hereby the term 'hybrid model' is not clearly defined and is used for various types of models, which use different representations within one system. In principle, the term can be used for all non-homogenous models. It is often used for systems that can handle wireframe and surface models at the same time. Others use the term ' hybrid model ' for using volume and surface models under the same graphical user interface.

Due to the progress in computer hard-and software, is may to remark a rapid development in the facilities of visualization in architectural photogrammetry. Simple façade plans are no longer suitable for the demands and applications of many users. 3D-real-time applications such as animations, interactive fly-overs and walk-arounds, which had needed the performance of high-end workstations a few years ago, are now also available on personal computers.

Regarding these models of a monument's 3D data as a basic storage concept, a large number of resulting products can be derived from it. As examples, arbitrary perspective views and orthoimages in scale should be referenced here.

3D object models can be viewed and inspected interactively by the user or animated in real-time even on a PC. Thus, VRML is well suited to create, for example, interactive environments, virtual museums, visualizations and simulation based on real-world data.

Another way to visualize real-world objects is creating panoramic images. This approach avoids the time-consuming process needed for a 3D model. There are several methods to achieve panoramic images. One is to take single images with 20 per cent to 50 per cent overlap from a fixed position while rotating the camera around a vertical axis. Warping them on to a cylindrical or spherical surface leads to a spatial imagination when navigating through the model. Another way is to move the camera around the object with a fixed target point. Complex objects can be so viewed and turned around on a personal computer by simply dragging the mouse.

4. EXPERIMENTS

Experiment was carried out at the "Popa Nan" church in Bucharest.
The church is considered a historical monument and it is a representative orthodox church for the Byzantine style. It was first built in the 17th century and it was rebuilt in its current form in 1960, the last renovation being performed in the year 1977-1986.

The "Popa Nan" Church

We made topographic measurements using a Leica Total Station (TCR 405 POWER) and the images were taken over by a non-metric digital photo camera HP PhotoSmart 945
The observations were processed by the SIPREG set of programmes (soft).
We shall continue our study programme with some more representative monuments.

5.CONCLUSION

This paper presents the advantages of digital exploitation in comparison with classical methods of photogrammetric exploitation, especially in architectural photogrammetry domain.
This was besides and the purpose this synthesis paper specify actually from title. The subsequent experimentations will be certainly prove this aspect.

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