

EXPERIENCES AND PROCEDURES ON MAKING TECHNICAL DOCUMENTATION FOR THE OBJECTS OF HISTORICAL AND CULTURAL HERITAGE

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Commission IV, WG IV/6

KEY WORDS: Photogrammetry, Architecture, Cultural Heritage, Reconstruction, Softcopy, Close Range, Digital

ABSTRACT:

This paper evaluates advantages of application of digital photogrammetry for the purposes of production of technical documentation for the objects under protection, comparing it with the classical photogrammetric procedures. Based on gained experiences, paper reviews procedures for the completely digital production of technical documentation. Process of making technical documentation is divided in two logical stages. First stage comprises of photogrammetric recording, necessary field measurements and production of archive documentation. Archive documentation is in completely digital form and it includes: geometrically rectified photogrammetric photos, data on control points, parameters of exterior orientation for all photos and digital orthophotos as a preliminary source of geometric information. Second stage involves the production of detailed documentation with data describing object geometry such as: floor plans, facades, sections, etc, by using suitable CAD tools. Considering that this constitutes the most complicated and the most expensive part of making technical documentation, this stage is done when needed. Proposed method will be illustrated in paper by using experiences gained on projects of making technical documentations for objects of historical and cultural heritage for the towns of Kragujevac (Serbia and Montenegro) and Banja Luka (Republic of Srpska).

1. INTRODUCTION

Application of photogrammetry in cultural heritage and protection of objects with high architectural value has a long tradition. Classical photogrammetry had been also used for these tasks, but it can be considered as slow and expensive technique for production of technical documentation. With application of contemporary methods of digital photogrammetry new possibilities arise for faster, cheaper and more flexible procedure, completely based on digital technique.

2. RESPECT FOR THE CULTURAL HERITAGE

Environments with proper respect to own historical and cultural heritage succeeded in their efforts to provide appropriate photogrammetric documentation (Kuipers, 1997). Some of them got even further and they are now dealing with problems of establishing information systems on cultural heritage (Potsiou et al. 1992; Bartolotta et al., 2000; Heine, 1999; Kölbl, 2000). These systems are not just about technical aspects of cultural heritage protection but they are also enabling high level of information technology application in this area (3D visualization, virtual models, data distribution via Internet, etc).

Unfortunately, some societies have not finished or even started this process. In spite of invaluable cultural value of many objects, many of them have no technical documentation which will serve as important information source for later rebuilding or reconstruction. At the other hand, typical phenomenon is the production of technical documentation immediately before rebuilding or reconstruction, when the object is in the worst condition and the time for high-quality documentation production is very short. Absurdity lies in the fact that very

often amount of the money spent in such cases is higher than in "regular" production.

So, relation to cultural-historical heritage depends not just on available finances, but on condition and organization of works in cultural heritage in certain environment. Timely production of technical documentation by using photogrammetry is the example which illustrates the importance of good organization. Authors of this paper support the idea that procedures of making technical documentation on geometric condition of objects with high cultural value should be standardized and works should be long-term planned.

3. PHOTOGRAMMETRIC PRODUCTION OF CLASSICAL TECHNICAL DOCUMENTATION (IN ANALOG FORM)

Photogrammetric production of technical documentation in classical, analogue form assumes traditional procedures, that is:

- Image capturing on glass plates or film;
- Determination of control points by standard surveying methods;
- Graphical stereorestitution of facades, sections, floor plans and other content in appropriate scale;
- Archiving of complete documentation in analogue form.

It can be said that these were standard photogrammetric procedures for production of technical documentation at the time when analogue and analytical photogrammetry were dominant. As such, it represented compulsory content of every photogrammetric course dealing with application of photogrammetry in cultural heritage protection.

In the period of analogue photogrammetry production of technical documentation was based exclusively on using glass plates or films. Graphical stereorestitution of such images was conducted on analogue photogrammetric plotters (special or universal ones).

Advances in technology of making technical documentation after introducing analytical photogrammetry were reflected in the following (comparing to analogue):

- more flexibility of analytical instruments in the orientation and stereorestitution of terrestrial images;
- possibilities of using non-metric and semi-metric cameras;
- more flexibility in photography planning (locations and orientation of camera)

Nevertheless, the most important issue in making technical documentation – archiving and production of graphic documents, remained in analogue form. Critical changes in photogrammetric application have happened with the introduction and expansion of digital photogrammetry.

4. DIGITAL PRODUCTION OF TECHNICAL DOCUMENTATION

Appearance of digital photogrammetry has opened completely new possibilities in production of technical documentation for cultural heritage. Changes were very important and they pertain not just on already existing phases, like:

- image capturing,
- graphical documentation production,
- archiving,

but also on possibilities to produce completely new digital products:

- digital orthophoto and
- 3D object model.

4.1 Image capturing

First of all, the new possibilities occurred for photography in digital technique. Of course, already existing terrestrial photography techniques are still useful, providing that high quality scanning is included. Non-metric (amateur) and semi-metric cameras can be used also because after scanning procedure all systematic errors could be corrected by applying digital resampling. Imaging became far flexible and faster cause, beside normal stereo pairs, images can be taken by the hand, from completely arbitrary position.

4.2 Archiving

Archiving of source material is based on using digital media only. In that way, the loss of photo documentation quality during the time is excluded. Of course, even digital photo documentation cannot be absolutely protected, but with proper archiving methods this problem can be brought down to theoretical level.

4.3 Orthophoto production

Digital form has opened new possibilities for digital orthophoto production as very fast and inexpensive part of technical documentation (Baratin et al. 2000). This procedure is based on similar process as in aerial photogrammetry. Important savings

can be done by simplifying digital elevation model (DEM) requirements. This means that for some simple facades DEM can be replaced with vertical planes.

4.4 3D object model

Completely 3D object model can be produced, providing that reasonable financial resources are available, or when user requests are higher (Kölbl et al. 2000; Dorffner et al. 2000). The process of 3D object model creation can be done by digital stereorestitution, automatic measurement of 3D model based on image correlation or by combination of both. Nevertheless, it should be noted that every object has its own specifics, so it is very difficult to formulate the standard procedure. That is why this product is not compulsory part of technical documentation. If the final goal of technical documentation is 3D object model, then it should be estimated whether digital photogrammetry is more economical than 3D laser scanning (Boccardo, Comoglio 2000).

5. PROCEDURE FOR MASS PRODUCTION OF DIGITAL TECHNICAL DOCUMENTATION

Procedure that is to be proposed in this paper is the result of our own experiences in application of photogrammetry for cultural heritage in Serbia by using already mentioned advantages of digital photogrammetry. Intention is to establish initial technical documentation for a number of cultural monuments and objects with high architectural value.

5.1 Assumptions

The basic assumption for formulating procedure is that it has to serve in campaign-type and systematic way of working, with intention to enable a lot of savings. Therefore, important role in procedure formulation was financial aspect of photogrammetric application. That is why the procedure is based on the following hardware and software assumptions:

- For image capturing Rolleiflex 6006 is used (colour film);
- EPSON Expression 1600 desktop scanner is used for scanning;
- Total station Leica TCR705 is used for determination of control points (reflectorless);
- Geometric rectification of scanned images is performed by *DigiScan 2000* (www.mapsoft.co.yu)
- Any available software can be used for digital triangulation;
- Some low cost software can be used for orthorectification.

5.2 Basic idea

Procedure of technical documentation production is divided into two logical phases. The first consist of image capturing, necessary field measurements and production of archive documentation. Archive documentation is completely digital and consists of three units:

- digitised and geometrically rectified photogrammetric images,
- digital orthophoto as preliminary documentation, and
- technical report in digital form with all the information on object and technical data necessary for further photogrammetric works in the second phase.

The second phase consists of detailed geometric documentation, such as: floor plans, facade appearance, sections and similar, all in digital vector form, by using appropriate CAD tools. Since this phase is the most expensive and the most complicated part of documentation production, it is not compulsory.

Division of procedures into two phases enables the first one to be performed in campaign manner (by object groups, environment entities or some other criteria) for relatively short time and with relatively limited financial resources. The goal of this phase is preventive capture of information about cultural object, because present object condition is 'frozen' at the moment of making documentation. At the same time, this is prerequisite for the second phase to be performed at any time afterwards without any danger of loss of information. The most important elements of suggested procedure will be explained further on in this paper.

5.3 Image capturing plan

The successful realization of mass technical documentation production demands certain preparation. This preparation involves inspection of object of cultural importance and determination of the target objects for each campaign. The disposition sketch should be made and it should serve as the basis for image capturing plan, as well as for checking of all critical elements for planning (visibility, estimated maximal extent of images in height and width, etc). Beside the data collected at the field, some other information sources are important for image capturing plan (photographs, cadastral maps, etc). Image capturing plan should contain approximate disposition (position and orientation) for all planned images (Figure 1).

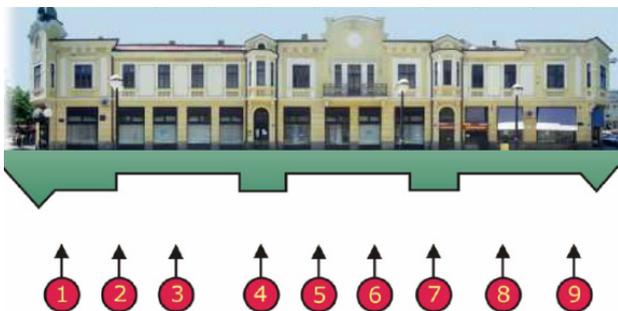


Figure 1: Image capturing plan

5.4 Image capturing

Suggested procedure assumes imaging with Rolleiflex 6006 color film camera (Figure 2). Images are taken by hand, from the ground or by moveable telescope crane. Imaging has all campaign characteristics. After short preparation (photo signalization of control points), imaging is done according to previously created plan. Films are developed after finished campaign or at the end of the day. At least one color contact copy should be made for each photo. Right after, it should be evaluated whether imaging plan has been satisfied. Image copies are used also for the selection and notification of control points during following phases.



Figure 2: Original image made by semi-measurement camera Rolleiflex 6006

5.5 Image scanning

Suggested procedure assumes scanning of photogrammetric images directly from negative by using desktop scanner Epson Expression 1600. Although it is not difficult to calculate appropriate resolution for each concrete case (Chong et al. 2003), it is recommended to do scanning in resolution 1600 dpi, full color. Namely, it was determined empirically that 1600 dpi is the resolution that corresponds to the limitations imposed by amateur color films and standard procedures of photo laboratory processing.

5.6 Geometric rectification of images

After scanning, it is necessary to geometrically rectify images, i.e. to eliminate errors introduced by image capturing, photo processing and scanning (Figure 4). Geometric rectification is based on theoretical values of image coordinates for grid points. These points are copied onto film during image capturing - 'resau' plate is built on Rolleiflex 6006 camera (Figure 2).

Collocation by least squares, with previous affine transformation for trend elimination is proposed mathematical model for geometric rectification. Example of systematic errors typical for camera Rolleiflex 6006 and scanner EPSON Expression 1600 is shown at Figure 4. For further processing only geometrically rectified images are considered.

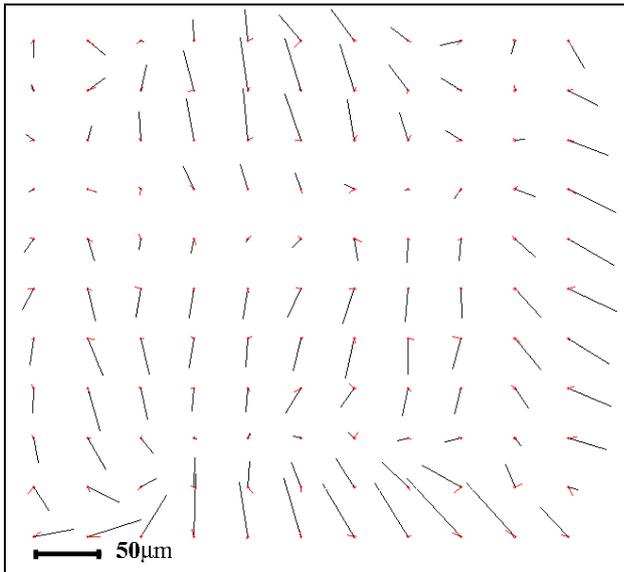


Figure 3: Residual vectors before and after elimination of systematic errors (Rolleiflex 6006 & EPSON Expression 1600)

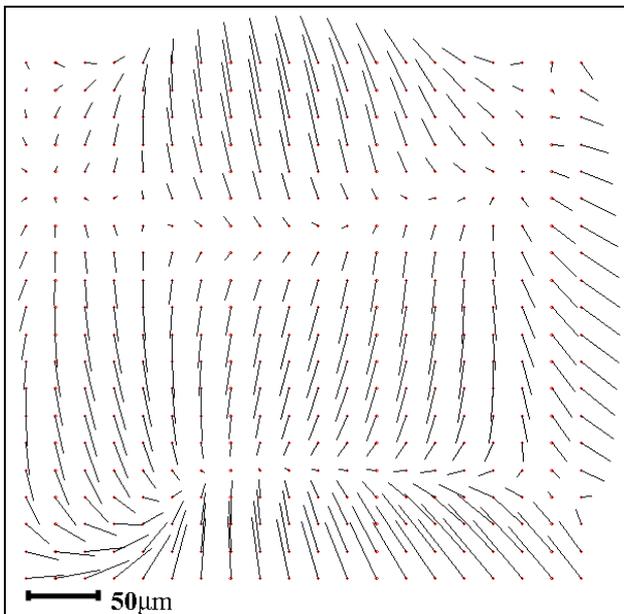


Figure 4: Systematic errors (Rolleiflex 6006 & EPSON Expression 1600)

5.7 Coordinate system definition

Coordinates of control points are determined in the local coordinate system, which is located arbitrary in relation to object (X_l, Y_l at Figure 5). Whenever it is possible, the local coordinate system should be unique for several closely located or connected objects. It is not necessary to materialize surveying points for realization of local coordinate system (points A, B and C at Figure 5) because it is done indirectly, by determination of control points located on facades. The final coordinate system (Y_t, Z_t at Figure 5) is defined by regression line calculated by using certain number of points located on facades (Y_t) and perpendicular on it (Z_t)

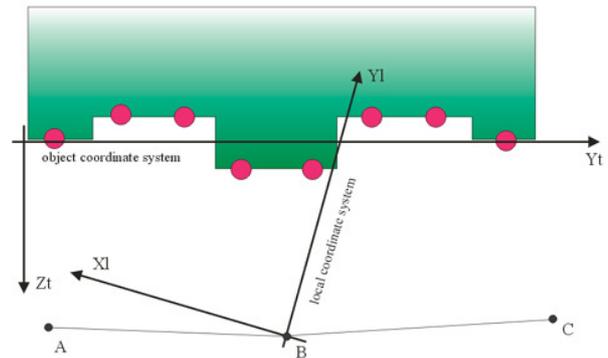


Figure 5: Transformation of local (Y_l, X_l) into object coordinate system (Y_t, X_t)

5.8 Control point selection

Control points should be located on the object. They can be artificially marked or chosen from clear facade details (Figure 6). In both cases, the position of control points should be well described.

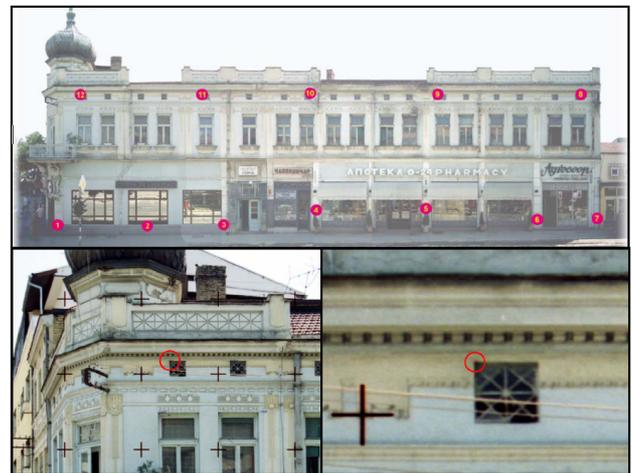


Figure 6: Control point selection

The best way to make description of control point position is digital (illustrated at Figure 6). Collected information about all control points of one object makes the catalogue of control points.

5.9 Control point determination

With appearance of reflectorless total station, determination of control points for the needs of technical documentation is significantly improved in terms of efficiency and reliability. Standard possibilities for automatic data registration, attribute codification and automatic transfer of data into computer also contribute to this issue. Accuracy of control points now depends more on proper selection of control points than accuracy of linear and angular field measurements.

Considering application of perspective bundles, the number of necessary control points is significantly reduced comparing to those required by measurements of independent stereo pairs. Nevertheless, the function of points defined by surveying should also be a control one, especially for very sensitive object details (points striking out, important constructive details, peak elevation, etc). The need for more reliable points is increased,

since their number is reduced. Reliability can be increased by applying the following principles:

- Additional linear and angular measurement from another surveying point should be made, whenever it is possible;
- Selection of pairs and groups of control points which fulfill certain geometrical conditions (lies in the same horizontal or vertical line, the same depth plane of facade, etc) should be made.

5.10 Exterior orientation of images

Exterior orientation is done by standard simultaneous procedure of bundle adjustment. Elements of exterior orientation are pertaining to the object coordinate system (X_t , Y_t , Z_t at Figure 5). Input data for bundle adjustment are field coordinates of control points, interior orientation data of camera and measured image coordinates of control and tie points. Measurements are performed using rectified photogrammetric images and appropriate software. Output results of this procedure are elements of exterior orientation of all images include in the block of perspective bundles. These elements are necessary for the next phase regarding facade's digital orthophoto production. There are two more reasons why bundle adjustment should be done following the suggested procedure. First, elements of exterior orientation will become part of archive technical documentation, so they will represent starting point for further works at any time. Since that moment isn't limited in terms of time, the importance of bundle triangulation lays also in the fact that accuracy and reliability of control points is simultaneously verified by the triangulation. Therefore, continuation of works brings no risks, no matter when or for what purpose it should be initiated.

5.11 Digital orthophoto production

Digital orthophoto production of object is suggested as standard procedure in the first phase of technical documentation production. Namely, there is one essentially huge step in between bundle adjustment and orthophoto production – creation of digital elevation model (DEM). As it is very often the case of having objects with regular geometric shapes, DEM can be simplified and approximated with mean vertical planes representing object's facades. Errors of digital orthophoto caused by such a simplification occur just at those points that stick out from mean plane and these errors grow from nadir towards peripheral image parts. However, since digital orthophoto, as seen from the suggested procedure's point of view, serves as preliminary geometric 'background' for perceiving object geometry, it is justified to produce it in a proposed way.



Figure 7: Printed form of digital orthophoto

Digital orthophoto might be represented also in printed form, in appropriate scale (Figure 7). Nevertheless, the suggested procedure does not anticipate this as a compulsory step, because expenses get higher and problem of archiving printed material arise (in addition, it is redundant with already archived digital content).

5.12 Technical report

Technical report represents usual form of engineering statement about the most important elements of conducted works. It consists of three elements: general part, textual part and supplements. General part contains information about organization and persons participating realization and technical control of works. Textual part of technical report has general information about object of cultural heritage, workflow and achieved results. Supplements of technical report should have the following elements:

- object disposition sketch with marked positions of camera during image capturing,
- catalogue of all control points with belonging descriptions,
- data about surveying calculations for control points coordinate determinations,
- data about the camera,
- data about image geometric rectification, with proof of achieved accuracy,
- report about results of bundle adjustment, with proof of achieved accuracy and reliability,
- adjusted elements of exterior orientation.

Suggested procedure assumes technical report in digital form. Recommended document format is *Acrobat PDF*.

5.13 Archiving

Final step of the first phase in production of technical documentation is archiving. Digital archive content is the following:

- rectified images in TIFF format,
- digital orthophoto in georeferenced TIFF format, and
- technical report in PDF format

The following remarks could be made regarding archive memory requirements:

- Memory capacity for archiving one image (6x6cm, 1600 dpi, full color) is 42Mb;
- Memory capacity for archiving technical report depends on number and quality of images used. Recommended is JPG format, in resolution not higher than 400 dpi in printed A4 form;
- Memory capacity for archiving digital orthophoto depends on number and the size of TIFF files.

Archiving represents logical end of the first phase in production of technical documentation for cultural heritage. Such documentation becomes part of archive that should be kept within responsible institution for cultural heritage. Nevertheless, very soon this kind of documentation will find a way to serve for certain information systems on cultural heritage or it will urge application of IT technology for protection of cultural heritage.

6. CONCLUSION

In spite of long-termed application of photogrammetry in the area of cultural heritage protection, for the large number of objects of high cultural, historical and architectural value there is no adequate technical documentation. Expansion of digital photogrammetry brought to much more flexibility in application of photogrammetry in this area, as well as to much diverse palette of possible products. However, for many environments this will not be enough stimulus to carry out this civilization duty. Facing this issue and permanent lack of financial funds, this paper tried to specify one rational procedure for mass production of initial technical documentation of objects of high cultural, historical and architectural value by application of digital photogrammetry.

The essence of suggested procedure is to reduce the costs of initial documentation production by selection of simple hardware and software, by reducing the processing to just necessary level and by utmost utilization of digital photogrammetry advantages. Proposed procedure is aimed for mass applications with the larger number of cultural heritage objects, which will further on reduce the costs of documentation production. All of this makes up the first phase of technical documentation production and it should be considered compulsory. It has minimum of works for assessing objects geometry. The second phase was not the subject of further discussion, because it is not compulsory. It is done just when needed, with level of processing which should be the subject of analysis for each specific case. Suggested procedure enables very simple continuation of works on technical documentation production in future, whenever there is a need. Created documentation describes original object condition, registered and ?frozen? during the first phase.

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