NUMERICAL INVENTORY OF ARCHITECTURAL OBJECTS

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ISPRSCommissin V

KEY WORDS: Architecture, Technology, Inventory, Non-metric, CAD

ABSTRACT:

This paper presents methodological and technological solutions of the numerical system of photogrammetric inventory of architectural objects. Applied analytical methods allow to utilise - both metric and non metric - terrestrial photographs and to minimise field works. Numerical inventory of the entire object is performed in three-dimensional space, within one co-ordinate system, basing on a set of models which have been reconstructed by means of photogrammetric instruments, with the utilisation of orientation elements, which are determined during the process of terra-triangulation. The proposed approach allows to reconstruct the solid body during the stage of edition, to generate the series of selected graphical presentation of a digitised object and to transfer data to an arbitrary CAD system.

1. INTRODUCTION

Utilization of photogrammetric measurements for creation of geometrical documentation of architectural monuments is one of the widest applications of this method for non-topographic purposes. As a result of conventional, analog approach, a graphical drawing is obtained; it presents the object projection on a vertical plane (parallel to the main axis of the object façade), which is amended by horizontal and vertical intersections which characterize the façade relief. Scale of the created plane (which usually equals to 1:50) ensures the field accuracy of documented details equal to several centimetres. Such accuracy may be obtained due to utilization of the stereoscopic effect, which ensures proper identification and recording of selected fragments of objects within the space of its reconstructed model.

Since the middle eighties, the tendency to document such object in numerical form has been observed. It is the result of introduction of analytical stereo plotters to the common use and wider utilization of CAD computer-assisted designing system by architects and conservators of monuments. Introduction of numerical technique allowed to register all elements within the selected spatial system. It allows to fully reconstruct the body of the object and to give up the idea of conventional, graphical presentation of the object as a drawing on the vertical plane, which is parallel to particular façades and amended with selected characteristic intersections. Three-dimensional registration in numerical form, allows, at any time, to read-out, by means of graphical editors, previously recorded co-ordinates. It is also possible to prepare graphical presentations in central or orthogonal projections, onto specified projection planes.

Together with the introduction of analytical methods, a tendency is observed to utilize the semi-metric or non-metric cameras for image registration as well as to limit field works related to measurements of grids, which are performed for the needs of reconstruction and elaboration of particular stereogrammes. It is possible due to common utilization of terratriangulation which determines geometric features (external orientation) for the network of photographs which cover the investigated object.

This paper presents methodological and technological solutions which have been created during the implementation of the research projects performed at the Institute of Photogrammetry and Cartography. The proposed approach allows to perform the global,

numerical inventory of the object, basing on the series of models reconstructed from the terrestrial metric or non-metric photographs, by means of photogrammetric equipment, such as the analytical stereo plotter or the modified precise stereo comparator (used for the implementation of stereo digitizing). Elements of external orientation, which were determined by the previous terratriangulation process, have been directly used for the reconstruction of photogrammetric models.

2. GENERAL IDEA OF THE SOLUTION

The following objectives have been assumed at the beginning of implementation of the research project, which aimed at design of technology of numerical measurements of architectural objects:

    a) the system should allow to utilize metric or non-metric photographs as raw data,

    b) to minimize field works,

    c) to utilize surveying measurements in the course of reconstruction,

    d) to utilize the analytical stereo plotter or modified precise stereo comparator for the needs of observation and measurements of photogrammetric models,

    e) numerical coding (stereo digitizing) should enable the explicit transfer of results of elaboration to typical CAD systems.

A tendency to utilise medium-format cameras for the registration has been observed for many years. Such a tendency has been supported by considerably lower price of equipment, which, at the same time, has a well developed attachments and additional devices which allow to optimally select the lens-camera-light source system, in order to obtain the best possible results of photographic registration of an object.

However, the utilization of non-metric cameras is connected with the problem of determination of internal orientation parameters of photographs which are taken by means of such cameras. In practice, in order to obtain satisfactory results related to accuracy, determination of internal geometric features of such photographs is required during the implementation of photogrammetric measurements, i.e. self-calibration process should be performed during the elaboration is performed. Thus, utilization of a software tool should be planned, which would allow to perform the self-calibration process for non-metric photographs, which are to be used

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for inventory of architectural objects. In the discussed case, it was decided to use the "ORIENT" system, obtained from the T.U.WIEN within the assistance for the Eastern European countries. At the same time, in order to publicize the created solution, it was also decided to elaborate own software package, basing on the condition of collinearity, which could be used for common calculation, in the variant way, the elements of internal and external orientation for the network of terrestrial photographs. In practice, the "TERRANET" package was designed and created; its functional features are discussed in the next section.

The above mentioned software tools also allow to accept the idea, that during the stage of object registering, it is possible to take many photographs which cover the entire object, with the assumed scale. Respective overlapping of photographs allows to perform the process of terratriangulation, basing on these software tools, and then, to perform stereo digitising of selected photographs, which would ensure to perform proper stereoscopic observations and to maintain the assumed accuracy of object co-ordinates. Implementation of the terratriangulation process results in maximum limitation of the number of points required for the ground control network. Characteristic feature of programmes which are to be utilized for the needs of the discussed process is the possibility of simultaneous consideration of surveying measurements, which create additional equations of conditions.

The calculated elements of external and internal orientation (in the case when non-metric photographs are utilized) are used for direct reconstruction of spatial models, by means of photogrammetric instruments.

Such an approach required preparation of specialised software, which enables to receive resulting data from ORIENT or TERRANET packages and to generate - after observation of fiducial marks (restoration of internal orientation) parameters of orientation of photographs in a photogrammetric model and its absolute orientation with respect to the ground co-ordinate system.
In the case of utilization of the analytical stereo plotter, it was additionally assumed that during the reconstruction of absolute orientation the following requirement should be met: when the reconstruction of the spatial model is completed, the measuring cursor, which is moving in the XY plane of the model, should move parallelly to the elaborated plane of the façade of the building.

Such a condition allows to create more convenient circumstances for the process of stereo-digitising. It has been assumed in the proposed technology, that the proper elaboration of particular stereogrammes should be possible on the modernised Stecometer produced by Zeiss. It has been accepted that the required range of modernisation of this instrument should include its adaptation to on-line work with a PC class computer and installation of a stepper motor, in order to eliminate the vertical parallax in a quasi-continuous way - this allows to perform stereoscopic stereodigitizing.

It was also assumed for the discussed idea, that correct inventory of architectural objects requires the observations and measurements of photographs with the utilisation of stereoscopic effect.

It was decided, that in order to ensure the proper transfer of results to standard CAD software packages, special drivers should be developed to control the movements of carriers and to process photogrammetric measuring data to field co-ordinates, which will be accessible for selected graphical editors to edit and archive data at the photogrammetric station. After comprehensive analysis was performed it was decided that the designed drivers will directly support the MicroStation system, under which the object measurements will be performed.

It was also assumed that coding should be fully three-dimensional and object-oriented.

Acceptance of such an assumption, during the stage of stereodigitizing, allows to split the information on an object into layers, thus enabling to simplify possible editorial works during the creation of thematic maps and presentation of results. Spatial measurements of particular façades, in a stable, ground co-ordinate systems, allows to fully reconstruct the body of an object and then to present it, in an arbitrary - perspective or orthogonal - projection, with an arbitrary orientation of the projection plane.

3.HARDWARE AND SOFTWARE

The discussed research project was implemented basing on the equipment existing at the Photogrammetric Laboratory of the Institute of Photogrammetry and Cartography: the precise stereo comparators STECOMETER ZEISS and the analytical stereo plotter PLANICOMP P3.

Original configuration of the stations using the precise stereo comparators has been modified. The stations were equipped with hardware and software elements, allowing to determine and automatically eliminate, in the on-line mode, the vertical parallax and to perform continuous registration of the measuring cursor, by means of the special card of electronic counters. The equipment of these instruments was amended by foot pedals and touch sensitive tablets in order to automatize and simplify the process of stereo digitising.

In order to allow for elaboration of terrestrial photographs by means of the STECOMETER, the software package was prepared which allows to perform the following tasks: acquire photograph co-ordinates (TLOWE) in formats which correspond to requirements of adjustment programmes, the MODEL ST routine which processes instrumental observations into ground co-ordinate system, basing on data from the network adjustment. Drivers allowing to perform the 3D stereo digitising process directly in the MicroStation system were also designed.
Besides, standard software of PLANICOMP P3, the analytical stereo plotter, was modified and amended with the MODEL ST routine; this routine allows to create a model basing on terrestrial photographs and with the use of parameters which are determined during the process of terratriangulation.

The ORIENT and TERRANET routines, elaborated within the discussed project, were applied to determine the initial data for the above mentioned routines.
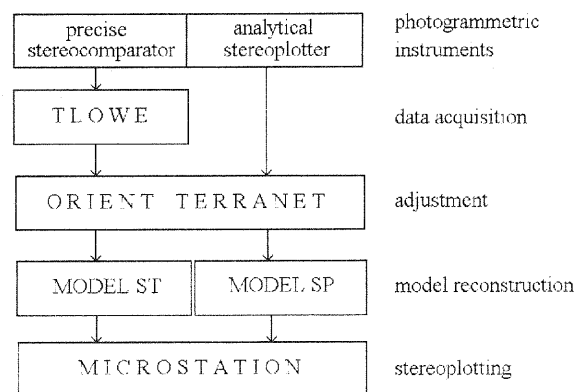

Fig. 1 Data flow in the system

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4. IMPLEMENTATION OF THE TECHNOLOGICAL PROCESS

In the proposed technology, elaboration of (metric and non-metric) terrestrial photographs, performed in order to inventory architectural objects, is implemented in the following stages: determination of geometric features of the photographs, creation of a model, stereo digitizing, editing of data, creation of a body of the object within the three-dimensional space.

The ORIENT System is utilised - in the discussed technology - for determination of geometric properties of a network of photographs, by means of the independent bundles method. The system allows to perform a series of plane transformations, determine the elements of external orientation, the elements of internal orientation (both, for a group of photographs or for individual photographs), intersections, resections, to construct a model and to perform its spatial transformations. Observations in the process of adjustment may be: fiducial co-ordinates, surveying co-ordinates, pseudo-observations, as the co-ordinates of ground points of control in the external co-ordinate system, co-ordinates of points located on geometric models; parametric conditions may also be considered. Due to these possibilities of the software it became possible to carry out investigations aiming at minimising the ground control network and to utilise surveying observations directly for the geometric restoration of objects.

The programme has also been used for verification of the created TERRANET software package.

The TERRANET software package - used for the adjustment of photographs by means of independent bundles - allows to determine parameters of internal orientation, additional parameters and, in particular, parameters of lens distortion (powers 3,5 and 7 of the polynomial of distortion or coefficients of Torlegard radial distortion model) and co-ordinates of tie points. Determination of internal orientation may be performed jointly for all photographs, or separately, for individual photographs.

It is possible to determine geometric features of 30 photographs. Elements of orientation may be considered as error-free or as the elements of known accuracy and - as such - they may be determined. The algorithm of adjustment is based on the colinearity condition with additional conditions, direct measurements , such as: horizontal distances, oblique distances, increments of co-ordinates, horizontal and vertical angles. All observations are weighted, basing on the a priori values of mean errors, which are considered as criterion of identification and elimination of gross errors. The procedure of adjustment allows to calculate the errors of determination of all determined values. Initial data for the TERRANET package (fiducial co-ordinates of points being measured) are prepared by means of the separate TLOWE package, which allows to use several models to correct systematic errors and to prepare data for other programmes used for the adjustment. Approximate elements of external orientation of the entire network of photographs, which are necessary for initialisation of accurate adjustment, are determined in a module of generation of initial data of the TERRANET package. The requirement to utilise this module is to ensure appropriate connection between photographs and their connection to a control network. Software used for determination of approximate elements of external orientation utilises procedures of relative orientation of a pair of photographs, local, photogrammetric resection or ground resection and transformation of a local co-ordinate system to a ground co-ordinate system.

Data collected by means of the TERRANET routine are used to reconstruct the model by means of the MODEL ST routine and the STECOMETER or the MODEL SP routine and the analytical stereo plotter. Algorithm of reconstruction of the model uses the elements of external and internal orientation and determined parameters of distortion. In both cases the files which control the stereo digitising process in the MicroStation system are generated basing on collected data. The projection plane is also defined (it is usually parallel to the façade); stereo digitizing will be performed in this plane. Retrieved data are recorded in the external system, which is uniform for all façades of the object. Accuracy of reconstruction of spatial model by means of the instruments, is, in practice, the verifying tool of successful performance of the TERRANET adjustment routine.

The process of stereo-digitising is preceded by testing the correctness of reconstruction of a model, basing on differences on location of a floating mark, obtained as a result of automated positioning, on the basis of data after adjustment, with respect to a proper position of a point of a network within the stereogramme; results of testing are recorded in a protocol.

It is also possible, using the MODEL ST routine, to determine the geometric features of photographs in the single model mode and to prepare data for the needs of stereo digitising, in the external system with known co-ordinates of control points, or in the local system, related to the object, also with the minimum grid. The control network may be created by point co-ordinates, oblique distances, differences in heights, differences of co-ordinates, azimuths with co-ordinates of a camera, in the external co-ordinates system. This solution is mainly applied in the case of utilizing metric photographs. Resulting parameters are transferred to the MS driver.

In the proposed technology, stereo digitising is performed in the INTERGRAPH MicroStation system. This system allows to perform the stereo digitizing in three-dimensional space with the possibility to separate up to 62 layers of the digitised contents and to assign separate attributes to particular elements of the drawing (thickness of lines, types of lines, colours). This allows to separate elements of different types on the screen, as well as in the data base. If the stereo digitising process is performed with respect to reconstruction of the body of the architectural object, it is proposed to record each façade in a separate, reference file, but in the unified, external co-ordinate system.

The edges elaborated from various stereogrammes may be matched directly when the neighbouring, completed façade is read-in. The elements of drawing should be recorded as closed polygons, shape type elements, stream type lines. Outlines of buildings, skeleton lines and other elements influencing the shape of a body should be recorded as surfaces. Details and decorations which are not linear elements, are presented by a stream type line, with parameters of the quasi-continuous registration, adjusted to the scale of object presentation.

Recording of retrieved data in the stable reference system allows to simply reconstruct the body of the object during the editing process, basing on the outline and main skeleton lines, which are recorded on separate layers. In the editing process, it is possible to prepare the series of presentations, which are adjusted to the user's requirements (as automatic generation of intersections, perspective drawings etc., covering with raster or an arbitrary hatchure, location of an object within the selected environment etc. Besides, the numerical inventory of an object allows to integrate photogrammetric data with designing data in other CAD systems.
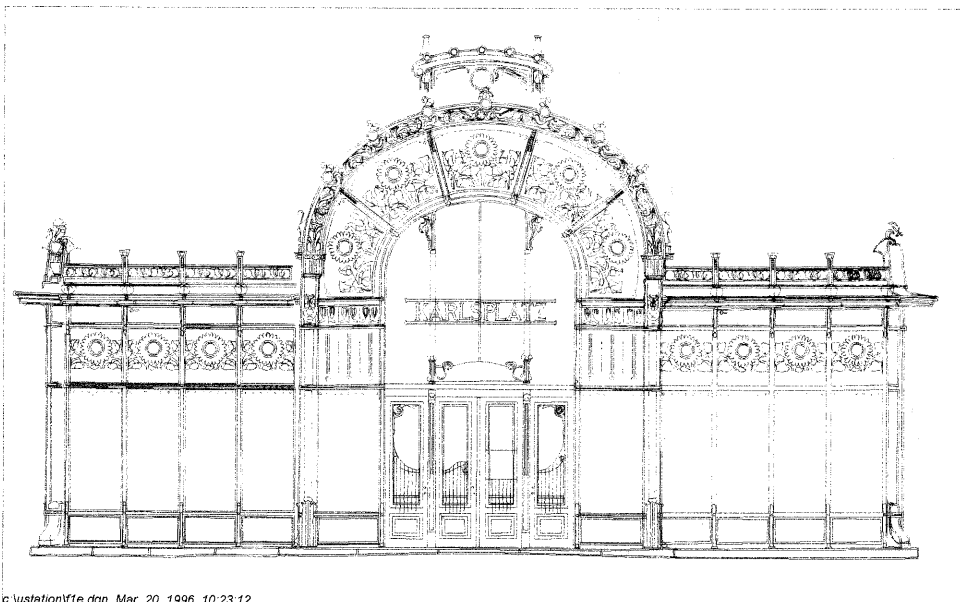
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Fig. 2 The result of stereoplotting

5.EXEMPLARY ELABORATION

Test data, delivered to the research groups which participate in the KARLSPLATZ test, by the CIPA, were used for the needs of experimental works.

A block of 13 non-metric, medium-format photographs (approximate scale of 1:400) taken with Hasselblad camera was measured by means of the Stecometer and then its geometric features were determined with the use of TERRANET and ORIENT package (elements of external and internal orientation and parameters of distortion polynomial). Obtained results were entered to the MODEL SP package. It was stated as a result of analysis of deviations, that the model was properly constructed and the maximum deviation on control points equalled to 20 mm (identified points) and the residual parallax did not disturb observation.

The same data (elements of internal and external orientation and parameters of Torlegard model of distortion) were utilised for the model reconstruction on the precise Stecometer with the use of MODEL ST package. Obtained results prove the proper functioning of software procedures. The residual parallax has not been observed for the constructed model and deviations on control points did not exceed 25mm.

Exemplary continuous elaboration in the discussed technology has been prepared with the use of the Planicomp P3 analytical stereo plotter. A file of data conversion to the MicroStation system has been created by means of the MODEL SP package, in the standard format. The initial data (resolution, stream type line parameters etc.) have been selected for the needs of presentation of a façade at the scale of 1:50 and details at the scale of 1:20. 15 objects have been distinguished in the data base (as, for example, an outline of a building, skeleton lines, details, advertisements, electric installations etc.); each of them has been recorded in a separate layer. Other attributes have been also assigned to each object (colour, style and thickness of lines). The effect of stereodigitizing is presented in Figure 2. A separate designing file has been created for each façade of an elaborated object; it is considered as a reference file during the process of stereo digitising of neighbouring walls of the building. Thus, as a result of editorial works, it was possible to create a body of an object with characteristic sections.

6.CLOSING REMARKS

Proposed technology of numerical inventory of architectural objects ensures the high accuracy and quality and limitation of field works, as well as it allows to utilize non-metric cameras for the needs of data registration.

Geometric features of particular models are determined in the process of network solution (terra-triangulation). The inventory process itself is performed with the use of the stereoscopic effect, with the use of photogrammetric instruments, which are supported by specialised software packages. Implementation of the stereo digitising process in the spatial model ensured the proper spatial measurement of all elements, independently from the characteristic features of an elaborated object.

Numerical technology allows to change the form of registration of results, simplifies and shortens the process of production of photogrammetric documentation, simplifies archiving procedures, data management and distribution and allows to automatically feed data bases of the systems of computer-assisted designing.

The way of performed inventory allows to create - by means of editorial activities - a wide range of presentation possibilities, what increases the number of customers of photogrammetric documentation.

Utilisation of non-metric cameras, elaboration of own software used for the adjustment and modified software which can be used with modified, precision Stecometers, creates the possibility to promote the elaborated technology in Poland.

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