DIGITAL PHOTOGRAMMETRY AT GRADUATED STUDY IN UACEG

N. P. Draganova [a, *], G. E. Hristova [b], B. D. Marinov [c]

UACEG, Faculty of Geodesy, bul. Hristo Smirnenski 1, 1046 Sofia, Bulgaria
([a] petrova_npd@yahoo.com , [b] gergi@gbg.bg , [c] marinovb_fgs@uacg.bg)

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ABSTRACT:

The education in Digital Photogrammetry is very important for the modern photogrammetry teaching courses. Different approaches, used methods and products are discussed. The main goals of educational process in Digital Photogrammetry are defined. The arbitrary digital systems are mentioned with the examples in the field of terrestrial, aerial and space photogrammetry. The main attention is paid to the systems of middle class. The implementation of main processing stages in Digital Photogrammetric systems for stereo plotting and orthorectification is discussed. The degrees of automation of different steps of measurements are compared in sense of automatic and semi automatic measurements. The special emphasis is made on the possibilities for education and training in the measurements of fiducial marks, tie points and control points. The comparison between monoscopic and stereoscopic methods for measurements is made based on the examples from PCI Geomatics and Leica Digital Video plotter. The application areas and possible technologies are introduced for purposes of urban cadastre and agricultural territories mapping. The two possible technologies for 2D digitising of orthophoto and for 3D stereo plotting are compared.
The integration of functionality of systems for Digital Photogrammetry and Digital Image Processing for Close Range Photogrammetry is demonstrated too. The adopted methodology is applied for archiving of architectural monuments. There are shown the experiments with images of wall paintings in the ancient church of Dragalevci monastery “The Assumption of the Virgin Mary”. The geometric and photometric problems that arise in mosaicking of multiple images, taken from short distance due to the small size of interior spaces, are solved. A two-stage procedure of image rectification is suggested for processing the transformation of such images. The sub-images of mosaic are tied and transformed to vector model before and after mosaicking. This procedure is corresponding to usage of finite elements methods for geometric transformation. Direct application of finite elements method is not possible to be used every time if there are not enough features in the images to create narrow net of points. The equalization of radiometric characteristics of mosaic images is made based on the histogram distribution of their overlapping parts. The suggested technology is suitable for production of adequate photo model for archiving of architectural monuments and virtual reality modelling (VRML).
The experimented technologies for cadastral registration and monuments archiving are implemented in the regular course of study. The implementations of interactive learning methods and user controlled training systems (for the basic photogrammetric operations) are suggested that will ensure future improvement of the quality of educational process.

1. INTRODUCTION

The education in digital photogrammetry is very important for the modern photogrammetry. Digital technologies are widely used now and replace the traditional photogrammetric methods. Digital image processing was initially used for space images but at present days it is used for processing in aerial and close range photogrammetry. Considering these reasons the teaching and training of students in the field of digital photogrammetry is very important. There exist different methods for interactive teaching based on computer technologies. Some of these approaches are appropriate for education in photogrammetry too. The digital photogrammetry is very convenient field because it is based on computer processing of photogrammetric images. The traditional way of teaching is based on presenting the information on theoretical and practical topics of educational subject. The information is presented in written or oral form. The modern presentation is based on slide demonstration by projector or by computer supported presentation. Another way for obtaining of this information is through Internet in the form of E-learning materials. They are arranged as static or more or less dynamic pages.

The universal digital photogrammetric systems can be used for practical demonstrations and training. They can cover fundamental problems of two main photogrammetric technologies, which are implemented in digital form - orthophoto production and 3-D digitising. Almost all digital photogrammetric systems support these two technologies. But the degree of automation and the adaptation of the systems are different.

The preparation of learning kit, which main objective is the creation of an interactive guide that furnishes both operative information and theoretical elements of digital photogrammetric restitution is presented in (Albery, E., A. Lingua, P. Maschio, 2000). The interactive guide is divided into modules, which supply both operative information and theoretic elements to photogrammetric processes. It allows the interactive leaning at three levels of experience.

The development of a modular educational system for digital photogrammetry is described in (Ireneusz, E., B. Roland, etc., 2000).

Depending on their power the systems in digital photogrammetry could be divided in three groups: low level systems, intermediate level systems and high-level systems. The low level systems usually do not have high automation of measurement and support only the monoscopic or anaglyph methods of measurement. The DOS version of Digital Video Plotter (DVP) is a system of such type. The intermediate set of digital photogrammetric systems is most numerous. It includes the systems: VirtuoZo of Supresoft, SISCAM, DVP (Windows) of DVP Geomatics, OrthoEngine of PCI Geomatics, Photomod of Racurce. They are usually universal systems that support othophoto production technology and digitising functionality. They utilise monoscopic or stereoscopic measurements of tie points and control points and the stereoscopic measurements in digitising. Almost all systems allow producing DEM from stereo but the diversity of editing of DEM and reliability of produced DEM is different. The supported function of 3-D digitising includes editing of the discrete data and the flexibility of attribute generated data. The high level systems usually have all possibilities of system of intermediate class but also possess high level of automation of separate processing and in their operation there are included some features of artificial intelligence to improve the accuracy and reliability of obtained results. The ZImaging of ZEISS-Intergraph and Digital Photogrammetric Workstation of Helava belong to this class of systems.

2. STEPS OF PROCESSING

Different steps of processing must be developed to achieve the final photogrammetric product. There are two main technologies that are implemented in the digital form – 3-D digitising and othophoto processing. They correspond to the two main traditional photogrammetric technologies. Both technologies require determination of the elements of the outer orientation of the images (digital photos) in the object coordinate system. A specific step of the processing is the preparation of epipolar images that are more convenient for extraction of Digital Elevation Model from stereo couple and for more accurate 3-D digitising.

2.1 Digital Triangulation

The process of triangulation in digital systems follows traditional steps specific for analytical photogrammetry. Depending on the used model is possible to separate inner orientation and absolute orientation of photos in programs based on the bundle block adjustment, or inner, relative and outer orientations in programs based on the method of models. The measurement of tie points and control points is applied in all cases. **Inner orientation** requires measurement of image coordinates of fiducial marks and appropriate choice of transformation methods. Depending on the type of the camera they are central, angle or reseau. Training for improvement the measurements of fiducials marks based on residuals is important feature of digital system. The applied transformation method allows usage of different number of parameters. The comparison between orthogonal, affine and perspective transformation is advantage but it is not implemented in all systems for digital photogrammetry. In some systems for digital photogrammetry are implemented algorithms for automatic measurement of fiducial marks. They are based on image matching algorithms between images of fiducial marks and their patterns. The measurement of tie points could be done manually or automatically. The automatic measurement of corresponding points for relative orientation is based on the image matching. The training for this process includes proper selection of tie points position and accurate measurement of corresponding points in stereo images. Estimation of the errors in **relative orientation** can be done by residuals in vertical parallax or more precisely by variance-covariance matrix. The measurements of control points are necessary for **outer orientation** of photogrammetric model. The knowledge about convenient choice of their position is important for good quality of the training process. The automatic identification of control points is more difficult. Usually the operator makes the measurements. The control points' residuals are criteria for proper selection and positioning on them. The monoscopic or stereoscopic measurements of tie points and control points are possible. If measured point occurs only in two photos then stereoscopic measurement or automatic matching is preferable. The quality of stereo viewing systems is important for visual stereo measurement. If point has three and more images in different photos monoscopic measurement and simultaneous visualization of all points gives better results. For automatic measurement correlation matching in different direction is preferable. Except in strip overlap the side overlap between strips is possible to be used. The accuracy of measurement can be controlled by recalculation of adjustment after each change of image co-ordinates.

2.2 Epipolar transformation

Generation of epipolar images is very important stage in digital photogrammetry. In analytical photogrammetry measurements are made over the images that are not optically oriented. Only in some models of Analytical plotters are included subsystems for rotation of images by Dove prisms after measurements of firsts two tie points (Kraus, K., 1993). The relative orientation in analytical photogrammetry is applied only in mathematical model. In digital photogrammetry the transformation is applied to the whole images not only to the measured points. These techniques allows to process corresponding points in the parallel image rows of transformed images. This procedure is based on the theory of epipolar geometry. The epipolar transformation is necessary stage not only for DEM extraction and orthophoto transformation, but for 3-D digitising too. The process of stereo visualisation and measurement is easily to be made over the epipolar images rather than in the initial ones. If images are not epipolar transformed then it is necessary to adjust the relative vertical position of two stereo images depending on the position of measured point in the stereo model. Such technique is not implemented in all system for digital photogrammetry but it is obligatory for system producing digital orthophoto by usage of DEM created from stereo couple.

2.3 DEM Creation

Digital elevation models that are used in Digital photogrammetry could be produced from different sources: survey data, vector topographic maps, analogue instruments with digitising equipment, analytical photogrammetric systems or digital processing of stereo photographs. In the most cases a raster terrain model with different resolution is generated. The break lines of the terrain are measured to achieve more adequate terrain model. The utilisation of structural terrain lines is not necessary in cases of very high resolution of raster terrain model. Such models are generated if DEM is produced from stereo photographs. **Extraction of DEM** from stereo images is based on the correlation matching of corresponding points in rows of epipolar transformed images. There are several parameters that can be controlled during this process. The main parameter is step of regular grid over which the model is created. The detail of processed model is another variable parameter. It corresponds to the maximum difference in the heights between two adjacent points in the model. The appropriate selection of this parameter is very important for the stability of generation and the creation of an adequate model. **Model Editing** is very useful feature of the automatic DEM creation procedure. In this process it is possible to arise a fail of correlation function and absence of terrain data for some parts of the model. Another type of error is the generation of wrong values. The raster matrix of correlation values at separate points is used for estimation the reliability of the model. Analysing this matrix it is possible to find areas of missing or wrong values and to edit them. Different algorithms for DEM restoration are possible. Some of them are based on filling with fixed values and another on interpolation from boundaries of wrong areas to the inside points. Training for proper editing of model is important for improvement the quality of the DEM. **Georeferencing (geocoding) of model** is necessary when DEM is produced from stereo images and created model is in a local co-ordinate system. If the georeferencing step is omitted then for every pixel of the transformed image it is necessary to calculate coordinates in the model co-ordinate system that increases the time of processing.

2.4 Orthophoto Production

Orthorectification requires knowledge of external orientation elements of digital photo parameters of projection and height data from DEM. The method of interpolation to calculate output pixel value can be selected. The visual quality and measurement characteristics of transformed image depend on it. The speed of processing depends on the order of interpolation and number of input pixels involved in interpolation process. The practical training for different types of transformation is possible. The mosaicking of images creates a full image from overlapping orthoimages, which are transformed in the same target co-ordinate system. In the process of mosaicking it is possible to select the method for choice of cutting line – operator controlled or manual. Another feature that could be controlled is the method of equalizing of radiometric characteristic of images based on transformation of histograms in the overlapping zone of two images. The results of image merging can be compared depending on different methods of image equalizing.

2.5 3-D digitising

The process of stereo digitising in digital images is very important in process of discrete data capturing. This process can be done in initial images or in the epipolar images. For this process there are important possibilities for creation of different graphic objects – lines, arcs, closed polygons, polygons with rectangular sides. Another group of features are space editing, snap in 3-D space. The flexibility of digitising system depends on the attributes of the graphic objects as layer, colour and width. Training of students must be done for different modes of editing and for different types of primitive objects.

3. TRAINING IN DIGITAL CLOSE RANGE PHOTOGRAMMETRY

The technological process of application the digital photogrammetry for documentation and photo realistic 3-D modelling includes the main steps of photogrammetric processing. The specific procedures are connected with enhancement and radiometric correction of images. These processes are traditional in processing of images in remote sensing data acquisition and processing.
The sequence of processing and applied procedures is described in (Marinov, B.D., Hristova, G.E., 2001). It includes following steps:

1. Photogrammetric shooting and survey measurements.
2. Creation of a grid model.
3. Processing the digital images of separate surfaces (generation of photo-textures).
4. Association of the grid model with the photo-textures.

Depending on the used software products and initial data the stages of grid model generation and assigning of images to the surface to be connected. In case of separate generation of grid model and photo-textures it is possible to use general - purpose software for digital processing of colour images of surfaces.

3.1 Processing of digital images

Digital processing of images includes colour balance and grey level value correction of images. For these purposes was used Photoshop. Visual comparison of adjacent images was made. The curves for transformation are adjusted based on analyses of colour histograms of merged images.

The Intergraph program Advanced Imager was used for merging of images. This is a general purposes image processing software. Functions for image rectification and transformation are used in conjunction with possibilities for transformation of image - to - image and merging of images. Training process includes the appropriate selection of tie points between images and usage the different order of two - dimensional transformation function. Final results of this processing step are mosaics of images, which are corresponding to separate surfaces. The transformation of image of surface is converted to grid model by usage of specific features on the surfaces. In cases of documenting the preserved architectural and historical monuments when signalising of tie and control points is not allowed the natural features are selected. They are chosen in such way that they could be easy distinguished in digital images and in the object. These features are mapped in process of creation of grid model as vector objects.
Rectification of surface photo-textures is made by function for image to map transformation of MGE Advanced Imager (Intergraph, 1995b).

Transformation of photo-textures of curved surfaces requires special procedure. They are suggested different approaches for transformation of images over the curved surfaces. For rectification of images over the cylindrical surface of vault of the church entrance is used two stage procedure (Marinov B.D., 2000). The first step is the rectification of separate images to the unfolded grid model of the arc. The second step is merging of rectified images in one common photo-texture and transformation of the whole image to the grid model. It is fit over the curved surface of grid model by program for space modelling. Experiments with usage of high order 2-D or spline transformation of merged images were not successful. The reason is that it is not possible always to find enough number of suitable located control points for such transformation.

3.2 Creation of vector model

The vector model was created by processing of scanned photographs, which were taken by photogrammetric cameras. For these purposes were used UMK 10/1318 of Zeiss-Jena and stereometric camera SMK 5,5/0808 with 40 cm baselength, which is Zeiss-Jena production. The usage of colour pictures was not very convenient because of small distances for taking the photograps that did not allow capturing whole wall in one photo. By these reason the traditional photogrammetric cameras were used. For mapping of photos was used software product DVP (Digital Video Plotter) of DVP Geomatics Inc. (Leica, 1995). The used version of this product is (working in DOS mode) is developed for processing of separate stereo images. It is convenient for mapping of separate facades of the object. The vector models of facades are produced. The control points, measured with surveying methods, were used to connect models of separate facades. All models of facades were transformed to local coordinate system of grid model.

3.3 Binding Photo-textures with Grid model

Binding of photo-textures with vector model requires assigning of textures to model surfaces and geometrical connection between the photo-textures and corresponding surfaces. Different software products could be used for these purposes. The requirements that these products must satisfy include are possibilities for such binding, easy creation of final model and possibilities for export in format compatible Internet browsers. Possible candidates are AutoCAD Land Development with AutoCAD Overlay, 3D Studio MAX and Micro Station. Highest flexibility shows 3D Studio MAX but this product requires very long period of training and is not very convenient for education in Geodesy. By these reasons in educational process are included initially Micro Station of Bentley and AutoCAD Overlay. The choice of the product depends on the environment in which the vector model is produced and processed. DVP product does not export directly *.dgn format but creates *.dxf file. Micro Station allows importing of *.dxf format and all following processing is made in the environment of Micro Station.

To create adequate model it is necessary to crop the photo-texture by the boundaries of surface. For educational purposes is used Photoshop. The boundaries are overlapped over the raster layer by converting the vector model to raster layer. The results for the west wall of the church "The Assumption of the Virgin Mary" are shown on the Figure 1.

Figure 1. Transformed image of west wall Cut image of west wall

4. TRAINING FOR DIGITAL ORTHOPHOTO PRODUCTION

Digital orthorectification produces the most precise results for orthophoto maps. The main importance for the accuracy of this process is the quality of digital terrain model. The Ortho Engine of PCI Geomatics was used for education purposes in preparation of orthophoto for cadastral purposes (Marinov, B.D., Draganova, N.P., 2003).

4.1 Processing Steps for Aerial Triangulation

The inner orientation with Ortho Engine allows examination the influence of different number of points over the residuals (PCI – Geomatics, 2001). The accurate measurements of fiducial marks decrease the errors of transformation. Disadvantage of inner orientation stage is that it is not possible to select type of transformation and operator could not estimate the difference in errors for different transformations.

At the relative orientation step it is possible to control the error of measurements and in such way to change the weights of the measurements. Simplification of measurement gives the possibility to "auto locate" the next point after measuring the initial three points. Simultaneous measurement of image coordinates in several photographs allows to study the influence between the measurements of corresponding image points in cases not only of stereo couple but in the cases of triple, quadruple or six-fold occurrence of points' images in the overlapping photos. The relative influence of tie points, their disposition and number can be studied by analyses the points residuals listed in the decreasing order. The outer orientation is made for whole block of images and requires measurements of all control points in all images. This causes sometimes instability of iteration process. To overcome this it is possible to include photos one after another and to make the calculation only for photos included in the project. For great pity it is not possible to deactivate defined photo without removing it from the project. The influence of control points' disposition can be demonstrated by the analyses of error in ground control points (GCP).

4.2 Orthophoto Generation

The generation of epipolar images is important stage of processing. This process is executed without definition of any parameters. But its results are important for the following steps of processing. Processing of DEM from stereo requires adequate choice of step of raster grid for DEM. It could not be very small but must not exceed too much the digitising step of rectified image. In opposite case the accuracy of model will not be enough for producing the accurate orthophoto image. The detailed of model defines the small spikes of the height and corresponds to the slope of rise or fall of the terrain. The step of orthophoto generation creates ortophoto of the whole digital image or for this part of it, for which terrain model exists. Main parameter that could be controlled is the type of interpolation function in orthorectification. OrthoEngine allows selection from several standard methods as nearest neighbour, bi-linear, cubic interpolations. More sophisticated methods can be selected too. They are sin(x)/x function for 8 pix and 16 pix windows, so as the methods based on digital filtering which are average, median Gaussian and User defined filters. This versatility allows to make appropriate selection and to make a comparison between processing speed and accuracy of interpolation. The possibility for choice of only part of the image allows the fast test of different methods. Finally the selected most appropriate method of interpolation can be applied to the whole image. The mosaicking step allows selection the method for cutting line selection manual or automatic and mode of radiometric equalizing between two merging images in the overlapping zone.

The advantage of usage the PCI Geomatics system is support of different models for aerial photos, Landsat and SPOTS scanners, radar images that allows creating DEM and orthoimages from different aerial or satellite sources. The processing technique is similar but the used mathematical models are different that affects the number and position of ground control points. This can be subject of the training process.

5. 3-D DIGITIZING

One of the main features of systems for digital photogrammetry is the digitising in 3-D mode. This feature is important for generation of vector data from digital stereo images. In education process in UACEG is used DVP of Leica for creating of Digital vector models of architectural objects, for generation of DEM from digital aerial images. This feature is important for generation of vector data from digital stereo photos. The combination of digital terrain model and vector model of objects is shown in Figure 2, which is part of diploma thesis of Theodora Miteva. Terrain modelling was produced by InRoads of Intergraph (Intergraph, 1995a), which allowed taking into account the break lines of the model.

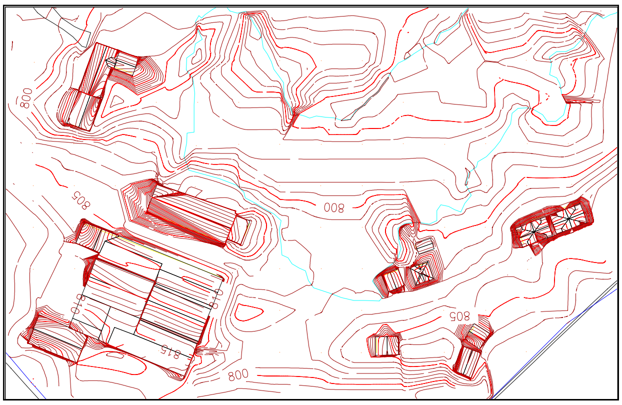

Figure 2. Orthogonal view of the terrain with models of buildings

The digitising features of PCI OrthoEngine are used for collection of data for object boundaries and linear features extraction. The definition of attribute properties for primitive objects is possible. This allows creating topological description in GIS environment. The possibilities of ArcView are used for these purposes. The results of combination between orthophoto and vector map are shown on Figure 3.

6. DISCUSSIONS AND CONCLUSIONS

The usage of systems for Digital photogrammetry allows demonstrating the whole technological process of photogrammetric production on the single or combination of systems. It is useful for learning of new different system based on the same principles. Disadvantage of more common purpose photogrammetric systems is that they are not specially designed for education and not all processes are visible for students. This requires developing the special systems, which are designed for education purposes. Such systems may not to be able to produce fast the final product, but are more adopted for analysing and demonstrating of the special features of processing steps and the most appropriate geometrical conditions and values of source data and parameters. Examples of such systems are LDIP (Höhle, J., 1996) and ARPENTEUR. High interest attracts the systems that are capable for educational purposes and practical tasks. The analytical photogrammetric system ORIENT of TU-Vienna possesses such features. Such versatility can be achieved if modules of system for digital photogrammetry are developed as independent modules for example based on ActiveX modules of Automation model of Microsoft Windows. The calling procedures can be developed to solve separate educational tasks or to create full functionally completed software product, which can be used for solving not only the educational purposes but for solving the practical tasks. In such way could be solved some conflicting requirements between educational and production system.

Figure 3. Map fragment

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