Design of Software Modules for Serving DPWs

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Abstract— **the paper deals with the capabilities of digital photogrammetry including all the possible evaluation processes and products gained from digital images. Nowadays the UAV technology is more and more popular not only in everyday life but also among the professionals dealing with map production or various data source collection methods for GIS. New software applications can offer full automation of the image processing and mainly focusing on DTM and orthophoto production. The paper tries to overview all the system components serving a digital photogrammetric workstation (DPW).**

***Keywords*— digital photogrammetry, orthophoto, DTM, DSM, aerial triangulation**

I. Introduction

Digital photogrammetry means of using digital images on digital photogrammetric workstations (DPWs). The classical photogrammetric evaluation instrument is changed into a computer, which means all the orientation and evaluation process of images is done in mathematical way. This fact offers the possibility of automation of essential tasks of photogrammetry like interior and exterior orientation, digital terrain extraction and orthophoto production. Some tasks remain manual work requiring the engineering planning and supervision. Typically, this task is the compilation of vector-based maps or in more general: vector-based collection of geographic information system (GIS) data. The UAS technology brought a new era simplifying the complicated evaluation processes.

The autocorrelation of common image points is a required module in every application since the number of tie points for aerial triangulation is too much for manual working [3]. On the other hand, the automatic processes hide any steps and the user has no possibility to control all the aspects in an evaluation process. Sometimes this black box effect makes harder to improve the results.

The other important and in the same time interesting topic for discussion is to find the borderline between photogrammetry and GIS. Photogrammetry is defined as a technology for primary data source collection. GIS is serving for analysis of these primary source data and deriving secondary source data using the built models. Some companies don't see sharp border between photogrammetry and GIS, and the software applications merge these two areas resulting very exciting and robust solutions.

In the following chapters we discuss the systems components of a DPW in narrow and in a wider sense.

II. System Components

If we decide to plan the structure of software modules for a DPW, probably we would follow the classical way of photogrammetric software packages. It means we need at least some basic modules like orientation, measurement of DTM points and contours, aerial triangulation, and vector-based mapping. Now, let's follow another way and plan a system by grouping the software modules into categories depending on the functions. On Fig. 1 we see also the hierarchy from top to down as the steps are following each other in the whole process.

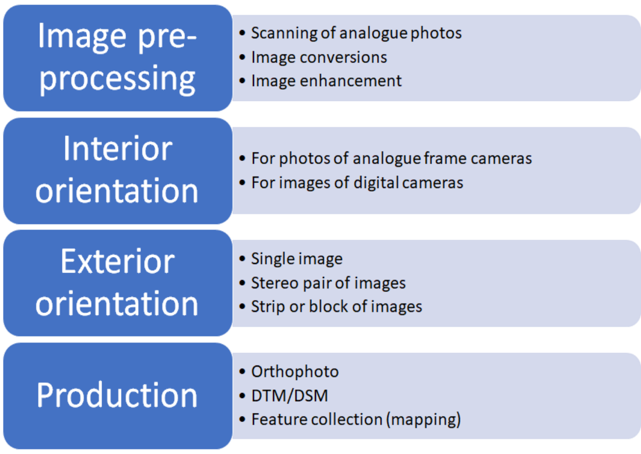

Figure 1. Modules of the evaluation process for a DPW

In the following chapters we discuss these modules in more details.

III. Image Pre-processing

This module is essential since the preparation of images has influence on the quality and accuracy of products at the end of the evaluation process. Here we should consider the following aspects:

- Geometrical resolution
- Image quality

A. *Scanning of analogue photos*

Before we start to process images, we need to prepare them for evaluation. If we must deal with analogue photos, first we must digitize them using an office scanner or a scanner designed especially for photogrammetric tasks. In both cases the scanning software should offer the scanner calibration as an extra tool to determine the systematic errors. These errors are then considered when the final image is prepared after scanning the photos.

The scanner calibration is usually done by scanning a well-defined grid of points. The scanned grid points then measured by an automatic process using an area-based image matching technique (Fig. 2). Comparing the error-free grid coordinates with the measured positions we can calculate an error matrix applying a plane transformation procedure. The transformation itself can be an affine or a second polynomial transformation.

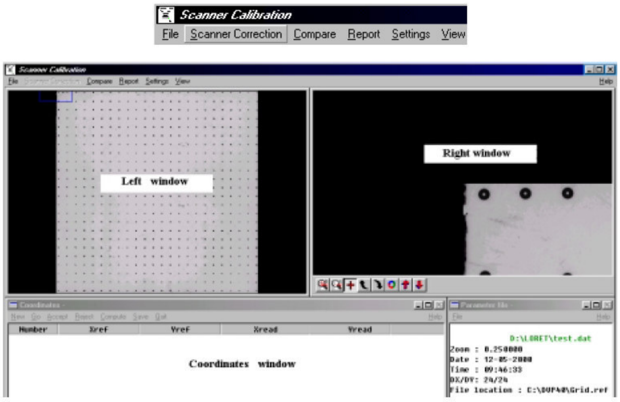

Figure 2. Scanner calibration using DVP workstation

It is important to note that when we decide on the scanning resolution we should consider several aspects like number of channels (grey or colour image), the radiometric resolution (number of bits for storing the grey values of pixels), and the pixel size. For practical reasons the pixel size is usually between 13-21 microns for conventional 23x23 cm aerial images. The experiments showed that pixel size under 13 microns doesn't give remarkable improvement in accuracy, but the image size will grow unnecessarily large as it seen in Table I for grey images.

TABLE I.
SCANNER RESOLUTION AND IMAGE SIZE

Scanning resolution		Image size	Ground resolution for some mapping scales (m)		
DPI	μm	MByte	1:40 000	1:20 000	1:5000
1000	25	81.0	1.0	0.5	0.13
1200	21	116.6	0.8	0.4	0.11
1500	17	182.3	0.7	0.3	0.09
2000	13	324.0	0.5	0.3	0.07
3000	9	729.0	0.4	0.2	0.05

B. *Image conversions*

It is essential to have image conversion module in our system since we need to convert images for different purposes. Usually the following formats are recognized: RAW, BMP, TIFF and JPEG. Here we also build image pyramids for later image matching and for acceleration of viewing images on the PC display. Conversions can be done by lossless compression, and some compressions, like JPEG are lossy.

C. *Image enhancement*

All the image enhancement techniques are necessary to enhance some properties of images. The content information is not increased just some aspects of the image are enhanced for specific goals [1], these goals can be grouped as it seen on Fig. 3. These functions are all important and useful for DPWs at visual interpretation, manual and automatic measurement of image points. Among the geometrical operations the georeferencing operation can be regarded as a separate evaluation method as well, since it produces a georeferenced image which can be used directly for mapping purposes with some limitations. especially it is a useful function for satellite images.

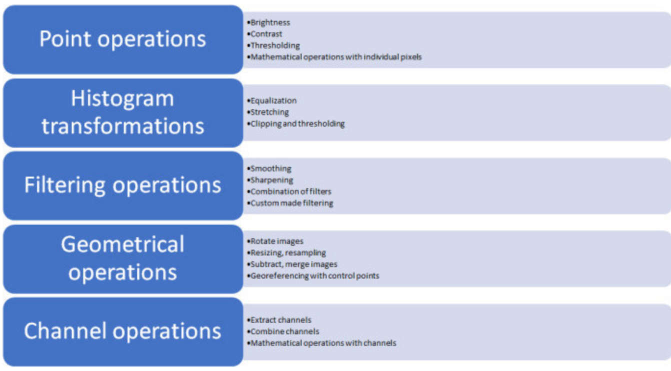

Figure 3. Image enhancement modules

IV. INTERIOR ORIENTATION

A. *Interior orientation of analogue photos*

After scanning of analogue photos, we must carry out the interior orientation which means we need to indicate the camera constant, the principal point coordinates, and we need to setup a photo coordinate system using the fiducial marks. The measurement of fiducial marks can be done manually or automatically using some area-based image matching algorithm.

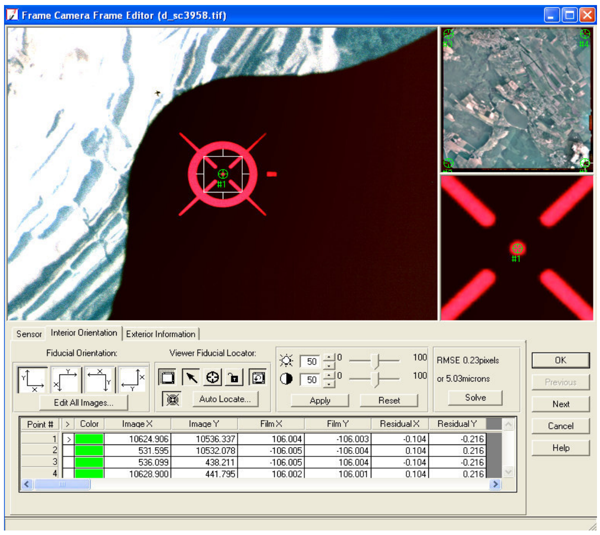

Figure 4. Measurement of fiducial marks in a Leica LPS system

After the measurement of fiducial marks usually a plane affine transformation is carried out, but the software should offer other transformations like plane similarity or second order polynomial transformation. transformation (Fig. 4). The interior orientation can be extended by indicating the lens distortion parameters or values.

B. *Interior orientation of digital images*

The interior orientation of digital images is a very simple process since here we just indicate the interior elements of the camera and the sensor data. The sensor is characterized by pixels size, width, length of the sensor. The lens distortion parameters are also indicated here. A sample screen is shown on Fig. 5.

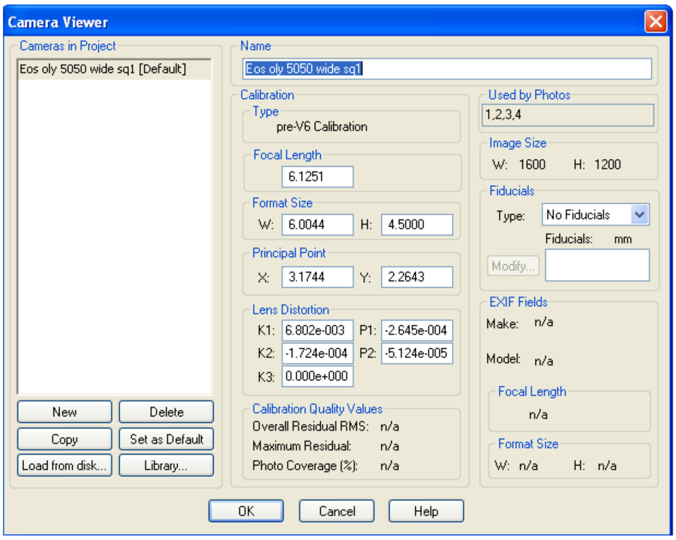

Figure 5. Interior orientation data for digital image sensors

Most of the sensor date can be read from the EXIF data, but these data can be inaccurate, therefore a camera calibration gives better parameters for a digital camera. The camera calibration is done usually during the exterior orientation by so called self-calibration procedure. It means that first we ca assign approximate interior data to the camera and later, during the exterior orientation these data are adjusted.

V. EXTERIOR ORIENTATION

A. *Space resection for a single image*

If we have only one image, then the exterior orientation becomes a space resection task. For this we need at least four control points to be measured in image. After that the software makes the calculation by least square adjustment solving the collinearity equations. Using only one image we can produce later an ortho-photo, or we can collect features for mapping by digital monoplotting. In both cases we need DTM or DSM for interpolation of heights, otherwise we can measure and calculate planar coordinates only. A sample screen is shown on Fig. 5 from AeroSys software.

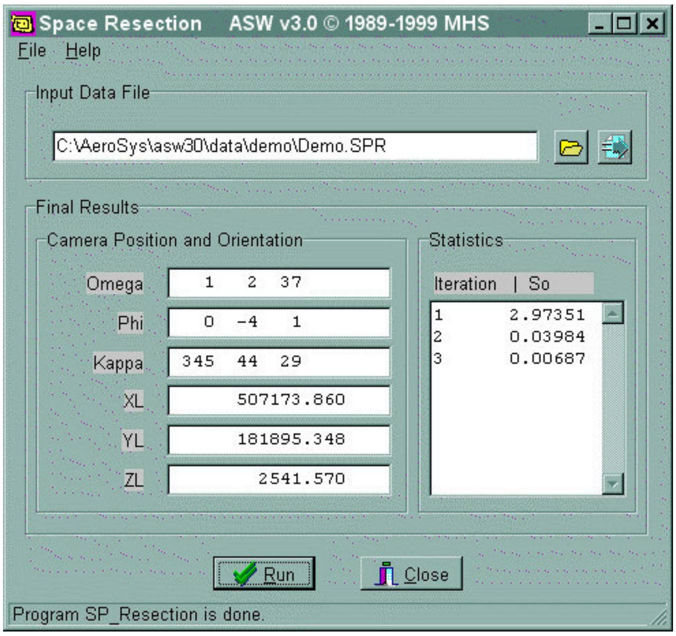

Figure 6. Results of space resection in AeroSys software

It's important to note that the measurement of control points can be automatized if we used well visible signalized terrain points. In this case the software should be capable to recognize these signs automatically. Especially it is a useful task if we need to measure large amount of control points, for example in camera calibration projects. The second remark is that if we have enough control points then the software should offer the calculation of lens distortion parameters as well, since the collinearity equations can be extended by these additional parameters.

B. *Exterior orientation for a stereo-pair*

The exterior orientation of a stereo-pair of images can be done in two ways. The first option is to measure first at least six tie points and build a model with relative orientation. After this the control points are measured manually or automatically. The automatic measurement of tie points is well known procedure. Here the software can offer not only the are-based matching techniques, but an object based, or a semi-global matching technique is also an option. The control points can be measured only if they are unified and signalized points.

The second option for exterior orientation is to use the bundle adjustment of all measured points regardless of their types, which means, the measurement of tie points and control points are put together to form a system of collinearity equations. In principal the bundle adjustment is more flexible and, in most cases, gives more accurate result thanks to additional parameters considering the camera and lens parameters. The bundle adjustment is also capable to carry out a camera calibration project. On the other hand, the relative orientation is useful for building a model without knowing the control point positions. The stereo model is then used for stereo measurement of additional points including the control points. If the measurement is completely automatized or we discard the stereo measurement of points, then the bundle adjustment is preferred. A sample screen is shown on Fig. 7.

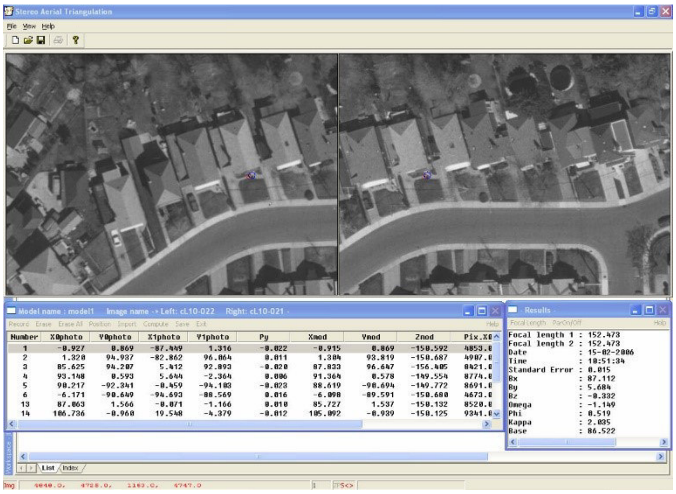

Figure 7. Relative orientation in DVP system

C. *Exterior orientation for a block of images*

The exterior orientation of a block of images is like the orientation of a stereo-pair, but here we must deal with multiple overlaps between the images and strips of images. Typically, this task can be more complicated for UAS images since there the strips of images are not always so regular. The whole procedure is called aerial triangulation. In many cases the measurement of tie points is the first step in order to build models and strips. after this the measurement of control points can be half automatic if we know the exterior orientation elements from GPS/IMU recordings. The half-automation means, the software tries to predict and locate the control points based on the approximate exterior orientation elements and the user should adjust it with manual measurement. Of course, if the points have well known signalized mark on the ground, then the measurement can be fully automatic, but this option is not offered by all systems. On Fig 8 we can see a sample screen from the Trimble UASMaster, which is specially designed for processing of UAS images.

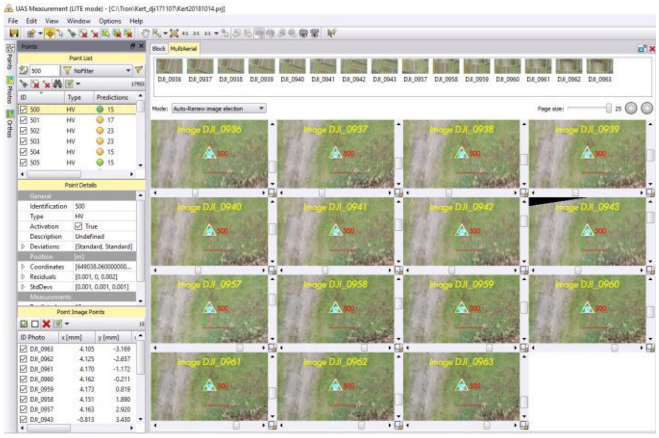

Figure 8. Measurement of control point in Trimble UASMaster

VI. PRODUCTION

A. *DTM/DSM extraction*

The production of DTM or DSM points is essential for producing orthophotos. The extraction of DTM/DSM points should be done by autocorrelating techniques, and the result is usually edited by manual measurement and corrections including the filtering, smoothing and object-based grouping of points. This module should be the most interactive and sophisticated part of the whole software package since here the resulting DTM/DSM effects the accuracy and quality of the orthophoto and other terrain-based derived products. The DTM/DSM file formats should include well-known formats including the LAS format. From the resulting point cloud, the software should be capable to derive secondary products like contour map, slope map, section lines and so on. The DTM/DSM points can serve area and volume calculations as well. On Fig. 9 we see a resulting DTM generated by PHOTOMOD software.

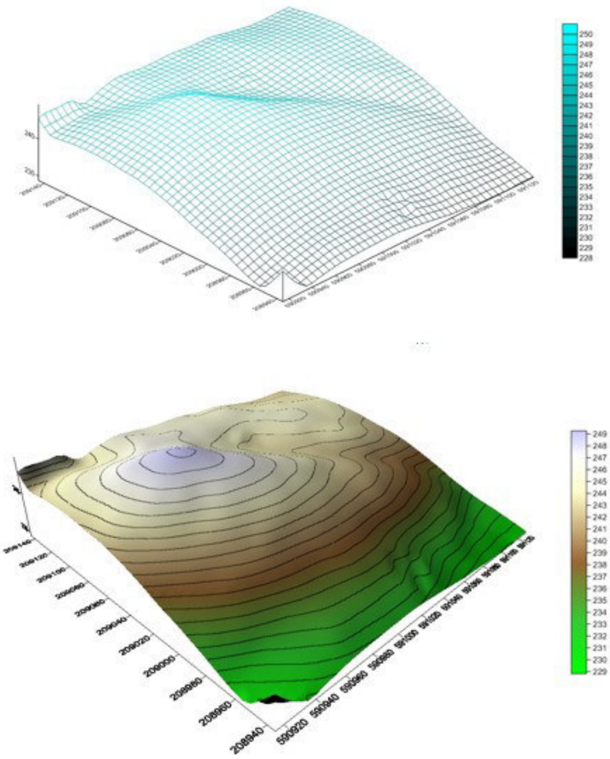

Figure 9. DTM generated by PHOTOMOD software

It's important to note that this process needs a lot of PC memory and multi-core processor. The software should recognize the characteristics of the PC and utilize all the possible sources for calculations including the graphic card processor as well. The multi-threaded and parallel processing can accelerate the calculation dramatically. Today the photogrammetric DTM generation can compete with the LAS technology in many aspects.

B. Orthophoto production

The software should support all the steps of orthophoto production. These steps are

- Orthophoto production separately for every image in the block
- Orthophoto mosaic by seamlines including the photo colour adjust and equalization
- Orthophoto map production

The process can be fully automatic if we don't insist on the manual drawing of seamlines. The well-known resampling methods (nearest neighbour, bilinear interpolation, third order convolution) should be applied for all pixels, although the software should be flexible to setup the resolution, the working area and the projection system of the produced orthophoto. If the DSM is known than we ca produce a true orthophoto. If only the DTM is known than a classical orthophoto is produces. Most simple case when we know only an average height on the terrain. in this case the accuracy of the produced orthophoto can be very low.

The resulting orthophoto can be used direct mapping of planar points (X,Y coordinates), or linking the orthophoto with the applied DTM or DSM, we can measure X,Y,Z coordinates and collect features for mapping in 3D. Although the digital monoplotting is very attractive way for evaluation of spatial points, we should admit that the measurement accuracy is directly depends on the used DTM or DSM. Therefore, in practice we use this evaluation method only in those cases where the high accuracy is not so essential. On Fig. 10 we see an orthophoto mosaic produced by UASMaster:

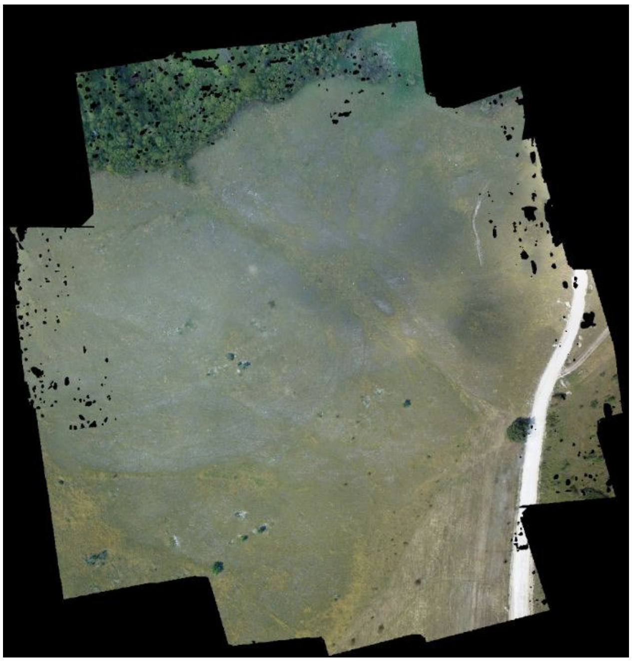

Figure 10. Orthophoto produced in UASMaster

C. Feature collection

For feature collection the DPW should offer at least the following functions in 2D or in 3D supporting the stereo-viewing and evaluation:

- Collection of points.
- Vector-based mapping including the support of features symbology with mapping legends.
- Interface for well-known mapping applications like AutoCAD, ArcGIS, and MicroStation.
- Import/export functions.

The feature collection is a very exciting area regarding the automation especially in city modelling. This a very intensive research area. Therefore, the DPW package should support new challenges like BIM (Building Information management) modelling as well [2]. On Fig. 11 we can see a 3D model produced by automatic photogrammetric feature collection.

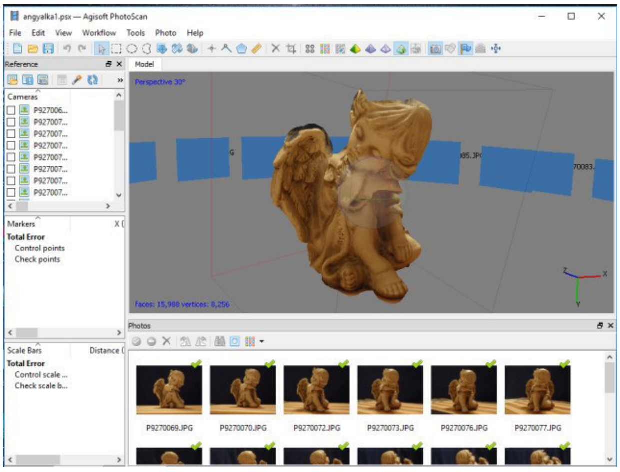

Figure 11. 3D model produced by Agisoft Photoscan

VII. Conclusions

As a summary we can say that a good DPW software supports the automation in all steps. A wide selection of import/export functions is a very important aspect and it enhances the portability. The UAS software market is developing very fast and hopefully it brings new, more sophisticated solution to the traditional aerial photogrammetry as well.

References

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