

A COMPARISON ANALYSIS OF DIFFERENT PHOTOGRAMMETRIC SOFTCOPIES FOR GEODATA PRODUCTION

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Abstract. Up-to-date mapping technologies for geodata production are widely applicable in Remote Sensing and Photogrammetry Communities. Therefore the education in Remote Sensing and photogrammetric methods becomes very important using different image processing software for the terrain mapping purposes, spatial data modeling, etc. The usage of new methods, technologies and professional widely known systems is the desire to increase mapping capability. Despite that, digital didactics photogrammetric systems might be used (particularly in education process) simultaneously, thus getting more efficiency results. The objective of research is to analyze some aspects of usage of digital photogrammetric softcopies, applied for terrain mapping: professional *IMAGE ERDAS* with *LPS*, *LISA* and Didactics Digital Photogrammetric Systems (*DDPS*). The experimental investigations lead to contiguity of this different software in consideration of the following criteria: accuracy, flexibility and time. The digital terrain models and orthophoto maps, created using two technologies, are almost the same due to time-consuming when performing separate image processing steps. However, full workflow on *DDPS* involves about 2.5 times less than it was performed on *LPS*. The photogrammetric measurements results demonstrate that there are some differences in accuracy due to stereoscopic measurements. When processing the images, defined value of accuracy estimators meets the requirements for topographic mapping; however *DEM* needs for separate study.

Keywords: photogrammetry, image processing, different software, orthophoto, accuracy evaluation.

Introduction

Modern digital image processing technologies have potential to improve the photogrammetric production at cost-performance relation. The digital production of three dimensional (3D) surface models and orthophotos currently turns to broadest usage. Such production is realized by Digital Photogrammetric Workstations (DPW) (Manual 2004, Kraus 2000, Ruzgienė 2008).

In digital photogrammetry some photogrammetric operations are performed by monocular mode, however the system of stereoscopic view is one of main parts of DPWs. Sophisticated computer hardware simplifies photogrammetric measurement processes, e.g., flat monitor as is *SD2620W*, *WUXGA* provides a high resolution 3D images and stereoscopic image can observe by multiple users. A variety of digital photogrammetric software is designed, however systems differs in functionality, features complexity and cost. The most common of the Digital Photogrammetric Workstations are: *SOCET SET*, *BAE Systems* (USA); *Softplotter*, *Autometric* (USA); *ImageStation*, *Z/I Imaging* (Germany/USA) (*Z/I Imaging* 2014); *Cardinal Systems*, *Vrtwo* (Cardinal

systems 2014); *Geomatica PSI* (Canada); *Delta*, *Geosystems* (Ukraine); *PHODIS*, *Zeiss* (Germany); *PHOTOMOD*, *Racurs*, Moscow (Russia) and others. The short overview of some other photogrammetric systems (Digital 2014): *AU4*, *Cartodata's* is designed for large scale mapping purposes; using *Summit Evolution*, *DATUM* objects of 3D can be extracted from photographs, is possible direct introduction geodata to GIS systems, software processes various types of photographic images and data (aerial photographs, high resolution satellite and radar images, point cloud from Aerial Laser Scanning, automatically generates orthophotos; *Leica Photogrammetry Suite (LPS)* from *ERDAS*, *Leica Geosystems Geospatial Imaging* is well known software for Remote Sensing image processing (Butowtt 2010).

In Lithuania the photogrammetric workstation *PHOTOMOD* is used in some production and education institutions. The main features of this software are: an interactive stereoscopic model creation, aerial triangulation, a digital terrain model and ortho images generation, images mosaicking, integration of several projects, etc. (*Racurs* 2014).

Implementing digital photogrammetric technologies for getting highest productivity, the comparison analysis of softcopies, applied in such processes as images orientation, aerial triangulation, digital terrain model and orthophotos generation, is actual (Nurminen 2013, Luhmann et al. 2006, Ruzgienė 2010). The investigations in such criteria as systems flexibility, production time, accuracy and costs consideration should be significant. The decision how mapping systems could be used lead to more flexible map production, reduce costs and time considering project deadline requirements and increasing demand for digital data and for topographic maps from imagery, as well as usage in educational processes.

The objectives of research is to analyze the main aspects of functionality from digital professional and didactics photogrammetric mapping software in generating 3D photogrammetric production, to investigate the two systems through experiments and to evaluate the accuracy of obtained geodata.

1. Methodology

The availability of different photogrammetric software has made photogrammetric operations a common procedure. The goals of digital photogrammetry are: to establish the relationship between image space and object space using photographs, to describe mathematical calculation of points coordinates based on camera calibration parameters, to measure images coordinates and ground control points (Wolf 2000). When stereo model is created, the relation between image and control points coordinates is established automatically and collection of 3D data is possible.

Digital photogrammetric systems have potential for processing image data from different sources (Kraus 2007, Ruzgienė et al. 2011); scanned aerial photographs can be used as well. The professional photogrammetric scanners are very sensitive instruments; however some errors may appear due to proper calibration, environmental, maintenance conditions and image processing software. The high scan resolution as 14 μm is required for better interpretability and higher accuracy.

The orthophotography production is an automated process because of that there is some cost variation in any country. The orthophotographic mapping when aerial photography is taken with analogue aerial camera is based on costs per image scanning — €10; aerial triangulation — €20; generation of digital elevation model — €90; orthophoto generation — €25 (Konecny 2003).

The usage of the different digital systems that complement each other is appropriate solution in getting complete knowledge for imagery processing and orthophoto generation as well. The education in photogrammetric images processing becomes increasingly important because of widely demand for applicability in Photogrammetry Communities. The training is based on usage of different software for processing of digital images. Digital image processing systems depends to set of high-level systems. Educational software is high desirable because of getting results in low time consuming and easy to use.

One of the main tasks in imagery processing is feature extraction, digitizing in spatial mode and getting vector data from stereo images. Only majority of educational systems has ability for stereo measurements. One of example in education process of that subject can be used Geo-Software *LISA* (Digital Photogrammetric Work Station) developed at University of Hanover (Germany). The advantage of usage the *LISA* is that it allows the control in orthorectification selecting several standard methods of interpolations as well as digital data filtering can be applied. This software's flexibility allows making decision on appropriate selection, to compare image processing time duration and accuracy of interpolation, to test chosen methods (Linder 2009).

For analysis in images processing is realized on the base of two aspects: use educational Digital Didactic Photogrammetric Station (*DDPS*) and professional photogrammetric software *Leica Photogrammetry Suite (LPS)* *ERDAS IMAGINE*.

The software *DDPS* was developed within the framework of a cooperative project between the Surfaces Laboratory, Department of Geomatics, University of Liege (supervising by Prof. J.P. Donnay), Belgium and the Institute of Geodesy and Cartography (IGiK), Department of Photogrammetry (supervising by Prof. R. Kaczynski), Poland. *DDPS* is complete and integrated photogrammetric package with user-friendly interface and easy for usage (Donnay 2005). A complete photogrammetric images processing is possible with Digital Didactics Photogrammetric Software with realized workflow showed in Fig. 1.

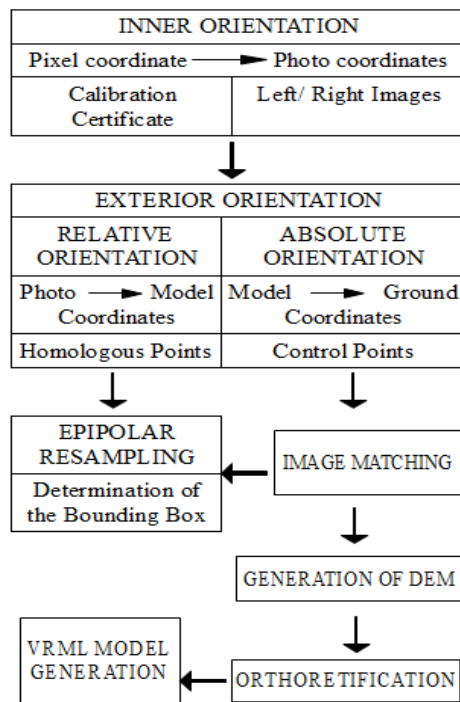


Fig. 1. General workflows on DDPS

For generation of Earth surface model from imagery is used very popular and professional software *ERDAS IMAGINE* suite of Leica Geosystems (Erdas 2014). It is as the world's leading geographic imaging software for the remote sensing and GIS needs. *ERDAS IMAGINE* offers a comprehensive solution that features extensive image processing capabilities: wide range of image classification tools, advanced and simple georeferencing, automated map production, transformation imagery into accurate GIS data, three-dimensional visualization, etc. The *Leica Photogrammetry Suite (LPS) ERDAS* is an images processing and workflow-driven system, which consists of numerous photogrammetric production tools. Using the *LPS*, can be performed: measurements of GCPs and tie points on multiple images, quality control; use photography or satellite imagery from various camera and satellite sensor types, triangulate multiple images automatically, orthorectify multiple images, etc. The general workflow on *LPS* involves: coordinate system selection, definition of camera calibration parameters, choosing of image data, interior and exterior orientation, aerial triangulation, DEM creation, orthophoto generation (Fig. 2).

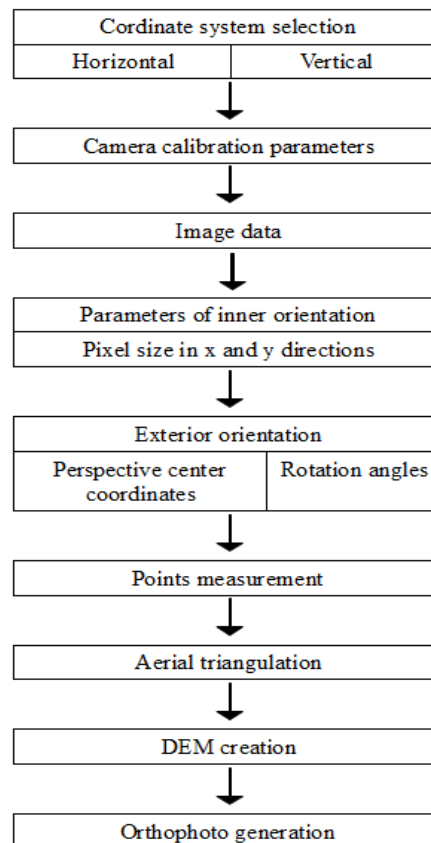


Fig. 2. General workflows on LPS

2. Experiments and comparison analysis of different softcopies

The goal of experiments was to investigate the workflow on a digital photogrammetric systems for production of geodata – professional and didactic; to compare images processing results; to analyze and evaluate different softcopies regarding to flexibility, time consuming and accuracy consideration.

As an input data the analogical images at a scale of 1:6000 with 62 % forward and 33 % sideward overlap covering the northern-eastern part of Vilnius were used for experimental measurements. The flight height was about 1000 m, the images have been taken by calibrated aerial camera *RMK TOP*, camera's focal length is 153.6 mm. The diapositives were scanned with pixel size 14 μm by photogrammetric scanner *Vexell Ultra Scan*. Digital photogrammetric images are size of 16862x16861 pixels.

The control point's network was created using photogrammetric technique – aerial triangulation and based on GPS measurements.

The image point's position accuracy depends on the camera sensor characteristics, the flight height, positioning by the GPS system, and some other factors.

The ground reference points were signalized on the territory before aerial photography and their coordinates were determined by the GPS. Coordinates are transformed to Lithuanian coordinate system LKS-94, and heights to Baltic height system. The accuracy is about 2-3 cm.

During the flight, camera positioning by the kinematic GPS has a RMS ± 5 -10 cm and IMU – $\pm 0,005$ -0,01 gon, when flight height is 1000 m such drift causes shift of around 10-15 cm on the ground.

Applying the aerial triangulation method, the dense ground control point network was created. The model of mathematics block network adjustment has been based on collinearity equations. Equations of aircraft GPS antenna coordinate corrections are involved into process of adjustment. The accuracy of photogrammetric block adjustment – the estimator of the variance (σ_0) was reached up to 8.28 μ m in image.

An aerial image at a scale of 1:6000 provides a positional restitution of about 20 cm, and images scanned at 14 μ m are suitable for generation of 8 cm ground pixel orthophotos. Therefore, the input data for image processing should satisfy the requirements of reference geodata base creation at a scale of 1:1000-1:2000.

The images processing was done on professional digital photogrammetric software *Leica Photogrammetry Suite (LPS)*, *ERDAS IMAGINE*; *LISA* Geo-Software and Digital Didactic Photogrammetric Station (*DDPS*).

The accuracy results of interior and relative orientation by *DDPS*, *LISA* and *LPS* respectively are: maximal residual for the plane affine transformation – 0,007 mm; 0,012 mm; 0,010 mm.

Exterior (absolute) orientation of photographic images was based on 11 reference points which rectangular coordinates were defined by aerial triangulation approach. The results of image absolute orientation using different software are shown in Fig. 3.

The accuracy of images orientation obtained by different software (*DDPS*, *LISA* and *LPS*) is similar. The exterior orientation using *DDPS* and *LPS* softcopies was performed with accuracy up to 15 cm.

a)

2226	10.635	-61.898	0.233	0.033	M
3227	0.195	-57.681	-0.027	-0.164	M
3230	-90.653	-97.065	-0.104	0.213	M
3307	4.800	3.242	0.241	0.055	M
3308	-91.401	-17.426	-0.065	0.163	M

(De)activate
Skip
X Y

Standard deviation [mm] 0.123 0.120

b)

Validation Results

Ground Points | Image Points

Row #	Point ID	Type	Usage	Active	X	Y	Z	Rx	Ry	Rz
1	3230	Full	Control	X	584396.215	606709.054	108.454	0.005	-0.085	-0.002
2	3234	Full	Control	X	584866.261	606709.785	112.230	0.064	0.137	-0.088
3	3308	Full	Control	X	584404.904	606593.939	96.872	0.068	-0.042	0.100
4	3309	Full	Control	X	584898.771	6066433.408	111.608	-0.016	-0.027	-0.024
5	3356	Full	Control	X	584370.010	6065901.399	101.526	-0.012	-0.002	0.104
6	3357	Full	Control	X	584409.800	6066011.230	98.303	-0.032	-0.087	-0.195
7	3358	Full	Control	X	584811.703	6066198.211	108.371	0.039	-0.025	0.030
8	3359	Full	Control	X	584748.202	6065903.105	105.047	0.002	0.068	-0.007
9	3360	Full	Control	X	585007.894	6065948.424	116.875	-0.018	0.036	0.078
10	3361	Full	Control	X	584876.423	6066064.805	108.807	-0.016	0.065	-0.069

c)

	xl	yr	yr	X.grd	Y.grd	Z.grd	dx	dy	dz
3883.2500...	1203.2500...	7625.5000...	1534.0000...	58466.197...	6067109.64...	112.298000...	0.0037463252	0.0658188453	-0.1292626...
3308	8573.0000...	7088.0000...	2374.0000...	7326.7500...	584404.836...	6066592.98...	96.772000...	-0.0840945...	-0.1149112...
3309	14242.2500...	8935.0000...	7940.5000...	9168.0000...	584898.787...	6066433.43...	111.632000...	0.0125320446	-0.0413471...
3356	8125.7500...	14993.2500...	1753.2500...	15326.2500...	584370.022...	6065901.40...	101.422000...	0.0478018500	0.1397349602
3357	8590.2500...	13714.5000...	2267.2500...	14013.2500...	584409.892...	6066011.31...	98.458000...	-0.0166781...	-0.0465709744
3358	13221.0000...	11631.5000...	6915.2500...	11884.5000...	584811.664...	6066198.23...	108.341000...	-0.0183265...	-0.0726184...
3359	12468.5000...	15016.2500...	6147.0000...	15340.0000...	584748.200...	6065903.03...	105.054000...	0.0161421089	0.0551340785
3360	15533.5000...	14578.7500...	9181.7500...	14885.2500...	585007.892...	6065948.38...	116.797000...	0.0087368955	-0.0860812...
3361	13964.0000...	13179.2500...	7652.0000...	13453.7500...	584876.439...	6066064.74...	108.876000...	0.0400624704	-0.0037984...

Fig. 3. Fragment of results from exterior orientation of left image on different software: a) *LISA* – the maximum residual error is 0,24 m, b) *LPS* – 0,15 m; c) *DDPS* – 0,14 m

The experimental area is not very roughed and not very dense of high buildings, therefore images matching by *DDPS* and *LPS* software results shows not too large number of wrong point position and needs for manual corrections only about 5%. Figure 4 shows the generated orthophoto using software *DDPS* and *LPS*.

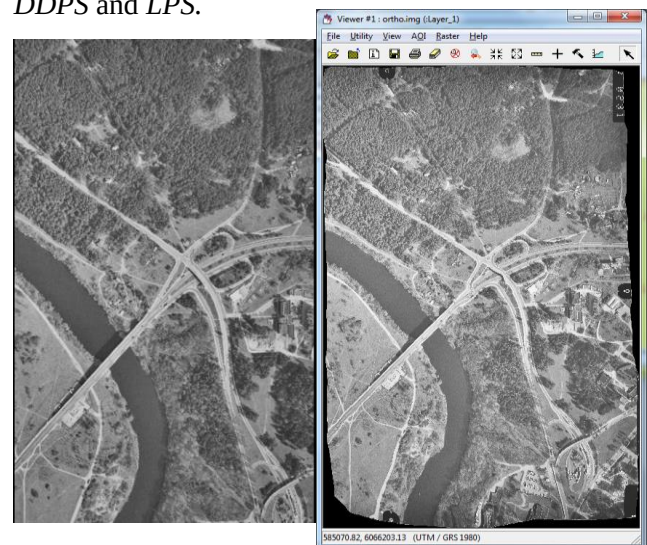


Fig. 4. Generated orthophotos in *DDPS* (left) and *LPS* (right) applications

The mapping processes by *LPS* *ERDAS* require high skilled employer, well knowledge in software

operations, photogrammetry, image processing, etc. Both digital systems are flexible because of high automation of most procedures. The operator's work is easier on *DDPS* system. Feature interpretation capabilities are not maximum effective, because the stereo viewing was not possible.

Time consideration. The inner orientation on the *DDPS* requires more time than on the *LPS*. The labor time for creation of digital terrain model depends of terrain types: flat or hilly, area covered by vegetation (for example, forests), urban or unbuilt territory. The DEM generation of complicated area in digital systems offers the large number of wrong measurements and needs for extensive interactive corrections. In test area terrain is an average open and not too much roughed. Therefore, automatic DEM have been processed successfully — only 2 % blunders were detected. The time consuming getting cartographic products on *DDPS* was about 2.5 times less than it was performed on *LPS*.

Accuracy consideration. The goal was to investigate point accuracy from processed image data by selected different software over the test area. For the evaluation of the image data geometric accuracy a comparison with results from stereoscopic measurements using *LISA* software has been carried out. Applying the stereo measurements approach a number of image points (65 points) were coordinated. Figure 5 shows the fragment of selected for investigation points in *LPS* application.



Fig. 5. Fragment of points selected for coordinates checking

The search of image points for control was carried out at a variable distances, e.g. from 1.0 up to 20 m. The distribution of height deviations regarding to stereoscopic measurements is presented in Table 1.

Table 1. Distribution of point's numbers regarding to defined height deviations

Technology / number of points (total 65)	Deviations number at intervals, m					
	0	0.1-0.6		0.6-1.1		1.1-1.5
		+	-	+	-	
<i>DDPS</i>	-	40	1	0	8	16
<i>LPS</i>	-	18	9	2	9	27

The accuracy of the image height points was investigated comparing image data processing results with stereoscopic measurements. Root Mean Square (RMS) and Standard deviation StD (σ_z) has been calculated using formulae (1), so reducing influence of systematic errors influence (Žalnierukas at al 2009).

$$\sigma_z = \sqrt{\frac{1}{n}(\sum \Delta^2 Z - n \bar{\Delta}^2 Z)}, \quad (\text{RMS})^2 = \sigma_z^2 + \bar{\Delta}^2 Z, \quad (1)$$

where $\Delta Z = Z_{\text{img}} - Z_{\text{stereo}}$, $\bar{\Delta} Z$ – mean of deviations, n – number of checked points.

The differences of ground points coordinates defined by both digital photogrammetric systems have been calculated and the accuracy estimators were determined. Results of aerial image processing image point's coordinate's accuracy investigation considering to stereoscopic measurements by *LISA* software are presented in Table 2.

Table 2. Results of point coordinates accuracy investigation compared with stereoscopic measurements

Measurement technologies	Checked points number	Accuracy assessments, m				
		Min. deviation	Max. deviation	Mean absolute deviation	Estimator, RMS	Estimator, StD (σ)
Accuracy of planimetric coordinates (x, y)						
DDPS	65	0.28	0.85	0.59	0.66	0.29
LPS		0.27	0.92	0.63	0.65	0.18
Accuracy of point heights						
DDPS	65	0.30	1.40	0.26	0.79	0.63
LPS		0.41	1.46	0.51	0.93	0.78

Results from the accuracy analysis shows that the accuracy of geodata collected from two systems are approximately at the same level (planimetric positional *RMSE* — 0.66 m, heights — 0.86 m). However, there was defined, that point's heights was determined with a lower accuracy, when collected on *LPS*. Performing many trials, with accurate identification of selected images points, the accuracy investigation results remains the same as shown in Table 2. Therefore, there is realized, that it is significant values of accuracy estimators regarding to very accurate stereoscopic measurements.

Conclusions

The digital technologies without any doubt have possibility to generate new accurate mapping products with low time consuming. However, choosing digital photogrammetric mapping technologies (production or educational) it is very useful to consider user's needs.

The investigation has shown functionality of two photogrammetric softcopies (*DDPS* and *LPS ERDAS*) and their application possibilities. Feature extraction from images by manual mode on the *DDPS* is not very desirable, because meets some inconveniences in managing images, there is not possible to process images from digital camera as well. So, the algorithm used in *DDPS* software should be supplemented. The digital photogrammetric image processing is fully reliable and functional with a lot of possibilities, when use professional softcopy as *LPS ERDAS*.

Stereoscopic measurements approach was used as the more relevant technique due to investigations of photogrammetric measurements accuracy. Accuracy assessments, when points coordinates have been determined using different softcopies, shows that results match to the accuracy requirements for getting mapping product, however more attention should be paid generating elevation

model. The result of accuracy investigation shows fulfillments the requirements for topographic mapping at scales of 1:5000 – 1: 10000.

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