Utilization of digital photogrammetry in forestry mapping

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ABSTRACT: At present, photogrammetric interpretation of aerial images is a dominant method of forestry mapping. In the last years, transition from analogue to digital photogrammetry has been distinct. Digital photogrammetry enables to achieve workflow effectivity, and so to decrease the final product costs. The objective of the submitted paper was to evaluate the availability of digital photogrammetry for the forestry mapping rationalization. Digital aerotriangulation using the ImageStation SSK system brings more accurate results without requirements for the use of a larger amount of control points. The results also demonstrated the use of colour infrared aerial images, and also black and white aerial images at the scale 1:15,000 for the orthoimage creation in the forestry mapping department. Compared with the black and white aerial images, the colour infrared images have an essentially more interesting content, mainly from the qualitative aspect, which shifts them to use in many forestry disciplines (mostly for determination of the health conditions of forests stands, ...), in combination with the remote sensing of the Earth and GIS (Geographic Information Systems).

Keywords: digital photogrammetry; forestry mapping; aerotriangulation

An important part of forest management is the knowledge of natural and production relationships, growth regularities and relations in the development of forest ecosystems. The application of this knowledge obtained from various forestry disciplines is closely connected with spatial localization. Forest management, management controlling and forestry evidence, almost all their partial tasks are assigned to the forest spatial organization units. Forestry mapping ensures their exact allocation in forest areas. Its objective is to obtain reliable planar and elevation data for the creation of forest maps and projects for various purposes such as position identification and for the survey of the forest spatial organization units and for the evidence of parcels.

Forestry mapping in Slovakia is carried out on an area of more than 2 million hectares, which represents approximately 41% of area of the Slovakia. At present this mapping is fully provided by the employees of National Forest Centre (NLC) in Zvolen. According to Forest Act No. 326/2005 they are authorized to create forestry maps of this area.

A larger part of forestry mapping is done in the spatial forest management. In accordance with § 39 of Forest Act No. 326/2005, the forestry spatial organization units are: forest management units, parts of forest land according to their use, forest stands, partial areas and forest stand groups.

A new unit in the spatial organization of forests has been established – the part of forest organized according to its use. The plan of forest management is made for these units (Žíhlavník A. 2005).

The boundaries of this unit in the case of forest parcels in private and common property are at the same time the owner's boundaries that have to achieve the accuracy for cadastral mapping. That is why the accuracy must be better for the mapping works and identification of the forest parcel boundaries of its original owners. This could be done only by synchronizing the rules for forestry mapping with cadastral mapping and suitable rationalization, especially the photogrammetric interpretation of the remote sensing materials (Bartoš, Gregor 1995), transition to digital photogrammetry (Bartoš 1998; Hricko 2000) and using of the photo interpretation (Hildebrandt 1996; Albertz 2001).

In the last years, forestry mapping has undergone significant changes. The establishing of digital pho-

Supported by the Scientific Grant Agency VEGA of the Ministry of Education of Slovak Republic and Slovak Academy of Sciences, Project No. 1/3525/06.

togrammetry as a method for the digital aerial image interpretation and a wide range of Global Position System methods (GPS) for terrestrial measurements enhanced forestry mapping to a qualitatively higher level. New knowledge from the remote sensing of the Earth and Geographic Information Systems (GIS) also enable higher rationalization of mapping work in forestry.

Digital photogrammetry represents a computer-supported technology of photogrammetric data processing and the computer must be equipped with powerful hardware and special photogrammetric software.

In this context the basic digital forest map is created today and in the forefront is the transformation of basic forest maps from an analogue form to a digital form. Progress in this sphere is fast and every year new modern products are developed that become more accessible, products with better accuracy, faster, but mainly processing input data more reliably and giving higher-quality outputs.

The objective of the submitted paper is to evaluate the availability of digital photogrammetry for the forestry mapping rationalization.

Digital photogrammetry in forestry mapping

Digital photogrammetry is a process of digital image interpretation in a computer without human assistance. Digital image is obtained by primary digitizing straight from a digital camera or by secondary digitizing – scanning of the aerial image. The information obtained in this way is called a record. The record is composed of a set of image units (pixels), the position of which is determined by their reference to the concrete row and column of the image matrix and the intensity of each image unit corresponds with the average brightness value or radiation that is electronically measured on the matching area in the field or with the secondary digitizing on the aerial image.

Transition from analogue to digital photogrammetry is inhibited the use of the other photogrammetric devices and all processing computers. Known algorithms have been implemented to solve the problems of classic photogrammetry such as triangulation, aerial image orientation, orthoprojection, stereoscopic measurement. Digital photogrammetry includes some methods for image processing and computer vision, e.g. filtering, sharpening, contrast changing. Algorithms for image comparison can be used with automatic orientation of aerial images, triangulation, manual, half-automatic, automatic digital terrain model generation. A digital photogrammetric system should include these modules:

– Import of scanned aerial images and data from GIS/CAD,
– Modification of the image radiometric attributes (filtering, contrast changing),
– Mono and stereo image interpretation,
– Photogrammetric data collection (aero triangulation, mono, stereo measurement),
– DTM processing (automatic generation, displaying, editing),
– Automatic modules (image comparison, image classification),
– Image transformation (planar, epipolar, orthophoto generation).

Development of digital photogrammetry takes place together with development of the remote sensing of the Earth. Photogrammetry and remote sensing of the Earth are overlapping each other, photogrammetry is the science about position determination, dimensions, shapes of features situated on the Earth relief (forest area), remote sensing researches mostly the qualitative aspects of features (e.g. damage to the forest stands).

At the beginning of the 90's, forestry mapping changed from the analogue making of the maps with thematic forestry themes into a system, the output of which is a digital forestry map. Financial conditions and hardware equipment (Stereometrograph – Lesoprojekt, Topocart D – Technical University in Zvolen) did not solve this problem complexly. Sensors for coordinate reading and their processing by the specialized software products (STEREOFOTO, MAPGEN – MDL application for Microstation) were added to some of those equipments. Testing the system Digital Video Plotter (DVP) did not bring the expected results although the attained accuracy of point position was quite good. However, other methods how to achieve the goal were searched, including the testing of digital interpretation methods of aerial images and various other photogrammetric materials, such as black and white aerial images (multispectral, colour infrared aerial images) with the support of specialized software products (TOPOL, EASY/PACE, ORTHOENGINE, ...), and a technique was selected of continuous map vectorization with digitizers, later by the ON SCREEN method, which partly works at present.

From two main solutions (transition to analytic photogrammetry and from it to digital photogrammetry, or straight from analogue to digital photogrammetry), based on the skills of digital photogrammetry operators (GEODIS, s. r. o., Brno, EUROSENSE, s. r. o., Bratislava, VTÚ Banská Bystrica, ...) and research (Technical University in Zvolen, Department of Forest Management and Geodesy), a technique of the mapping by digital image processing at the Department of Forestry and Photogrammetry was selected, thus transformation straight from analogue to digital photogrammetry.

The basic operating system is Windows NT and XP Professional. Specialized photogrammetric software ImageStation SSK is solved modularly and it contains: Microstation SE/J, ImageStation Feature Collection, ImageStation DTM Collection, ImageStation Stereo Display, ImageStation Automatic Elevations, ImageStation Ortho Pro and Geomedia Professional.

Facing these new technical challenges Z/I Imaging, as a photogrammetry system provider, has recently upgraded and enhanced its existing automatic triangulation system. Special emphasis has been given to the Image Station Automatic Triangulation (ISAT) user friendliness, reliability, and integration. Some of the main features of the ISAT are: automatic and manual interior and relative orientation, semi-automatic and manual tie point measurement, bundle block adjustment and so on (Madani, Mostafa 2001).

In 2003 forestry mapping was done of approximately 199,800 ha of the forest land, of that 120,000 ha with digital and 79,800 ha with analogue technology.

Mapping in 2004 was performed approximately on the area of 188,700 ha, reambulation on 83,100 ha, and new mapping on 105,600 ha of the forest land. Expected advance of the digital photogrammetric mapping technology secured the processing of 70–80% of the mapped area. Saved capacities were used mainly for measurements of the forestry detail not visible on the aerial images and increased the production of digital orthomaps.

In 2006 we expect a progressive increase of the digital mapping technology to 100% of the mapped area.

The results confirm the correctness of the fast transition from analogue to digital photogrammetry in regard to forestry mapping.

Forestry mapping is included by its character in the thematic purpose mapping. This mapping is characterized by its requirement for an appropriate cartographic accuracy and requirement for displaying various specialized forestry features (classical black and white aerial images offer only few possibilities). We can see from the results that the colour infrared images at the scale 1:15,000 could be used for completing the planimetry within the reambulation of forest maps or digital forest maps in the 5th class for the forestry mapping accuracy. These materials are suitable as a supplement to classical black and white images (there are indications that they could substitute them). From the results of the digital automatic aero triangulation at the aerial images at the scale of 1:15,000 we can say that in the planar accuracy they match the 4th class of cadastral mapping. Based on the results from aerial images at the average scale 1:16,000 we can say that images scanned with the resolution 1,700 DPI are more suitable for cadastral mapping, besides images with the resolution 850 DPI. From the forestry mapping aspect, the results fully comply with the 5th class and in the case of images scanned at 1,700 DPI with the 4th class of the accuracy. Attaining the 4th class of the accuracy fully meets the requirements for the determination of the customer unit boundaries, which represent owner boundaries from the aspect of forest spatial organization (Žíhlavník Š., Chudý 2002).

The use of digital photogrammetry in forestry practice points to a larger use of the information displayed on classical black and white aerial images, and also on the other accessible materials, such as colour, colour infrared or multispectral ones where the specialized forestry information is more visible.

MATERIAL AND METHODS

Experimental material contains data obtained from a terrestrial measurement and data obtained from aerial images. Forest maps and forest management plan from the area of interest were used at the same time.

Material from terrestrial measurement

Control points

The points were taken from the measurement and interpretation of aerial images, for the signalization of the control points crosses from the white PVC foil were used. Material from a terrestrial measurement was obtained by the tachymetric measurement in the area of the University Forest Enterprise. The measurement was realized with an electronic tachymeter ELTA 4, using methods of the polygonal courses and with connection to the existing geodetic network and the accuracy $m_d = \pm$ 3–6 mm. The measurement of the control points with the tachymeter ELTA 4 meets the requirements for the 2nd class of accuracy for mapping according to the standard STN 01 3410 (Tunák 1998). In areas with bad connection to the geodetic network we used a GPS receiver TURBO – S II with the static method of measurement and the 2nd class of accuracy for mapping.

Table 1. The coordinates of control points from the terrestrial measurement

Number	*Y* (m)	*X* (m)	*Z* (m)	Characteristic
1	423,081.663	1239,568.518	416,438	pole
2	423,108.902	1239,589.325	418,122	pole
3	423,141.461	1239,614.005	419,436	pole
4	423,174.705	1239,638.809	421,165	pole
5	423,207.215	1239,662.754	421,399	pole
6	423,240.643	1239,687.625	421,540	pole
7	423,270.925	1239,710.118	422,241	pole
8	423,301.924	1239,733.206	422,626	pole
9	423,336.701	1239,758.851	423,200	pole
10	423,367.949	1239,782.257	423,258	pole
11	423,451.583	1239,855.835	422,259	bush at the top
12	423,464.299	1239,835.334	426,197	birch at the top
15	423,505.552	1239,832.186	420,034	bush at the top
17	423,525.994	1239,787.062	421,075	pine at the top
19	423,506.221	1239,748.224	428,043	bush at the top
21	423,365.352	1239,725.756	429,772	pear at the top
23	423,348.638	1239,700.175	434,580	bush at the top
25	423,397.264	1239,804.531	423,635	pole
26	423,430.718	1239,829.602	422,093	pole
30	423,262.303	1239,380.890	439,316	spruce at the top
32	423,193.257	1239,349.633	423,441	bush at the top
34	423,174.863	1239,339.425	426,129	hornbeam at the top
36	423,114.254	1239,387.100	421,428	bush at the top
38	423,076.803	1239,385.550	423,873	pine at the top
48	423,051.492	1239,545.265	413,506	pole
51	423,007.228	1239,342.486	427,265	bush at the top
53	422,956.263	1239,374.808	427,473	corner of the sluice
60	422,880.402	1239,393.567	426,998	corner of the sluice
64	422,843.624	1239,410.458	424,767	corner of the crossroads
65	422,848.614	1239,413.920	427,099	bush at the top
67	422,788.169	1239,426.695	419,289	corner of the crossroads
68	422,912.501	1238,949.492	453,121	bush at the top
71	422,735.031	1239,128.044	415,746	bush at the top
73	422,585.754	1239,218.931	407,215	bush at the top
75	422,538.486	1239,264.039	395,652	spruce at the ground
76	422,639.820	1238,773.550	419,610	front of the roof
79	422,607.079	1238,693.160	431,916	range row 1
81	422,634.860	1238,659.694	433,202	range row 1
82	422,674.364	1238,683.373	433,164	range row 2
84	422,564.226	1239,480.127	407,831	bush at the top
86	422,551.503	1239,492.047	407,811	bush at the top

Measured data were transformed into the coordinate system S-JTSK.

Check points

In the area of interest 41 check points were selected. Trees, bushes, sluices, crossroads, poles, building corners etc. were used as the measurement points in landscape (Table 1).

To determine the position and elevation accuracy of the digital photogrammetric interpretation of black and white and spectrozonal aerial images, modules for the stereo interpretation in the ImageStation environment were used.

Aerial images

Diapositive black and white aerial images:
Scale 1:15,000

Characteristic: panchromatic materials receive rays from the whole visible spectrum (400–700 nm). They are used most frequently in the aerial scanning. They enable to create the stereo image, interpretation of planimetry and hypsometry, recognition of each kind of features.

Table 2. Control points used in project No. 1

Point number	Y (m)	X (m)	Z (m)
1	423,191.860	1234,542.780	568,140
2	427,232.580	1234,527.220	878,840
3	424,520.840	1242,953.450	397,190
4	424,725.590	1241,508.500	396,420
5	424,684.460	1236,722.510	651,760
6	427,755.860	1244,362.400	480,270
7	428,401.110	1237,998.340	807,930
8	429,878.840	1239,416.780	809,300
9	430,600.090	1243,450.670	599,120
305910	418,718.930	1241,236.370	299,140
405910	415,820.090	1241,210.780	469,510
505910	419,592.970	1243,996.460	353,660
805920	433,084.780	1242,412.880	498,970
905915	424,448.820	1243,545.820	416,600
1505910	416,636.780	1246,013.730	349,350
1805910	414,657.760	1247,460.670	325,670
2205914	421,603.700	1238,668.570	400,880
2305914	422,850.100	1239,287.400	437,320
2405909	418,160.930	1238,203.060	309,040
2605909	412,991.420	1238,691.140	439,360
2705909	419,995.110	1239,108.700	319,850
2805909	417,979.390	1239,827.420	304,380

Diapositive spectrozonal aerial images:
Scale 1:15,000

Characteristic: spectrozonal or FALSE COLOUR aerial images, output image is different from real colours. The first layer is panchromatic (sensitive in the wavelength range of 520–720 nm) followed by the infrared layer (with sensitivity in the range 720–800 nm). After developing them, the image on the panchromatic layer displays purple colour and on the infrared layer green. This composition is characteristic of the spectrozonal aerial images. When needed a three-layer material can be used.

Aerial images were scanned with the LMK 15 camera. Its focal length was 152 mm.

Aerial image interpretation using the ImageStation SSK system

System description

The system ImageStation SSK was used for the photogrammetric interpretation of aerial images and for their planimetry and elevation accuracy determination. The main working absolute and relative orientation was processed in the ImageStation Model Setup (ISMS), using 5 control points for each image pair (black and white, infrared). The module ImageStation Stereo Display enabled their stereo displaying, coordinate readout, as well as bright and contrast correction in the case of the bad resolution of objects. Stereo glasses with the infrared emittor and pointing device were used for the interpretation, as well as stereo zoom, stereo displaying and movement over the stereo model. Measured data were saved to a database. For the infrared and black and white image pair the coordinates (X, Y, Z) were read out at 41 check points only once.

Digital aerotriangulation

After aerotriangulation ISAT automatically generates computed coordinates at the check points, so it is possible to statistically evaluate their accuracy. These check points are imported and edited with the control points, but with the check point attributes given. So they do not enter into the computing but serve for the accuracy verification. They can also be used for densification or as detailed points. If there are no such points imported before, their coordinates can also be determined in the software product (ISSD), by measuring with the stereo cursor. Schematic workflow is displayed in Fig. 1.

To check the digital block aerotriangulation accuracy in relation to the number of control points used two series of projects were created with different placement of control points in the block and

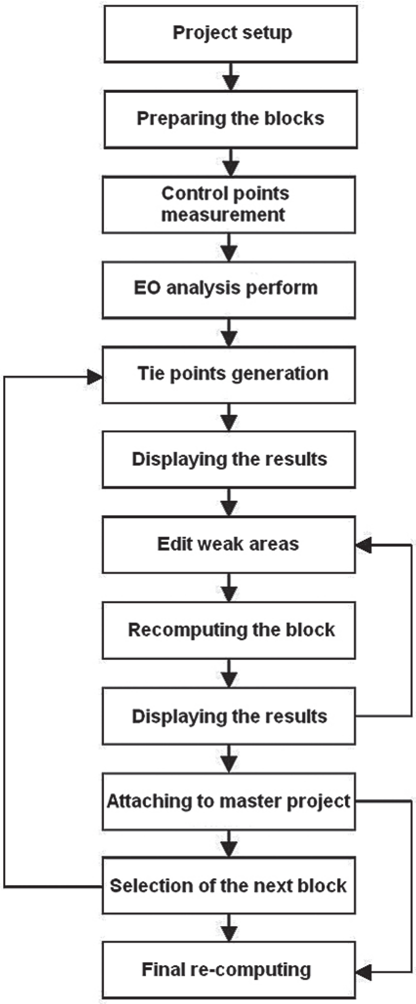

Fig. 1. Software ISAT workflow

with various number of check points. The first set was composed of projects number 1, 2, 3, and 4, the second set of projects number 5, 6, 7, and 8. All projects were situated in area of the University Forest Enterprise in Zvolen. 88 aerial images were used in each project aligned in 7 rows. We tried to keep the basic principles of control point selection, such as their uniform distribution in the block of aerial images (planar and vertical because of the vertical diversity of the area) and their good position for the identification. To show the control point distribution project number one was selected (Table 2, Fig. 2.)

Stereo interpretation

For the planar and elevation accuracy determination of the digital photogrammetric interpretation of aerial images, modules for the stereo interpretation (ISSD) were used, applying the special stereo glasses with the infrared emittor and positioner. Each image pair did relative and absolute orientation with the same control points used. Coordinates *X*, *Y*, *Z* were acquired from the stereo model at 41 check points for the black and white and infrared images. On the same area, stereo models were generated, from them DTM's and finally orthophotos on two various terrains using the modules ISDC, ISAE, ISBR. The areas (12 overlapped areas) were chosen according to the terrain variability and crop density. The first type was characterized by the flat terrain and it was mostly without forests (area No. 1), the second was situated in the mountainous terrain and in the area with high crop density (area No. 2). Two series of projects were also created. For each area in the first series DTM was generated automatically. In the second series 25 control points were used and for both areas DTM was generated automatically and manually and then orthophotos were created. Finally six projects were created.

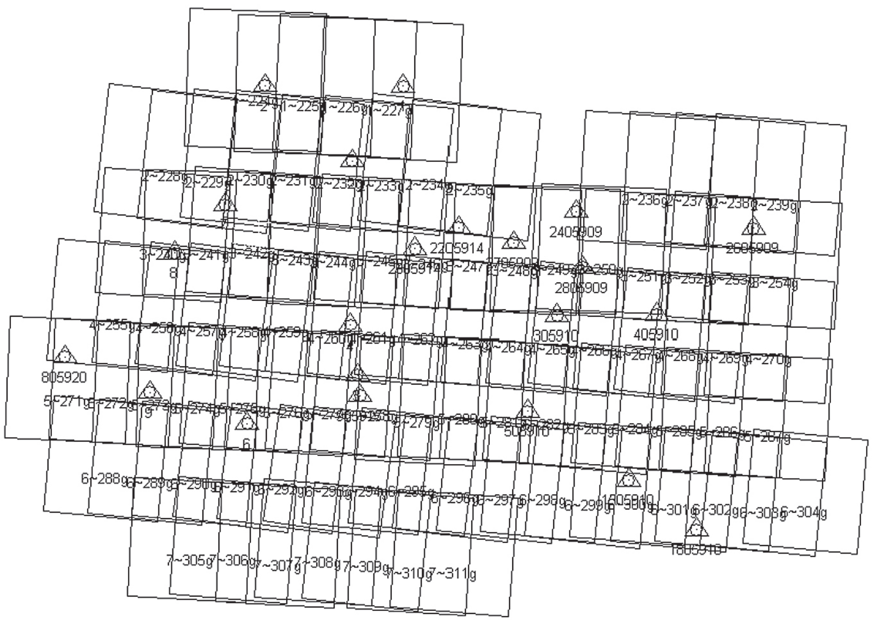

Fig. 2. Distribution of the control points in project No. 1

RESULTS AND DISCUSSION

Automatic digital aerotriangulation executed by the module ISAT automatically generates computed coordinates on the control points and so we can statistically evaluate the accuracy of aerotriangulation. These points have the check attribute, so they do not enter into the computing, but they serve as check up for accuracy. To evaluate the accuracy of the final orthophoto could be used comparison between the point coordinates readout from orthophoto with the coordinates of the same points, which were measured terrestrially by the GPS, or electronic tachymetre, or taken from the cadastre as trigonometric points. For the accuracy determination of stereo interpretation the coordinates of well identified points (features) on the aerial image and terrain were used. The coordinates of these points measured by terrestrial methods were taken as accurate.

In general eight projects were created in two independent series in relation to the number and distribution of control points. In the fifth project after its connection into the master project, 6 images did not connect into the block. These aerial images were connected manually, step by step on each image by identifying tie points. Those were defined not only on the unconnected images, but also on the nearest two images around those unconnected ones. After defining all the points the calculation of the whole block must be run once more. The calculation of the block is time consuming and so we premised that the same error would be generated on the other projects, so these relative points in the next projects (6, 7, 8) were defined before starting the calculation of the block.

To determine the planimetry and elevation accuracy on the aerial images the ImageStation environment was used, especially the module ImageStation Stereo Display (ISSD) and ImageStation Model Setup. Stereo glasses with the infrared emittor were used for the evaluation.

Table 3. Accuracy criteria according to the standard STN 01 3410

Accuracy classes	u_{xy} (m)	u_v	u_H (m)
1st class	0.04	0.03	0.30
2nd class	0.08	0.07	0.40
3rd class	0.14	0.12	0.50
4th class	0.26	0.18	0.80
5th class	0.50	0.35	1.50

For the stereo evaluation and comparison models were created from the blocks where 6 and 22 control points were used for the orientation.

The accuracy of the planar point fields is evaluated by the basic coordinate error *mxy* and the accuracy of the elevation point fields by the basic coordinate error m_H. These cannot exceed the values of the allowed errors u_{xy}, u_v and u_H. For each class of the mapping accuracy according to the standard STN 01 3410 the large scale maps are presented in Table 3.

Comparing the results achieved in each project, we can see that from the digital automatic aerotriangulation aspect, the number of the used control points is not significant for the new point position determination accuracy (Table 4). Mean position error values were in the range from 0.20 to 0.28 m. Comparison of the results with the standard STN 01 3410 (Table 3) show that each project except project No. 5 did not exceed allowed deviation of the mean position error for the 4th class of accuracy. Although this value was exceeded in the 5th project (m_{xy} = 0.276 m), it was only 0.016 m, which is nearly to the bottom interval for the 5th accuracy class. There is a visible variability between the first and the fourth project, i.e. between the projects with

Table 4. Results organized according to the number of control points used in the projects

	Aerotriangulation accuracy				Orthophoto accuracy *mxy*	
	m_x	m_v	m_z	m_{xy}	area No. 1	area No. 2
Project 1	0.2717	0.2429	0.6457	0.2577	0.9087	0.7008
Project 8	0.2015	0.1985	0.5103	0.2000	–	–
Project 2	0.2908	0.2384	0.6417	0.2659	11.6960	0.9429
Project 7	0.2103	0.2095	0.5522	0.2100	–	–
Project 3	0.2516	0.2322	0.6803	0.2421	–	15.8450
Project 6	0.2167	0.2216	0.6032	0.2190	–	–
Project 5	0.2733	0.2792	0.7072	0.2760	–	–
Project 4	0.2125	0.2305	0.8227	0.2217	0.3545	0.8470
DMT-auto.	–	–	–	–	0.5664	0.7075
DMT-man.	–	–	–	–	0.4069	0.5494

Table 5. Comparison of the analogue and digital method; final values of the mean position error (m_{xy}) and mean height error (m_z)

	Black and white images		Colour infrared images	
	m_{xy}	m_z	m_{xy}	m_z
TOPOCARD D	0.623	0.712	0.521	0.325
ImageStation	0.376	0.275	0.374	0.338

the highest and the lowest number of control points from the aspect of height determination accuracy. The results on the final orthophotos and comparison with STN (Table 3) show that projects No. 1–3 and project No. 4 (mountainous country region) exceeded allowed deviation for the mean position error for the 5th accuracy class. Comparing with the thematic forestry mapping we may get acceptable results. In project No. 4 situated on the flat area 0.35m accuracy was reached, which corresponds to the 5th accuracy class. This project has the lowest number of control points and the greatest elevation determination error so it should have an influence on DTM accuracy and orthophoto accuracy. But we can premise that this error was not shown at the flat country projects. The orthophoto generated from the mountainous area was the second most accurate instead of project No. 3, where 11 control points were used and where the accuracy is rapidly decreasing.

According to the forest management workflow forest thematic mapping belongs to the 5th accuracy class. These boundaries were accomplished in the projects. Digital stereo interpretation was compared with the classical analogue methods and the results are described in detail in the work (Tomaštík, Kardoš 2004) (Table 5).

These results show that the digital photogrammetric method is more accurate than the analogue processing at the given positions. The m_z error and the m_{xy} error at the black and white and colour infrared images are reciprocally comparable. From the above mentioned we can say that the colour infrared images are suitable for the forestry mapping purposes, so it is convenient to replace presently used black and white photos with the infrared ones, despite of their higher costs. These aerial images are suitable for the forest state determination (health conditions mapping, remote sensing...) not only for forestry mapping.

CONCLUSIONS

Digital photogrammetry enables to increase work effectivity, and so to decrease the final product costs. This is also influenced by a decrease in the cost of hardware equipment. Operators need not have so detailed knowledge of the computer technologies, so it has more users from the public. It brings us new possibilities in the digital image processing and manipulation, such as with digitized aerial images, with the creation of orthophotomaps and their qualitative interpretation. Automation affects and simplifies the mapping workflow, which has been very time consuming till now. Digitized aerial images from the analogue aerial cameras offer image information at the high geometric resolution 10–15 μm. In future they will be substituted with digital image data obtained with digital cameras.

Digital image processing at the scale of 1:15,000 achieved really good results at the workstation, but higher quality can be achieved only through transition to larger scales – 1:10,000 (mainly for the cadastral mapping) and point elevation accuracy. It relates with higher economic difficulty for obtaining such images, because it increases their number in the block. The number of control points used in the block does not have an expressive influence on the images processed at the given scales. An economic analysis for the quantification of those methods should be done.

In the forested areas the signalized points are not visible enough at all the images. It is necessary to synchronize signalization with the aerial scanning of the area. In the analogue scanning of images control points visible at the aerial images were scanned at first and then they were determined and measured. The onset of digital photogrammetry and automatic triangulation makes the analogue methods applicable only in exceptional cases.

The results regarded the utilization of colour infrared (spectrozonal), black and white aerial images at the scale of 1:15,000 for the stereo interpretation and forestry mapping. It shows that by the help of stereo interpretation "on screen" it is possible to achieve more accurate determination of new detailed points, as on the orthophoto created from a stereo image pair. Digital stereo interpretation represents a fast and useful tool for forestry mapping, especially for the planimetry and hypsometry creation and reambulation.

In comparison with the black and white images, the colour infrared ones have more abundant content so they are predetermined to be used in various forestry disciplines (health condition determination, ...) in regard to the remote sensing of the Earth and GIS.

From the orthophoto accuracy aspect generated DTM have the great influence. Precise DTM need to be corrected (edited), because they contain points that software marks with various levels of redundancy. However the achieved results are suitable for forestry mapping, there is a requirement for checking the dependence of the final orthophoto accuracy from a DTM grid width and from the edited automatically generated points with redundancy because manual generation of DTM is more time consuming.

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Received for publication August 8, 2006
Accepted after corrections January 26, 2007

Využitie digitálnej fotogrametrie v lesníckom mapovaní

ABSTRAKT: Fotogrametrické vyhodnotenie leteckých snímok je v súčasnosti dominantnou metódou lesníckeho mapovania. V posledných rokoch je jednoznačný prechod od analógovej ku digitálnej fotogrametrii. Digitálna fotogrametria umožňuje zefektívnenie pracovného postupu a tým zníženie finálnych nákladov. Hlavným cieľom príspevku bolo posúdiť vhodnosť digitálnej fotogrametrie pri racionalizácii lesníckeho mapovania. Digitálna aerotriangulácia použitím systému ImageStation SSK prináša presnejšie výsledky bez potreby použitia veľkého množstva vlícovacích bodov. Dosiahnuté výsledky tiež demonštrujú použitie farebných infračervených snímok, ale tiež čierno-bielych snímok s mierkou 1 : 15 000 pre tvorbu ortofotosnímok vhodných pre lesnícke mapovanie. Porovnaním s čierno-bielymi snímkami farebné infračervené snímky majú bohatší obsah (hlavne z kvalitatívneho hľadiska), ktorý ich posúva na použitie do mnohých lesníckych disciplín (najmä zisťovanie zdravotného stavu lesov ...) v spojení s diaľkovým prieskumom Zeme a GIS (geografickým informačným systémom).

Kľúčové slová: digitálna fotogrametria; lesnícke mapovanie; aerotriangulácia

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