Digital image analysis of hyperspectral images

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Abstrakt. Hyperspektrálne záznamy patria k moderným progresívnym technológiám, ktoré umožňujú získať oveľa presnejšie informácie o objektoch. Za ich najväčšiu výhodu možno považovať počet kanálov, ktoré v sebe zahŕňajú a priestorové rozlíšenie obrazu. Pre odvodenie presnejšej informácie o korunách stromov mladého porastu (20 – 30 rokov) sme vykonali digitálnu obrazovú analýzu tohto typu dát podľa už publikovanej metodiky pre extrakciu korún stromov v prostredí GIS [6]. Hyperspektrálne dáta sú veľmi vhodné pre identifikáciu korún mladých stromov, menej starších. Výsledok tejto analýzy sme porovnali s výsledkami analýz analógovej infračervenej leteckej snímky a snímky VEXCEL. Výsledky tohto porovnania potvrdili výsledky digitálnej obrazovej analýzy hyperspektrálnych dát. Na ich základe môžeme tvrdiť, že hyperspektrálne záznamy a snímky VEXCEL, charakterizované veľmi vysokým priestorovým rozlíšením, sú veľmi vhodné pre extrakciu obrysov korún stromov mladých porastov, nie starých – dospelých porastov. Na druhej strane, letecké snímky s menším priestorovým rozlíšením (0.5 – 1m) sú vhodné pre identifikáciu starých porastov, nie mladých. Napriek všetkým získaným poznatkom, ešte stále zostáva problém s tieňom a jeho prahovou hodnotou.

Klíčová slova: Hyperspektrálne dáta, koruny stromov, obrazová analýza.

Abstract. Digital image analysis of hyperspectral data. The hyperspectral data belong to modern progressive technologies that allow obtain more precise information about objects. For the biggest advantage we can consider the number of channels they contain and the spatial resolution of the image. We processed the digital image analysis using this type of data to derive more precise information about tree crowns of young forest stands (20 – 30 years) using already published methodology for tree crowns extraction in GIS environment [6]. Hyperspectral data are very suitable for tree crown identification of young trees, less the older trees. Results of this analysis were compared with results of analyses of an analogue color infrared aerial image and VEXCEL image. Results of the comparison confirmed the results of digital image analysis of hyperspectral data. Based on them we can claim that hyperspectral data and VEXCEL data, characterized with very high spatial resolution, are very suitable for extraction of crown outlines of young trees, not the old – mature trees. On the other hand, the aerial images with less lower spatial resolution (0.5 – 1m) are suitable for identification of older trees not for younger. Despite of all this obtained knowledge, the problem with shadow and its threshold value still remains.

Keywords: Hyperspectral images, tree crown, image analysis

1 Introduction

With tree crown identification from remote sensing data have been engaged more authors and also more different methodologies exist. One of them is the tree crown extraction from the shadow valleys, which is based on shadow threshold value finding out [1]. Among the others that influenced the methodology described here belong the methodology based on local maximum of image spectral values finding [3], the multiresolution segmentation in Definiens Professional environment and the tree crown outline extraction based on accumulation surface calculation [7].
Nowadays a lot of remote sensing data exist that can be used for different tasks. Aerial images with various spatial resolutions, satellite data scanned with different sensors, multispectral and hyperspectral data, data from laser scanning and radar data are just examples. This data can be used for mapping of land cover and its changes, for other various analyses as for tree crown identification

as it is showed in this paper. Single data have their advantages and disadvantages which designate each data type for different tasks. Different spatial, spectral, radiometric and time resolution as well as the economical aspect of the data type, they all have important influence for selection of data type to be applied.
Using of remote sensing data in forestry has long history. Aerial images with high spatial resolution are mainly used forest mapping. The results are used in forest management, forest protection and in others forestry discipline.
Also multispectral data are used in forestry for different tasks, e.g. for tree crown extraction, forests health state detection, etc. Hyperspectral data have possibility to retrieve multispectral data because of their parameters. Hyperspectral data use in forestry has motioned many authors and the research in this sphere still continuous. The disadvantage of hyperspectral data is the higher hardware requirements because of the increased data volume that requires bigger capacity of the HDD and CPU for processing.
Among applications of hyperspectral data in forestry belong the tree species classification, chlorophyll volume and tree health state assessment, based on tree crown parameters assessment of timber stock in the forest stand.
Using of the new technologies, new data, it is possible came from forest stand parameters, the basic unit of forest management, to single trees. Having such exact information about forest it is possible to use these technologies for common monitoring of the forests in the future. It is possible because of the increasing information quantity that increases also the information quality.

Tab. 1. Different sensor resolution [6]

Sensor	Spatial resolution	Spectral resolution	Time resolution
Aerial camera	high	low	potential high
Aerial scanner	medium	medium till high	potential high
Satellite scanner	low till medium	medium till high	low till high
Laser scanner	high (3D)		potential very high
SAR	low		potential very high

According to advantages of new materials use against the elder (analogue data) we have to mention the better image quality, the higher sensitivity, almost no costs on film meaning its processing, no need to scan the images and no requirements on internal orientation processing. That made these data more popular and required.

2 Experimental area

Kováčová forest district, from which the analyzed orthophoto sub-plot images come, administratively belongs to Zvolen forest management unit. Management of this area is provided by the University Forest Enterprise of the Technical University in Zvolen. The whole territory belongs to eruption rock region (Kremnicke vrchy) and is under panon clime effect. This territory characterized with broken relief with different climate attitude.
In analyses, there were used forest stands characterized with different age:
Forest stand no. **308a** is young mixed stand with 3.85 ha, slope 35 %, NE exposition, 25 years old, species: pine, oak, beech, larch, hornbeam, birch, spruce.
Forest stand no. **365a** is grown up deciduous stand with 5.59 ha, slope 30 %, N exposition, 90 years old, species: oak, hornbeam.

3 Experimental materials

In 2006, there was performed scanning with AISA Eagle scanner on 16 km^2 of University Forest Enterprise of the Technical University in Zvolen area. The scanning was performed in cooperation with Institute of Systems Biology and Ecology of the Academy of Sciences of Czech Republic and Topographic Institute in Banska Bystrica, which offered data from reference station for post-processing. 18 strips with 200 m width and 50 % average vertical coverage were scanned. The images have origin spatial resolution of 0.6 m, every strip contains 130 spectral bands. The width of particular bands is 4.6 nm. Captured electromagnetic radiance is from 400 nm to 1000 nm. It is represented by the R, G, B and NIR band.

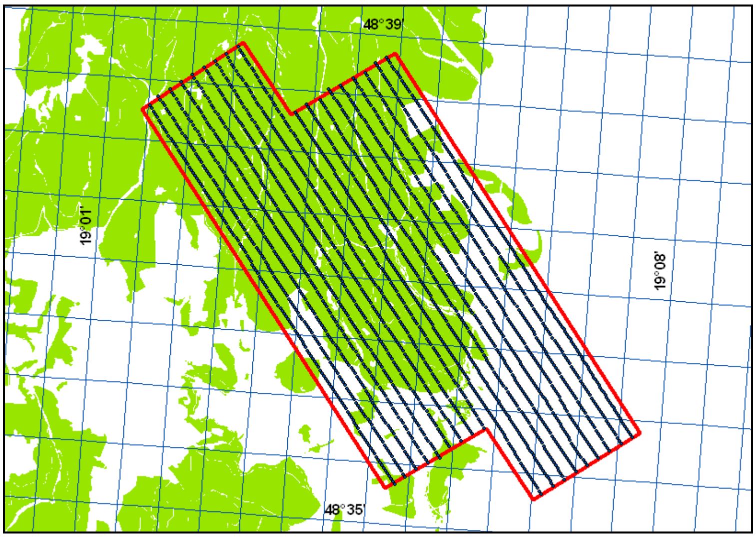


Fig. 1. Flight scheme of the University Forest Enterprise of the Technical University in Zvolen area [2]

In 2006 was also performed scanning with digital camera UltraCam$_D$ on the University Forest Enterprise area. As a result of this scanning we obtained the panchromatic and multispectral VEXCEL data with these parameters:

- Radiometric resolution: 12 bit in dynamic range
- Pixel number of panchromatic image: 11 500 * 7 500
- Pixel number of multispectral image: 4 008 * 2 672
- Largeness of picture segment on image: 9 μm
- Digital camera constant: 101.4 mm
- Flight highness: 1620 m
- Average vertical coverage: 80 %

Already in 1999 there had been performed the CIR images of the area of the University Forest Enterprise. These were produced by Aero Slovakia a.s. for Geo Systems s.r.o. The scanning to 1200 dpi had been provided by Topographic Institute in Banska Bystrica with photogrametrical scanner. Stereo model was made in Laboratory of Geodesy and Photogrammetry at Forestry Faculty of Technical University in Zvolen using ImageStation SSK environment. Based on the stereo model, there were produced orthophoto images using orthorectification. Parameters of the aerial images:

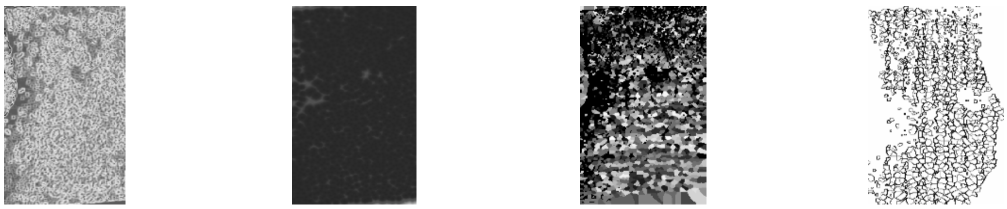
- Scaling factor: 1 : 15 000
- Image format: 23 x 23 cm
- Camera type: LMK 15
- Camera constant: 152.138 mm
- Filter: 500 nm
- Material: KODAK AEROCHROME 2443

4 Methodology

In process of individual tree crowns identification, there was used the IR band by analogue color infrared image from 1999, RED bands of the AISA hyperspectral image and the VEXCEL digital image. For identification of individual tree crowns we used the methodology published by Majlingova [5].

Automatic identification (extraction) of individual tree crowns was performed in Idrisi Andes environment. To find the optimum spatial resolution of the input image for given forest stand, we tested these resolutions of the input images: 0.4 m, 0.6 m, 0.8 m, 1.0 m, 1.2 m and 1.6 m. The effect of input

image spatial resolution has been already published [8]. They showed the important relation between spatial resolution of input image and the size of an expected object (tree crown).
As the input data for processing there were used the focal maxima spectral values images together with filtered images of the aerial images. These were performed in ArcGIS – ArcToolbox (Filter and FocalStat modules) environment. As the base image for focal maxima image production was the filtered image. For image filtration there was used the mean filter with 3x3 cell size window (low pass filter).
Focal maxima image was used for individual tree crown tops extraction. The tops (local maxima) were obtained by subtraction of focal maxima image and the filtered one and its next reclassification – RECLASS module. The real tree crowns tops were obtained by multiplication of tree tops image with the binary image representing the shadow areas (value 0) with forest areas (value 1).
To derive the probable tree crown outlines there were used the distance operators – cost distances (COST functions – COSTPUSH module). COST module generates the distance surface (cost surface), where the distance is measured in way to find the lowest costs (breaks, costs) over the friction surface. The image containing the source data, the distance is measured from, is the final tree tops image. The friction surface image is represented by focal maxima image.
Then, using ALLOCATE module, there were extracted final tree crown outlines. ALLOCATE module is used to assign every cell to the nearest feature class. It is used after COST module use. In the input from COST module, there is assigned the distance to the nearest class, but not to the feature name itself. This role performs ALLOCATE module. To every cell assigns just one ID of the original features, the distance was measured from. As the cost distances image we used the image containing probable tree crown outlines (output of COST module), the target image is the tree tops image with assigned IDs (the image has been obtained by processing of original image processing, output of COST module, in GROUP module).
The vector layer of individual tree crowns was obtained using RASTERVECTOR module (conversion of polygon features from raster to vector form).



a. b. c. d.

Fig. 2. Identification of tree tops and crown outlines

a. Inversion of input filtered image
b. Focal function – cost surface
c. Flow function – cells allocation
d. Raster – vector conversion

5 Results and discussion

The results of the tree crowns identification process are shown in following tables.
There are results for forest stand No. 308a and No. 365a:

Tab. 2. Results of tree crown identification – forest stand No. 308a – analogue image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	766	762	504	258	4
0.6 m	766	661	571	89	105
0.8 m	766	565	489	76	201
1.2 m	766	321	371	21	445
1.6 m	766	276	245	30	490

Tab. 3. Results of tree crown identification differences – forest stand No. 308a – analogue image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (766 crowns)	% of tree crowns identification correctness
0.4 m	762	-4	99.5 %
0.6 m	661	-105	86.3 %
0.8 m	565	-201	73.8 %
1.2 m	321	-445	41.9 %
1.6 m	276	-490	36 %

Tab. 4. Results of tree crown identification – forest stand No. 308a – AISA image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	216	318	163	53	0
0.6 m	216	227	204	18	0
0.8 m	216	191	186	20	25
1.2 m	216	132	131	85	84
1.6 m	216	94	94	122	122

Tab. 5. Results of tree crown identification differences – forest stand No. 308a – AISA image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (216 crowns)	% of tree crowns identification correctness
0.4 m	318	+102	147.2 %
0.6 m	227	+11	105.1 %
0.8 m	191	-25	88.4 %
1.2 m	132	-84	61.1 %
1.6 m	94	-122	43.5 %

Tab. 6. Results of tree crown identification – forest stand No. 308a – VEXCEL image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	487	846	77	769	0
0.6 m	487	470	183	287	18
0.8 m	487	354	65	289	133
1.2 m	487	228	41	86	259
1.6 m	487	160	23	113	327

Tab. 7. Results of tree crown identification differences – forest stand No. 308a – VEXCEL image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (487 crowns)	% of tree crowns identification correctness
0.4 m	846	+359	173.7 %
0.6 m	470	-18	96.5 %
0.8 m	354	-133	72.7 %
1.2 m	228	-259	46.8 %
1.6 m	160	-327	32.9 %

Tab. 8. Results of tree crown identification – forest stand No. 365a – analogue image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	390	388	26	361	2
0.6 m	390	384	95	288	6
0.8 m	390	334	104	225	56
1.0 m	390	357	183	173	63
1.2 m	390	321	223	98	81
1.6 m	390	292	239	61	98

Tab. 9. Results of tree crown identification differences – forest stand No. 365a – analogue image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (390 crowns)	% of tree crowns identification correctness
0.4 m	388	-2	99.5 %
0.6 m	384	-6	98.5 %
0.8 m	334	-56	85.6 %
1.0 m	327	-63	83.9 %
1.2 m	309	-81	79.2 %
1.6 m	292	-98	74.9 %

Tab. 10. Results of tree crown identification – forest stand No. 365a – AISA image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	404	588	228	74	0
0.6 m	404	379	347	32	25
0.8 m	404	338	315	39	66
1.2 m	404	234	61	29	170
1.6 m	404	157	11	146	247

Tab. 11. Results of tree crown identification differences – forest stand No. 365a – AISA image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (404 crowns)	% of tree crowns identification correctness
0.4 m	588	+184	145.5 %
0.6 m	379	-25	93.8 %
0.8 m	338	-66	83.7 %
1.2 m	234	-170	57.9 %
1.6 m	157	-247	38.9 %

Tab. 12. Results of tree crown identification – forest stand No. 365a – VEXCEL image

Image spatial resolution	Total number of reference crowns	Number of identified tree crowns	Number of correctly identified tree crowns	Number of incorrectly identified tree crowns	Number of not identified tree crowns
0.4 m	647	2276	159	643	0
0.6 m	647	1234	298	56	0
0.8 m	647	808	335	413	0
1.0 m	647	634	473	139	13
1.2 m	647	471	371	342	176
1.6 m	647	302	430	194	345

Tab. 13. Results of tree crown identification differences – forest stand No. 365a – VEXCEL image

Image spatial resolution	Total number of automatically identified tree crowns	The difference against visually identified tree crowns from stereo model (647 crowns)	% of tree crowns identification correctness
0.4 m	2276	+1629	351.8 %
0.6 m	1234	+587	190.7 %
0.8 m	808	+161	124.9 %
1.0 m	634	-13	98 %
1.2 m	471	-176	72.8 %
1.6 m	302	-345	46.7 %

The process of tree crowns identification was evaluated based on two factors. One of them was the number of automatically identified tree crowns in comparison to number of tree crowns in reference vector layer created by their digitization, based on stereo model, in ImageStation SSK environment.

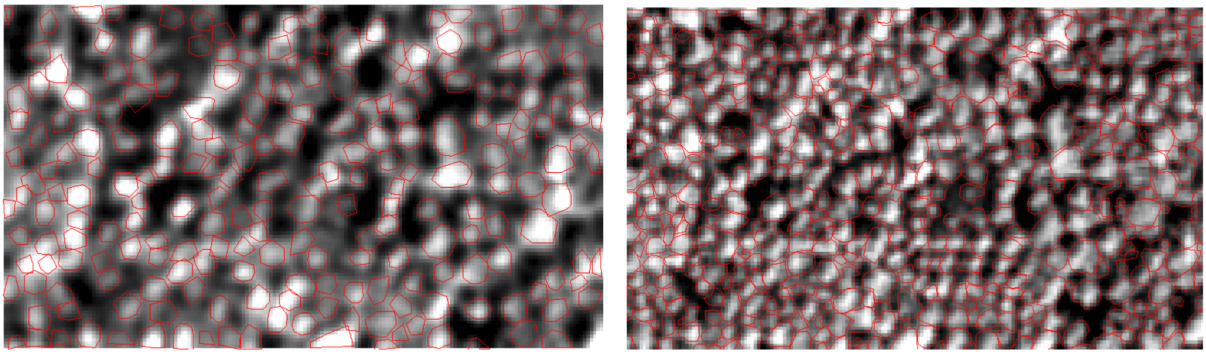


Fig. 3. Reference tree crowns obtained from stereo model in ImageStation SSK – AISA and VEXCEL images, spatial resolution of 0.6 m

The results of this evaluation area are shown in Tables 3, 5, 7, 9, 11 and 13. Based on the obtained results we can say that in case of young forest image analysis it is the best to use spatial resolution of 0.6 m by AISA and VEXCEL images. The error of the crowns identification is + 5% by AISA image and – 3.5% by VEXCEL image. In case of analogue CIR image, the best resolution for input image is 0.4 m and the error of crown identification is 0.5%.

For the old tree/forest stand we prefer the spatial resolution of input images – for AISA 0.6 – 0.8 m, where the identification error is in range [-4 %;-16 %]; for VEXCEL the spatial resolution of 1 m and for analogue CIR images 0.4 – 0.6 m, where the error is less than 3 %.

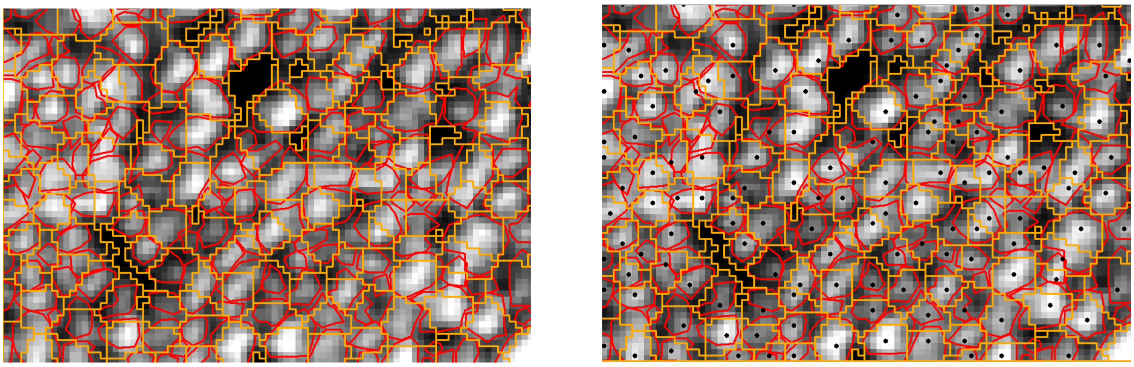


Fig. 4. Result of tree crowns identification of the VEXCEL image, forest stand No. 308a, resolution of 0.6 m

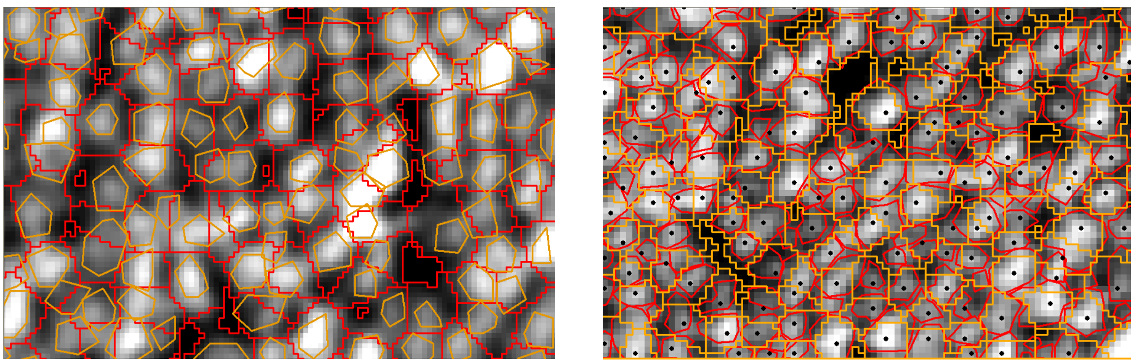


Fig. 5. Result of tree crowns identification of the AISA image, forest stand No. 365a, resolution of 0.6 m

The other type of results evaluation is oriented to evaluation of the overlay of individual tree crowns obtained by automatic processing using algorithm with the tree crowns from reference layers. Results are shown in tables 4, 6, 8, 10 and 12.

These results are more important than the before, talking only about number of identified tree crowns. Based on them we have to talk about following spatial resolutions of input images:

AISA images – young trees with 0.6 m and against them old trees with spatial resolution 0.6 – 0.8 m.

VEXCEL images – young trees with 0.6 m against them old trees with spatial resolution 1.0 m
Analogue CIR images – young trees with 0.6 m and against them old trees with 1.2 – 1.6 m.

Obtained results showed that by AISA and VEXCEL images is in case of young trees to use the spatial resolution of input images of 0.6 m. It is confirmed by the both ways of results evaluation. In case of analogue data, it is confirmed the rule published by Tuček, Majlingová [8], that by young trees/forest stands is better to use higher spatial resolution, in this case of 0.6 m.
Results obtained by old trees showed that by older trees is better to use lower spatial resolution. By AISA images the spatial resolution increases from 0.6 to 0.8 m. By VEXCEL data the resolution decreases to 1.0 m and by analogue data even to 1.6 m, based on the size of expected crown parameters in given age of tree.

The results of these analyses confirmed previous knowledge published by Tuček and Majlingová, however the differences are not significant as we can see by AISA images analysis.

6 Conclusion

Also in sphere of aerial images application, there is progress from analogue images to digital images. The advantages of new data types have been already mentioned before. Among the disadvantages of the analogue data type belongs the need of its scanning before using. This need is canceled in case of AISA hyperspectral images or VEXCEL images. The prime advantage of these data types is their quality and very high spatial resolution (AISA 0.6 m and VEXCEL even 0.12 m)
But, that what is considered as advantage in the general level, is not always advantage in case of application of such data type. This fact is also confirmed by the results of our analyses, oriented to individual tree crowns identification (extraction).
High spatial resolution of original images (AISA, VEXCEL), that reaches 12 cm shows as not very suitable as for crown identification of as young as old trees, respectively forest stands. The spatial resolution of the original image with spatial resolution of 12 cm caused, based on its data volume, visibility of individual tree branches, that did not create compact crown and this way the final tree crown was separated to more small crowns along the branches. This caused the big amount of identified local maxima of the image – identified tree tops, in the beginning of the analysis. Therefore it was necessary to generalize the image using lower image spatial resolution of 0.6 - 0.8 m by young trees on AISA images and 0.6 on VEXCEL images. And of 0.6 m by old (mature) trees on both AISA and VEXCEL images.
According to all here mentioned, it could be said, that these data use for tree crowns identification is not very suitable. It could be also said, that these could suitable for the purpose but not for the algorithm we have used.
The great advantage they have is their quality, at all. The input spatial resolution of the image should be decreased in the future, to ensure that we will obtain objects of size and number as we expect. But using the scanned analogue images we will never reach the quality of digital ones.
In case of tree crowns identification it is not possible to talk generally about an enhancement of the crown identification process result using the images with high spatial resolution that have AISA or VEXCEL data, as we thought before. Because of the high spatial resolution (12 cm) of input (original) image that makes a problem by this kind of application.

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