TEXTURE STRUCTURE ANALYSIS IN ENVIRONMENTAL IMAGES

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Abstract

Air pollution is a global problem all over the world. Bioindicator approach is a modern and progressive way how to determinate an amount of damage caused by pollution in nature. We have gained electron-microscope pictures of pores of needles from Norway spruce. These needles have miscellaneous structure of epidermis when the air is clean. If the tree grows in polluted air, the needles start to cover by epicuticular waxes to protect themselves and their epidermis became coherent. Coherence can indicate an amount of air pollution and it is possible to resolve it into five classes by damage.

In our work, we have decided to exploit this effect and tried to divide pictures into classes by means mathematic detection of edges. We used Prewitt, Sobel, Robinson, Kirsch and Canny methods and compared them in use for resolving pictures to pollution classes without human senses, only according a sum of detected edges.

1 Air Pollution and Image Processing

Air pollution is a serious problem all over the world. Research of bioindicators is simple and high-quality approach how to find and determinate traces of various pollutants in the air. One of the most common bioindicators in the Czech Republic is a Norway spruce (*Picea abies*) and this is a main reason for choice this tree for mapping air pollution in selected areas.

Previous studies proved that structure properties of needle epidermis are dependent on degree of air pollution. If the tree grows in a clean air, the epidermis with stomas* has miscellaneous structure. But when a quality of the air became worse, the needle epidermis starts to cover by epicuticular waxes to protect themselves against pollutants. For the air pollution quantification, five classes of epidermis coverage were defined and it specifies a pollution degree in depend of epidermis damage. [1]

If a qualitative origin of sensual sensation is converted to quantitative computer meaning, edge detection can be one of possibilities how to determine a pollution class. For our research, an electron-microscope images of needle stoma were used and representative parts were chosen.

Table 1: CLASSES OF COVERING EPIDERMIS BY EPICUTICULAR WAXES IN DEPEND OF AIR POLLUTION

Class	*Description*
1	unaffected generous stoma wax with clearly visual funicle**, wax covers max. 10% of stoma area
2	count and size of the funicle is growing up on different places of the stoma, creation of low area aggregates (wax “tuffs”), wax covers 10 - 25% of stoma area
3	often wax tuffs and a large area plates of waxes, wax covers 25 - 50% of stoma area
4	advanced degree of pollution damage, 50 – 75% of stoma area is covered by low area aggregates and large area wax plates
5	epistomal area is almost whole covered by amorphous wax crust, more than 75% of stoma area is covered by large area wax plates

* stoma (bot.) = part of needle/leaf epidermis which flower/tree use for breathing
** funicle (bot.) = fibre

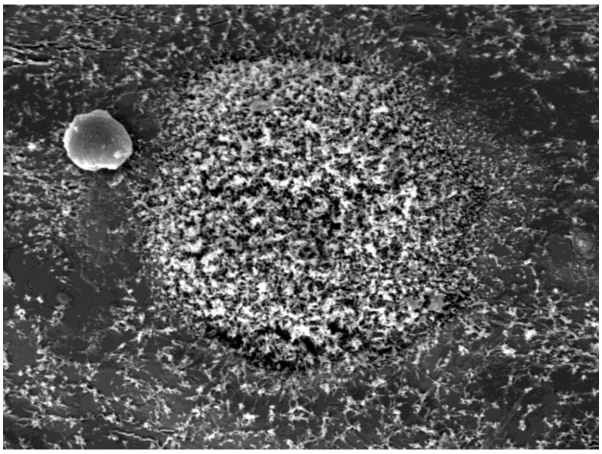


Figure 1: Stoma of class 1

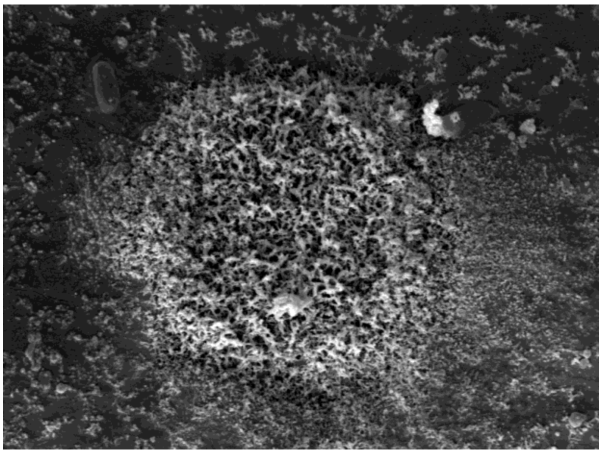


Figure 2: Stoma of class 2

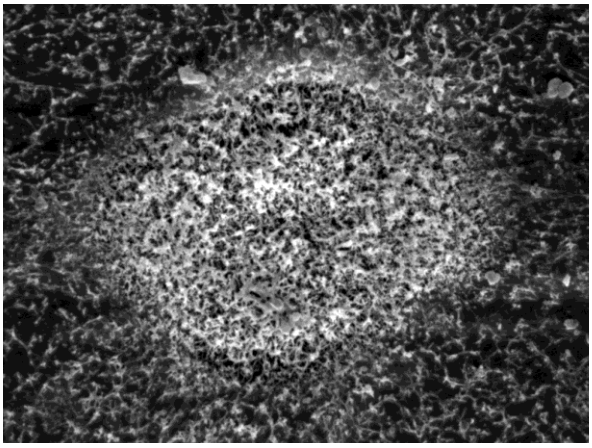


Figure 3: Stoma of class 3

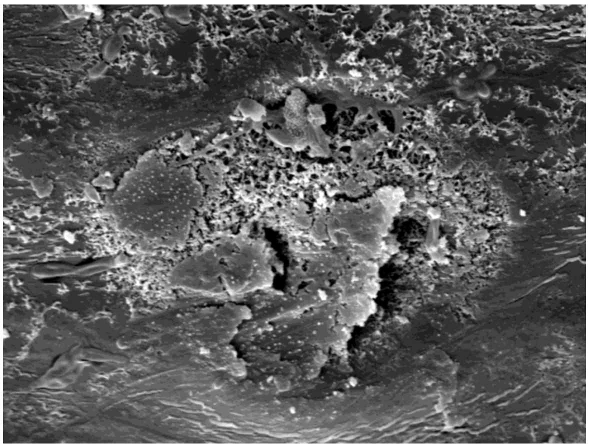


Figure 4: Stoma of class 4

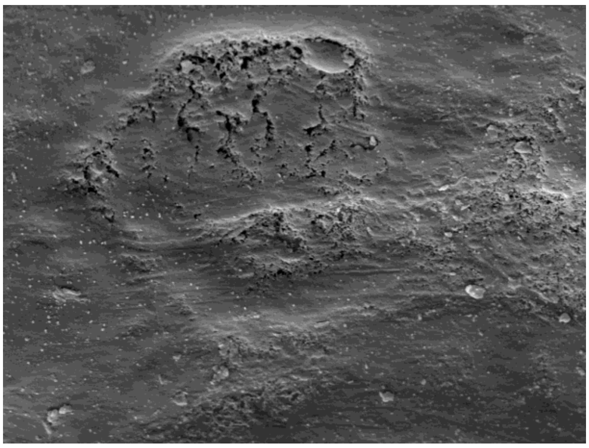


Figure 5: Stoma of class 5

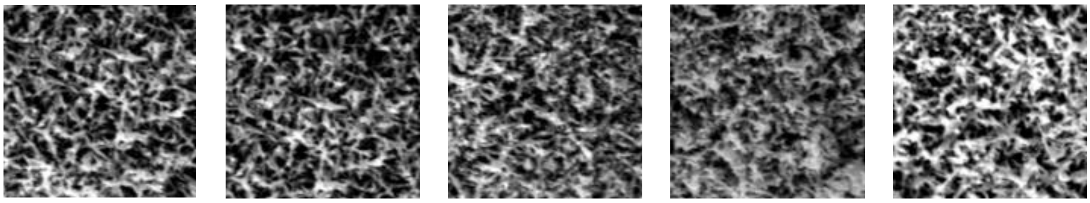
2 Texture Analysis

An idea of image processing is based on the principle of texture analysis for each class and it complains a number of detected edges for each class. According to Fig.1-5, the first class stoma has miscellaneous structure, so the number of edges would be the largest of all. For next classes, the stoma structure becomes more and more coherent and the edge number is decreasing with increasing degree of damage.

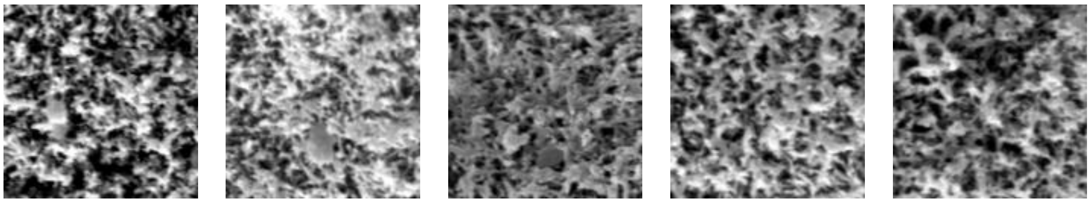
This study was applied to images gained from scanning electron microscopy. Every image contains a stoma and its nearby surroundings. For image processing, it would be ideal to handle with the stoma only and vanish everything else which could have an influence on computing. Because of that, only parts (128×128 pixels) of stomas from known images were chosen for generating library of representative samples (Tab.2).

Table 2: LIBRARY OF SAMPLES FOR EACH CLASS OF AIR POLLUTION

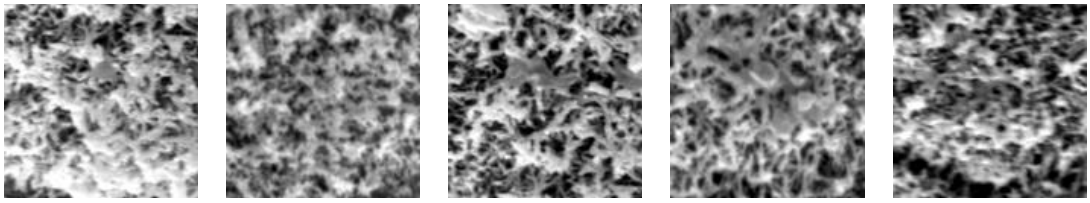
1



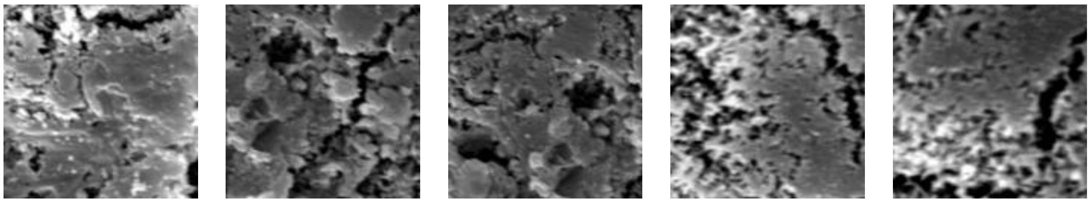
2



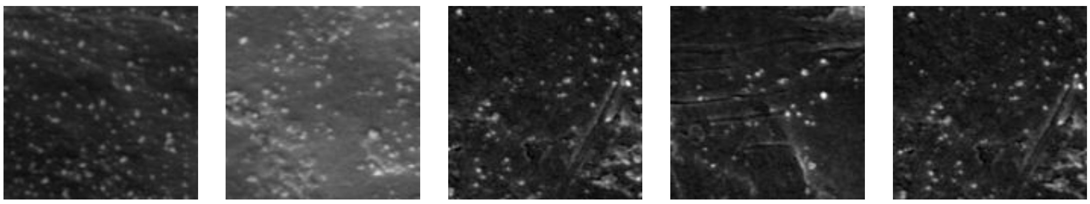
3



4



5



It was necessary to standardize images to same parameters to make them comparable. Images were fitted with completive files containing information with additional properties and an origin of the image. These data were used for conversion to standard brightness level, resolution and size. Further processing showed that these procedures are needful for success of following mathematical methods.

At the beginning of the research, the simplest methods of edge detection were used. They showed that they could be sufficient and that they could solve the problem with particularly success. These methods were Robinson, Prewitt, Kirsch and Sobel approach. The last one was Canny method which consists of the complex algorithm and it is more efficient than the others.

Edge detection methods were applied to each sample of the library (Tab.2). Numbers of edges were gained and their statistic characteristics (mean value and standard deviation) were evaluated for each class. According these values, the key table of edge number was generated.

3 Mathematical Background

As was meant, Robinson, Prewitt, Kirsch and Sobel approach are simple methods for edge detection. The principle of these methods is the same – filtration of the image saved in a matrix *x* with a proper convolution kernel *h* according to Eq. (1).

$$y(n,m) = x(n,m) * h(n,m) = \sum_{j_1=0}^{n} \sum_{j_2=0}^{m} x(j_1, j_2) h(n - j_1, m - j_2) \quad (1)$$

These methods catch fast brightness changes of edges in the image. [2] Thresholding of resulted gray-scale image follows to get binary image only. Otsu method was used for this operation. [4] The other principle for edge detection could be Canny algorithm. [3]

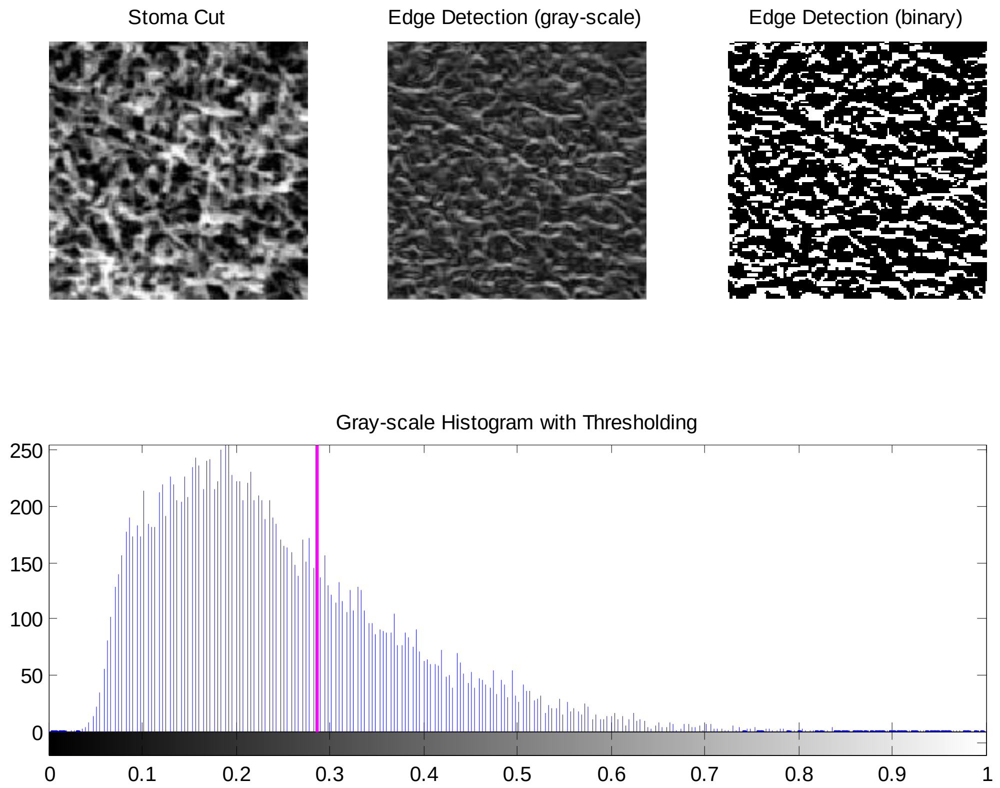


Figure 6: Edge detection and thresholding of selected image

4 Results and Conclusion

Resulting Table 3 and images in Figs 7 - 11 shows that Canny algorithm is the best method for given image edge detection. Mean values of edge pixel number fall gradually and it is possible to use them to recognize and to compare all classes together. Kirsch method provides particularly satisfactory results, as well. Prewitt and Sobel approaches give similar diagram. It is obvious that these methods cannot recognize class with low pollution damage. Robinson method results could be interesting. Diagram 9 shows expected decreasing of the edge number from the first to the fourth class but it's followed by unexpected high increase in the fifth class. This event could be explained by physiological changes of epidermis that seems to be notable at the fifth class samples. The tree is trying to regenerate its needles at this event is represented by degree of small white points in the image. So we can say that Kirsch method can be useful for determination of the epidermis regeneration degree.

Table 3: NUMBER OF EDGE PIXELS GAINED BY PREWITT, SOBEL, ROBINSON, KIRSCH AND CANNY METHOD

	1		*2*		*3*		*4*		*5*	
	4954		4958		4723		3707		2821	
	5001	5226	5512	5209	6598	5654	3158	3442	2795	2343
Prewitt	5321	±	5222	±	5215	±	3573	±	1870	±
	5336	240	5712	427	5984	719	3481	218	2522	148
	5517		4641		5752		3293		1706	
	5049		4876		4821		3617		2534	
	4882	5203	5547	5200	6297	5564	3156	3436	2742	2451
Sobel	5296	±	6297	±	5106	±	3560	±	1848	±
	5343	231	3156	445	6009	611	3469	181	2396	447
	5446		2742		5585		3377		1707	
	6411		5603		4799		4158		14845	
	5916	6230	6293	6054	7387	5634	3665	3847	15523	11110
Robinson	6292	±	6409	±	4942	±	4785	±	8075	±
	6217	188	6059	320	6018	1092	3407	632	8824	3736
	6314		5908		5022		3219		8285	
	3561		3736		3048		2755		1864	
	3745	3807	3920	3468	4376	3870	1920	2267	1797	1744
Kirsch	3968	±	3456	±	3535	±	1993	±	1546	±
	3565	275	4131	805	4475	594	2375	334	2248	367
	4198		2099		3918		2294		1267	
	2994		2689		2564		2152		1887	
	3040	2992	2676	2698	2597	2578	2168	2141	1842	1753
Canny	3028	±	2663	±	2575	±	2263	±	1621	±
	2976	47	2762	39	2581	12	2095	88	1775	119
	2922		2702		2575		2027		1639	

Table 4: KEY TABLE ACCORDING TO CANNY ALGORITHM

Class	*1*	*2*	*3*	*4*	*5*
Σ edge pixels	> 2850	(2850;2650)	(2650;2300)	(2300;2000)	2000 >

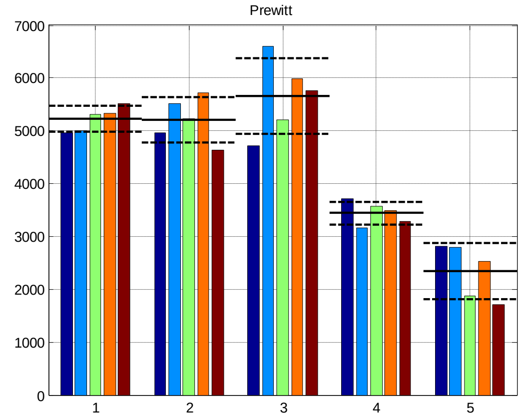


Figure 7: Number of edges by Prewitt

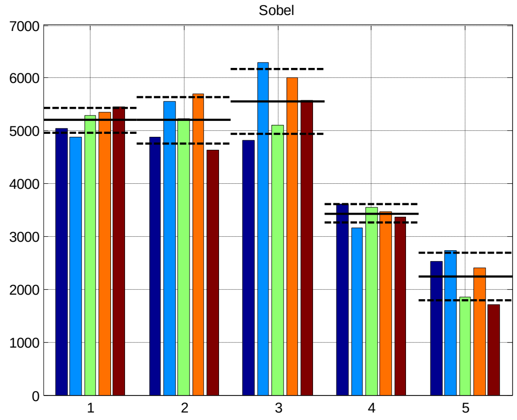


Figure 8: Number of edges by Sobel

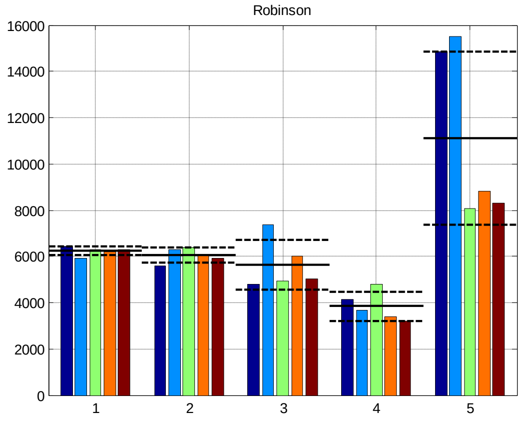


Figure 9: Number of edges by Robinson

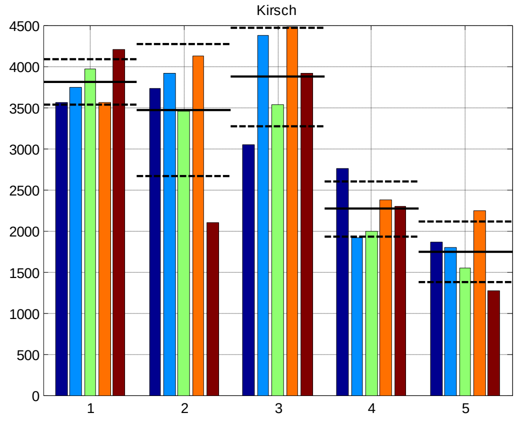


Figure 10: Number of edges by Kirsch

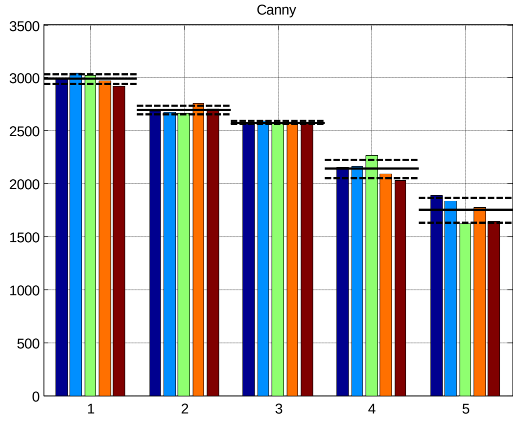


Figure 11: Number of edges by Canny

For results verification, Canny key table (Tab.4) was applied at unknown images of needle epidermis classification. Selected example is presented in Fig.12, 13. Sum of detected edges is 2228 which leads to the fourth class of pollution. This result corresponds with sensual meaning.

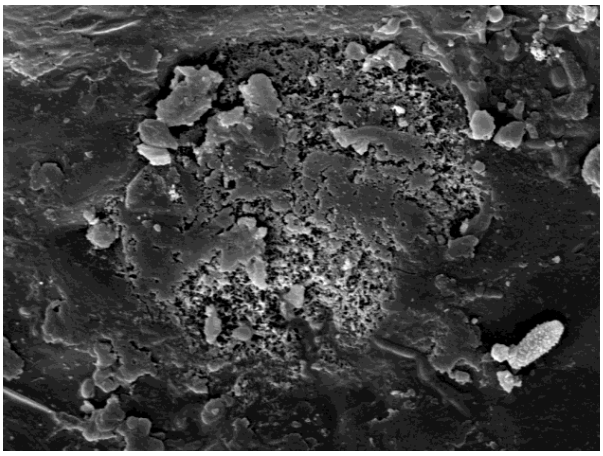


Figure 12: Image *b2_1p*

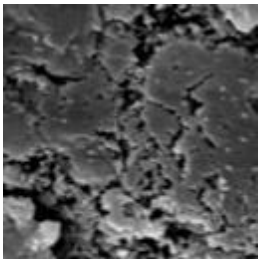


Figure 13: Sample (128×128p) to identification

References

[1] J. Náhlík, P. Cudlín, E. Kašová, R. Bartoníčková. *Study of stomatal waxes morphology of Norway Spruce at chosen areas by through the use of scanning electron microscopy*. International scientific conference "State and perspectives of ecological research of mountain forest ecosystems" – Polana(SK). 22th – 25th October 2001. Czech

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[3] J. Canny: *A computation approach to edge detection.* IEEE on PAMI, 8(6): 679 – 698. 1986

[4] N. Otsu. *A Threshold Selection Method from Gray-Level, Histograms*, IEEE Transactions on Systems, Man, and Cybernetics, Vol. 9, No. 1, 1979, pp. 62-66.

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