SUPPLEMENTARY MATERIALS

to the article E.G. Komyshev, M.A. Genaev, D.A. Afonnikov
"Analysis of color and texture characteristics of cereals on digital images"

Table 1. Equations for calculation of second order matrices when analyzing the texture of images

Eq.	Feature (abbreviation)	Equation	Reference
1	Gray level co-occurrence matrix (GLCM)	$$P_d(i,j) = \sum_{x=1}^{n}\sum_{y=1}^{m}\sum_{\Delta x,\Delta y}\begin{cases}1, \text{ if } I(x,y)=i \text{ and } I(x+\Delta x, y+\Delta y)=j \text{ and } \delta(\Delta x,\Delta y)=d,\\ 0, \text{ otherwise}\end{cases}$$ where x, y are the coordinates of pixels in the image; $0<x<n$, $0<y<m$; $i, j = 0, \dots, k-1$, k is the number of levels of image luminance quantization; $\delta(\Delta x, \Delta y)$, the distance between pixels (x, y) and $(x+\Delta x; y+\Delta y)$; $I(x, y)$, pixel intensity in gray scale; Δx, the shift along the X axis; and Δy, the shift along the Y axis. Normalized matrix: $p(i,j) = \frac{\sum_x^n \sum_y^m P_{x,y}(i,j)}{C}$, where $C = 2n(m-1)+2m(n-1)+4(n-1)(m-1)$	Haralick et al., 1973; Astafurov et al., 2014
2	Gray level run length matrix (GLRM)	$$q(i,j) = \sum_{\theta} Q_\theta(i,j),$$ where $Q_\theta(i,j)$ is the number of runs of length j of the pixels with the gray level i in the direction θ from pixel (i, j)	Galloway, 1975
3	Local similarity patterns (LSP)	$$LSP_{SRR}(i,j) = \max_{s=0,\dots,7} LSP_{SRR}(s)$$ $$LSP_{SRR}(s) = \sum_{i=s}^{s+7(mod\,8)} t(g_i-g_c, SRR)2^i$$ $$t(x,d) = \begin{cases}1, \text{ if } \lvert x\rvert \le d\\ 0, \text{ if } \lvert x\rvert > d\end{cases},$$ where SRR is a constant (similarity range radius); s is a parameter (starting point for traversal of neighboring pixels); $t(x, d)$, threshold function; $g_{0,1,\dots,7}$ is the intensity of the numbered neighboring pixels; and g_c is the intensity of the central pixel	Pourreza et al., 2012
4	Local binary patterns (LBP)	$$LBP = \max_{s=0,\dots,7} LBP(s)$$ $$LBP(s) = \sum_{p=s}^{s+7(mod\,8)} t(g_p-g_c)2^p$$ $$t(x) = \begin{cases}1, \text{ if } x>0\\ 0, \text{ if } x<0\end{cases},$$ where s is a parameter (starting point for traversal of neighboring pixels); $t(x)$, threshold function; $g_{0,1,\dots,7}$ is the intensity of the numbered neighboring pixels; and g_c is the intensity of the central pixel	
5	Local similarity number (LSN)	$$LSN_{SRR}^{P} = \sum_{i=0}^{P^2-2} t(g_i-g_c, SRR)$$ $$t(x,d) = \begin{cases}1, \text{ if } \lvert x\rvert \le SRR\\ 0, \text{ otherwise}\end{cases},$$ where $p = 3, 5, 7, \dots, 2n+1$, size of the neighborhood; SRR is a constant (similarity range radius); $t(x, d)$, threshold function; $g_{0,1,\dots,P^2-2}$ is the intensity of the numbered neighboring pixels; and g_c – is the intensity of the central pixel	

Table 2. Characteristics computed from the normalized GLCM matrix, where $p(i, j)$ is its element in the ith row and jth column

Eq.	Characteristic	Equation	References
1	Mean	$\mu = \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} ip(i, j)$	Majumdar, Jayas, 1999
2	Variance	$\sigma^2 = \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} (i-\mu)^2 p(i, j)$	
3	Homogeneity	$\sum_{i=1}^{N_g} \sum_{j=1}^{N_g} \{p(i, j)\}^2$	
4	Entropy	$-\sum_{i=1}^{N_g} \sum_{j=1}^{N_g} p(i, j)\log_2\{p(i, j)\}$	
5	Correlation	$\sum_{i=1}^{N_g} \sum_{j=1}^{N_g} \frac{(i-\mu)(j-\mu)}{\sigma^2} p(i, j)$	
6	Homogeneity	$\sum_{i=1}^{N_g} \sum_{j=1}^{N_g} \frac{1}{1+(i-j)^2} p(i, j)$	
7	Inertia	$\sum_{i=1}^{N_g} \sum_{j=1}^{N_g} (i-j)^2 p(i, j)$	

Note. See V.G. Astafurov et al. (2014) for an example of computation of a GLCM.

Список литературы / References

Astafurov V.G., Evsyutkin T.V., Kuriyanovich K.V., Skorokhodov A.V. Statistical model of cirrus cloud textural features based on MODIS satellite images. *Optika Atmosphery i Okeana = Atmospheric and Oceanic Optics.* 2014;27(07):640-646.

Haralick R.M., Shanmugam K., Dinstein I.H. Textural features for image classification. *IEEE Trans. Syst. Man Cybern.* 1973;6:610-621.

Galloway M.M. Texture analysis using grey level run lengths. *Comput. Graph. Image Proc.* 1975;4:172-179.

Majumdar S., Jayas D.S. Classification of bulk samples of cereal grains using machine vision. *J. Agric. Eng. Res.* 1999;73(1):35-47. DOI 10.1006/jaer.1998.0388.

Pourreza A., Pourreza H.R., Abbaspour-Fard M.H., Sadrnia H. Identification of nine Iranian wheat seed varieties by textural analysis with image processing. *Comput. Electron. Agric.* 2012;83:102-108. DOI 10.1016/j.compag.2012.02.005.