USE OF STATISTICAL APPROACH FOR CLASSIFICATION OF VISUALIZED TRANSPARENT POLYMERIC FOILS

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Abstract. *The contribution treats the topic of processing the experimentally gained information on the properties of optically transparent polymeric foils. Schlieren optical system was used to examine and visualize refractive index distribution. Statistical approach enables a useful classification of different types of foils into classes. Experimental results and their statistical interpretation are presented as well.*

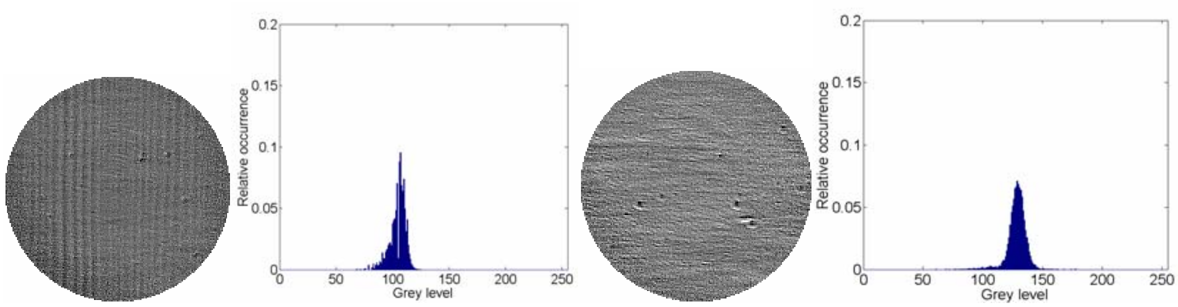
Keywords: schlieren, refractive index, optical visualization, polymeric foil, classification.

1. Introduction

Optical visualization methods use changes in the absorption of photons during their transmission through mechanically loaded regions of transparent polymeric foils. The main advantage of these methods is that they provide information that can be used for further processing after photographic or digital recording. Of the many methods for visualizing refractive-index inhomogeneities in transparent media, the schlieren method is one of the oldest and simplest. As an instrument, a schlieren apparatus is sensitive to transverse refractive index gradients in the test object. These gradients cause incoming light rays to undergo angular deviations, which are in turn encoded by means of selective interaction with a spatial filter, named a knife edge cutting off part of the transmitted light, e.g. an appropriate spatial filtering blocks the undeviated light while allowing the transmission of some refracted light. The camera objective focuses the test object onto the recording plane, where one receives a reduced intensity of light, depending on the amount of light cut off by the knife edge [1].

2. Image properties

For image processing it is necessary to correct influence of light source inhomogeneity, influence of the optical string and of the sensing device for evaluation of images gained by the optical visualization of polymeric foils. One of the possibilities is to use reference image picked up without presence of tested object. The reference image can be taken as an image of errors of the whole optical system on the assumption that we have used a virtual light source [2]. Correction of brightness errors is necessary for the further image processing by the statistical methods.



a. b.

Fig.1 a/ Modified image of foil AG36 and its histogram, b/ Modified image of AC700 foil and its histogram

In an ideal image of visualized foils the changes of brightness reflect changes of the refractive index of the test material, changes of thickness of material and presence of impurities and defects. The refractive index depends on the density of material through which light beams traverse [1]. In fig. 1.a and 1.b are displayed the sharpened corrected images of two different foils (AG36 and AC700). From images it is seen, that different foils have different characteristic features, that are well observed, images of different foils can be distinguished and on the contrary images of different samples show some similarities. Figures show some regularity of stochastic character. One of the possibilities how to describe character of foils images is to use the statistical characteristics. In figures 1.a and 1.b are histograms of relative occurrences of grey levels.

It can be seen, that there are some differences between histograms in regard to the position and the shape. The attributes of histograms can be numerical characterized using moments of distribution as the mean value of grey level

$$m = \sum_{i=1}^{L} x_1 p(x_i) \tag{1}$$

and centred moments of the distribution of the k-th order

$$\mu_k(x) = \sum_{i=1}^{L} (x_i - m)^k . p(x_i)\,, \tag{2}$$

where x_i is the value of i-th grey level, $p(x_i)$ is the relative occurrence of this grey level, which can be taken as the probability of occurrence of grey level, and L is the number of grey levels in the image. The regularity in structure of the foil can be described by the two-dimensional autocorrelation function [3].
In order to quantify properties of foils images it is possible to use the grey level co-occurrence matrix [4],[5]. We can characterize it as a matrix with the elements giving the occurrence of pairs of grey level in the defined direction and distance. Such a matrix can reflect the character of image structure unlike the characteristics (1) and (2) . Indices of the matrix elements correspond to the grey level of the pair. The matrix is square and symmetric to the main diagonal. Dimensions of the matrix are given by the number of grey level in the pre-processed image. Owing to the discrete character of image the direction angles of pairs of pixels is quantized by the step 45° . Matrix for the distance d=1 and the angle α=0° can be expressed by

$$P(i,j,d,0) = \#\{[(k,l),(m,n)] \mid k = m, |l-n| = d, I(k,l) = i, I(m,n) = j\ \}, \tag{3}$$

where (m,n) and (k,l) are coordinates of pixels separated by distance d in the horizontal direction, i, j are grey levels of such pixels, where symbol # denotes the number of elements in the set. In order to calculate characteristics from such a matrix it is more suitable to use relative occurrences (frequencies) according to (4)

$$p(i,j,d,\alpha) = \frac{P(i,j,d,\alpha)}{\sum_{i=0}^{L-1}\sum_{j=0}^{L-1} P(i,j,d,\alpha)} \quad . \tag{4}$$

In [4], [5] are some features computed from the co-occurrence matrix (4). From the suitable features we can present contrast

$$f_{1,d,\alpha} = \sum_{n=0}^{L-1} n^2 \left\{ \sum_{i=0}^{L-1}\sum_{j=0}^{L-1} p(i,j,d,\alpha) \right\}_{|i-j|=n}, \tag{5}$$

correlation

$$f_{2,d,\alpha} = \frac{\sum_{i=0}^{L-1}\sum_{j=0}^{L-1} (ij)p(i,j,d,\alpha) - m_{x,d,\alpha} m_{y,d,\alpha}}{\sigma_{x,d,\alpha}\sigma_{y,d,\alpha}} \tag{6}$$

and standard deviation

$$f_{3,d,\alpha} = \sigma_{x,d,\alpha}\ , \tag{7}$$

where the mean values $m_{x,d,\alpha}$, $m_{y,d,\alpha}$ and the standard deviations $\sigma_{x,d,\alpha}$, $\sigma_{y,d,\alpha}$ can be computed from (8)

$$m_{x,d,\alpha} = m_{y,d,\alpha} = \sum_{j=0}^{L-1} j \sum_{i=0}^{L-1} p(i,j,d,\alpha) \qquad \sigma^2_{x,d,\alpha} = \sigma^2_{y,d,\alpha} = \sum_{j=0}^{L-1} (j - m_{x,d,\alpha})^2 \sum_{i=0}^{L-1} p(i,j,d,\alpha). \tag{8}$$

There are 3D-representation of a section of the grey level co-occurrence matrix for two different foil samples in fig. 2.

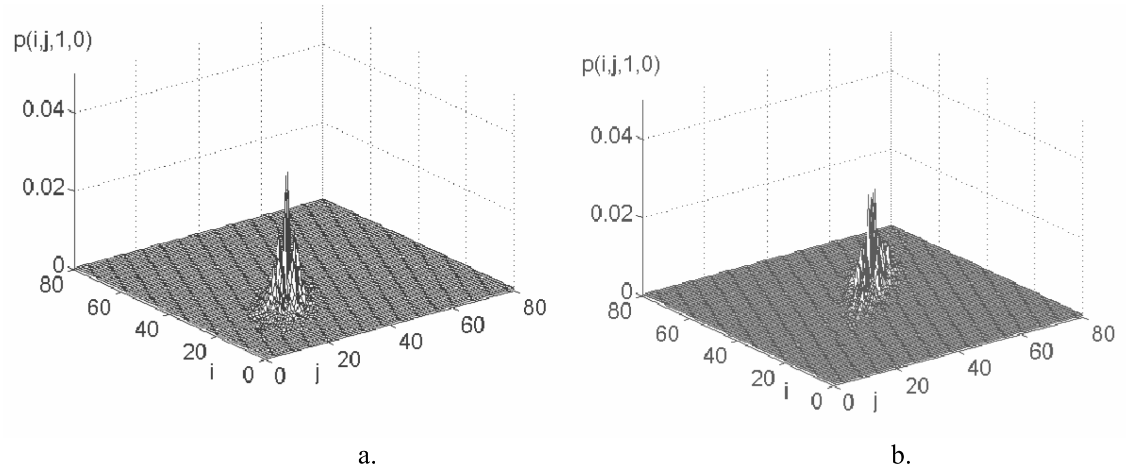


Fig. 2 3D-representation of the grey level co-occurrence matrix of foil images for d=1 and α=0° a/ AG36, b/ AC700

3. Experimental results

To verify the possibilities of classification of foil images of ten foil samles from which two samples of the foil are the same, have been gained in the same condition. We chose the signature vector, which components were the mean value and the centred moments of distributions of the 2nd to the 4th order . In addition to the whole images characteristics, we have also assigned their four disjunctive parts. Fig.3.a shows projection of signature vectors of individual classes (classes are individual types of foil) into the plane which coordinates are the mean value and the variance. Using a suitable choice of signatures there is a tendency to the grouping of patterns of individual classified classes . In fig. 3.b a detail from fig.3.a is illustrated. By the probabilistic neural network was verified 100% successfulness to classify all samples from the training set. Selected signature vector for given groups of foils enables to create separable clusters in the space of features, that fig. 3 demonstrate.

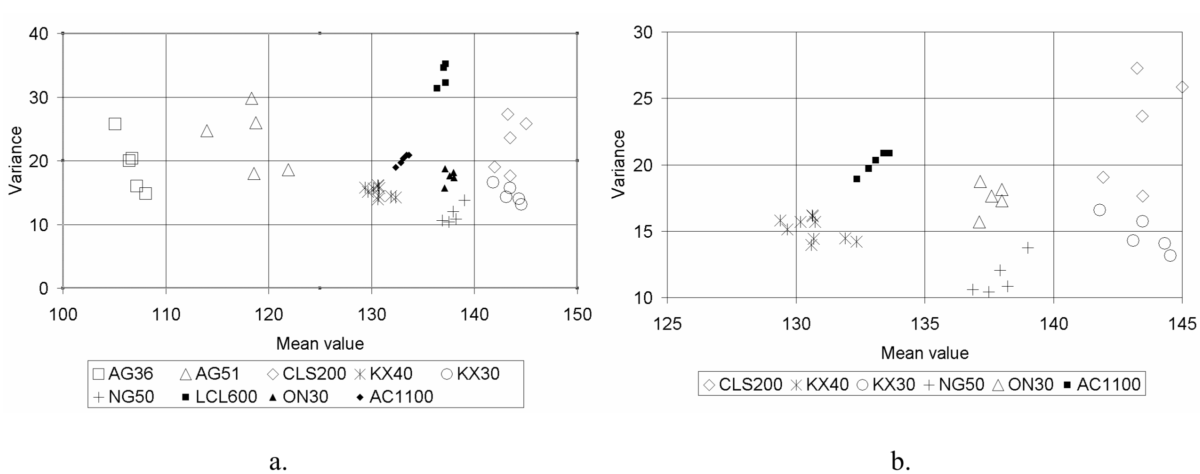
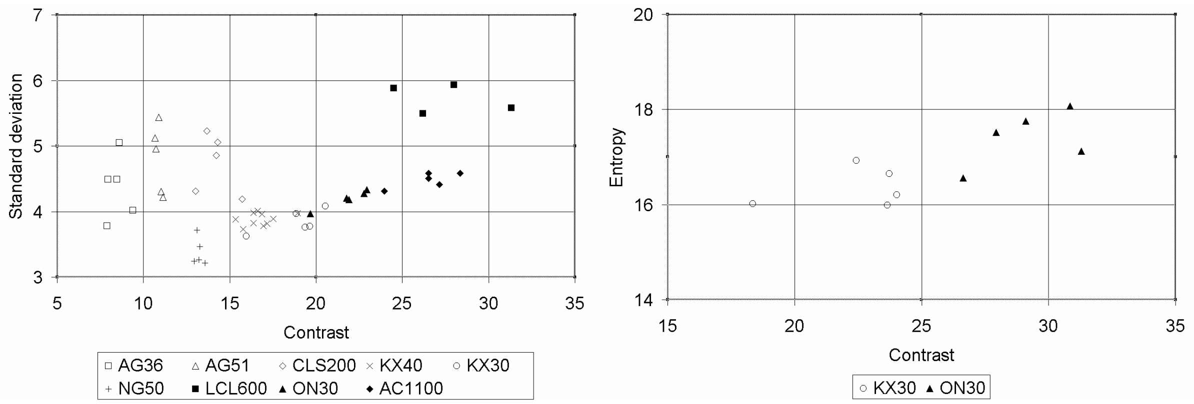


Fig. 3 a/ Projection of patterns of tested foils images to the plane mean value x variance, b/ projection of patterns of tested foils images to the plane mean value x variance (part of graph from fig. 3.a)

Fig. 4 exemplifies tendency to the grouping and to the separation of patterns of the same classes as used in previous case. The features were computed from the co-occurrence matrix. For the successful classification it was necessary to use signature vector containing 3-elements, e.g. contrast, standard deviation and correlation.



a. b.

Fig 4. Projection of patterns of tested foils images to the plane
a/ $(f_{1,1,90}\ x\ f_{3,1,90})$ (contrast for d=1 and α=90° , standard deviation for d=1 and α=90°),
b/ $(f_{1,1,45}\ x\ f_{2,1,45})$ (contrast for d=1 and α=45°, entropy for d=1 and α=45°)

4. Conclusion

Schlieren visualization method completed with some statistical characteristics calculated from the pre-processed image is a suitable tool enabling classification and identification of polymeric foils. Methods of identification of transparent polymeric foils are possible to apply to the comparison of different types of foil samples, or to the evaluation of technology parameters . In [6] there is an interesting application of comparison pieces of foils in forensic science even if in this case only visual comparison of various pieces of the same polymeric foil was used without the quantitative assessment of images.

References

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