The Use of Colour Image Properties in the Classification of Transparent Polymeric Foils

R. Ravas, L. Syrová, J. Grman

Department of Measurement, Faculty of Electrical Engineering and Information Technology, Ilkovičova 3, 812 19 Bratislava, Slovakia
Email: rudolf.ravas@stuba.sk

Abstract. *The contribution treats the problem of experimental analysis of statistical properties of colour image of visualized optically transparent polymeric foil by means of schlieren method. Intensity images of red, green, blue component and grey-scale representation of colour image were used. Subject of the analysis was recognizability of the type of foil by the features calculated from characteristics of histogram of intensities level and intensities co-occurrence matrix of foil image. Minimal numbers of incorrect classified foil samples into feature convex subspaces were compared. Subspaces were separated by the linear hyper-spaces. Experiment showed that number of errors of foil sample classification depends on the used colour component, eventually on the combination of colour components and combination of characteristics describing the image. The use of colour images increases reliability of the classification of the foil type.*

Keywords: polymeric foil, classification, colour images

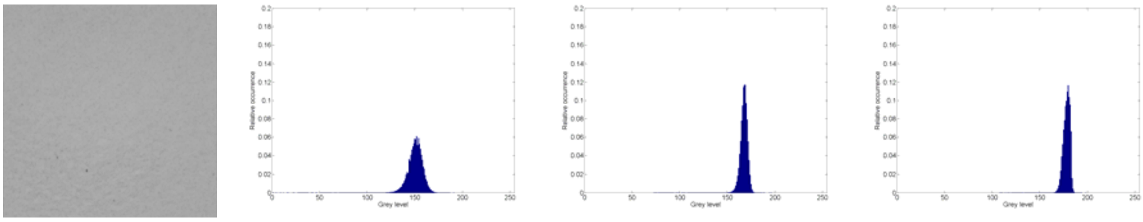
1. Introduction

Optical visualization methods are sensitive to the changes in the absorption of photons during their transmission through mechanically loaded regions of transparent materials such as optically transparent polymers and, especially, polymeric foils. The methods use the fact that the material density is a function of the refractive index of tested foil. The intensity of photon absorption changes especially in the area of deformation, which results in a change of the refraction index. The change of the refraction index can be visualized [1]. Therefore the main advantage of all visualized methods is, that they provide useful information for further processing after photographic or digital recording. Considering the available instrumental facilities and required sensitivity of measurement, we have chosen the schlieren method. The schlieren system [2] enables to measure the amount of light deflection generated by a transparent optical phase object. When there is a disturbance in the optical path the light is deviated from its nominal course in the absence of refractive index variations. Optical disturbance in the test object will produce variations of recorded light intensity that are a measure of the deflection experienced by the light in the test object. Obtained results can be processed using methods of image processing. Results of papers [3], [4] refer to possibilities of schlieren visualization method in the field of the diagnostics and classification of optically transparent polymeric foils by means of statistical methods.

2. Image Processing of Colour Visualized Polymeric Foils

At the experiments whose results already have been published, the image characteristics were calculated by different methods only from the greyscale images. One of the problems of experimental analysis is to find whether numerical characteristics calculated for the individual colour components would have similar properties (values) to the characteristics of greyscale image. It can be of course expected that properties wouldn't be the same because of two reasons. At first the source of homogenous light won't have the same intensities of RGB components after decomposition and for the second schlieren method is based on the visualization of anomalies due to light beam deflection caused by the change of refractive index in tested material. The angle of deflection depends on the value of refractive index and wavelength of light beam. The purpose of experimental analysis is to find, whether the numerical characteristics calculated for the different spectral component would be redundant to the characteristics calculated for the greyscale image or whether they would be useful for the classification.

In Fig.1 are presented sample of corrected image of visualized polymeric foils and its histograms of colour components.



a. b. c. d.

Fig. 1. a/ Sample of corrected image of visualized polymeric foil KXE30, b/ Histogram of intensity of blue c/ of green d/of red component

One of the groups of classifiers are signature classifiers. They are based on the object description by the vector ***x*** of numerical characteristics x_s belonging to the classified object. Purpose of the classification is on the basis of the vector ***x*** describing the object to classify the object into one of the finite set of classes ω_r. Under the class we understand the subset of objects with the common property. In our case the common property is the type of foil of classified sample represented by the image. Objects are assigned to the class ω_r on the basis of decision rules. For the analysis of classifiability of foils we use simple decision rule (1)

$$d(\mathbf{x}, \omega_r) = \arg\min_r \sum_{s=1}^{S} \frac{(x_s - E_{rs})^2}{D_{rs}} \quad (1)$$

where

E_{rs} mean value of feature x_s of images of foil from the class ω_r

D_{rs} variance of feature x_s of images of foil from the class ω_r

The rule (1) separates the S- dimensional signature space into disjunctive convex subspaces bounded with linear hyper-planes. In the case when the signature subspace is separated in such way that all patterns of the objects belong to the subspace for their class we reach 100% successfulness of classification. In opposite case we can use either the statistical approach of classification or the space can be separated by the nonlinear hyper-planes.

3. Results

The effect of colour of light on the properties of classifier was experimentally examined. We used 6 samples of foils. One sample (OOL30) belongs to foils with marked structure of foil image. For 5 of other samples the indistinctive image structure is characterized by weak changes of intensities that are typical for very thin foils. Recognition of this group is more difficult what is caused by the imperfection of intensity correction of schlieren apparatus and by the presence of small deformation on the foil surface. Proportion in deformations intensities of foil images is very small for foil with marked structure. There were 16 samples of foils KXE20, OOL30, 15 samples KXT21, ON25, 14 samples ONE21 and 6 samples KXE30 in the set of analyzed samples. We used a colour digital camera with resolution 5 mega-pixels. The signatures were calculated from the part of images with dimensions 1400x1400 pixels. The signature vector consists of 13 components for each colour component (r, g, b) and greyscale, together S=52. Signatures were calculated from histograms of intensities level and from co-occurrence matrix [5]. In table 1 is a survey of characteristics,

Table 1. Survey of characteristics calculated from histograms and co-occurrence matrix and their indices

s	Feature	s	Feature	s	Feature
1	$m = \sum_i ip(i)$	6	$\sum n^2 \left\{ \sum_i \sum_j q(i,j) \right\}_{\lvert i-j \rvert = n}$	11	$\sum_i \sum_{j \neq i} q(i,j) / (i-j)^2$
2	$\sigma = \sqrt{\sum_i (i-m)^2 p(i)}$	7	$\left(\sum_i \sum_j (ij) q(i,j) - m_C^2 \right) / s_C^2$	12	$\sum_i \sum_j q(i,j) / (1 + \lvert i-j \rvert)$
3	$\left(\sum_i (i-m)^4 p(i) \right) / \sigma^4$	8	$-\sum_i \sum_j q(i,j) \log_2 q(i,j)$	13	$\sum_i \sum_j (i+j-2m_C)^2 q(i,j)$
4	$m_c = \sum_i i \sum_j q(i,j)$	9	$\sum_i \sum_j q^2(i,j)$		
5	$s_C = \sqrt{\sum_i .(i-m_C)^2 \sum_j q(i,j)}$	10	$\max\{q(i,j)\}$		

where

i, j intensity level of image i, j $\in <1, I_{max}>$

p(i) probability of occurrence of intensity level i in the image

q(i,j) element of intensity co-occurrence matrix defined by (2)

$$q(i,j) = \frac{Q(i,j)}{\sum_i \sum_j Q(i,j)} \qquad Q(i,j) = \# \{ [(x,y),(u,v)] \mid y = v, \lvert x-u \rvert = 1, I(x,y) = i, I(u,v) = j \} \qquad (2)$$

where

\# denotes number of elements of set

I(x,y) intensity function of image

Signature space was normalized for all coordinates to the interval <-1, 1>. At first subspaces they were sensed for each component separately. It is not possible to realize systematic search of the whole space in regard to the number of the possible combinations 2^{52}. We should find such a combination of features that would reach minimal non-successfulness of classification at the minimal number of features. One of the possible results for each type of image is presented in table 2. Table contains results of several experiments. In the first part of the table there are numbers of incorrect classified foils for the classes marked by the index 1-KXE20, 2- KXE30, 3- KXT21, 4- ON25, 5- ONE12, 6- OOL30.

Those marked features, whose combination with the minimal number of features gave minimal number of non-correct classified foils samples are listed in the second part of the table. The total number of non-correct classified foils for the features calculated from red, green, blue, grey images and their combination are presented in the third part. The value behind the slash means the number of non-successfully classified samples in the case that all 13 features were used.

Table 2. Number of incorrect classified foil samples into the individual classes for minimal number of features and for minimal total number of incorrect classified samples

	Index of class						Index of selected feature													Sum of errors
	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11	12	13	
Red	1	4	3	8	0	0	1	1	1		1	1								16/18
Green	0	2	1	2	1	0			1				1			1	1			6/10
Blue	1	1	2	1	1	0	1	1	1		1		1							6/10
Gray	0	2	1	4	1	0	1		1			1		1						8/12
Blue& Green	0	0	1	1	0	0			1				1	1		1 1	1 1			2

4. Conclusions

Better results were reached for all types of images when compare the case of selected features and the case when all features have been used. The decomposition of the signature space to the convex subspaces separated by the linear hyper-planes was more successful for intensity images from blue and green component of acquired colour image. When we compared results for grey-scale image (that was formally used by means of all features when the non-successfulness of the correct classification was 14,6 %) the non-successfulness dropped to 2,4% at the selected combination of features of green and blue component. Experiments showed that the statistical properties of visualized images of optically transparent polymeric foils were dependent on the choice of the colour component of the image.

Acknowledgements

We gratefully acknowledge that the results presented here were solved as partial goals of the research task VEGA No. 1/0480/09.

References

[1] Smith A. J., Lim T. T. Flow Visualization. Imperial College Press, London, 2000.

[2] Bolf J., Bajcsy J., Bolf P.: Methods of the Properties Testing of Optically Transparent Materials. *Journal of Electrical Engineering* , 44 (8): 244-247, 1993.

[3] Syrová L., Ravas R., Jambrich, M., Grman J. Use of Statistical Approach for Image Analysis of Visualized Transparent Polymeric Foils. *Vlákna a textil,* 12(4): 177-184, 2005.

[4] Syrová, L., Ravas, R., Grman, J. The Use of Schlieren Visualization Method in the Diagnostic of Optically Transparent Polymeric Foils. *Journal of Electrical Engineering*, 58, (5): 257-264, 2007

[5] Haralick, R.M., Shapiro, L.G. Computer and Robot Vision. Addison-Wesley Publishing Company, New York, 1992.