APPLICATION OF THE IMAGE ANALYSIS TECHNIQUE FOR TEXTILE IDENTIFICATION

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Abstract

Computer image analysis techniques used for identifying textile products, especially linear textile products, are presented in this paper, together with a brief review of the historical development of these methods. Automatic and semi-automatic image correction methods are described, which are often applied for identification of linear textile products, and can also be used to identify spliced yarn-end connections.

Key words:

digital image acquirement, image modelling, image quality improvement, image correction methods, median filtration, Laplace filter, threshold function, autocorrelation, Fourier transform, erosion, dilatation, digitalisation algorithm

Introduction

The dynamic development of computer techniques creates broad possibilities for their application, including identifying and measuring the geometrical dimensions of very small objects including textile objects. Using digital image analysis permits a more detailed analysis of such basic structural parameters of linear textile products as thickness, hairiness and number of twists. What is more, this technique also enables the estimation of other characteristic features of the external structure of linear textile products, such as twist parameter and linear density coefficient [6]. The process of identifying structural yarn parameters is a significant problem, in the light of both hitherto conducted scientific investigations and current industrial practice. On the basis of the literature considering this problem, we can state that the image processing technique enables images of longitudinal & transversal cross-sections of fibres to be obtained, the fibres' diameters to be further assessed, and images of linear textile products create which allow the observation of possible yarn faults and the determination of their causes. The images obtained can help to create two-dimensional and three-dimensional textile products, including images of spliced yarn-end connections and estimates of their correctness. On the basis of the literature, it can also be concluded that digital image processing of the textile products' images mainly considers the computer processing of 2D-images.

Basic concepts used for digital image processing

The digital analysis of two-dimensional images is based on processing the image acquirement, with the use of a computer. The image is described by a two-dimensional matrix of real or imaginary numbers presented by a definite number of bytes [1]. The system of digital image processing may be presented schematically as shown in Figure 1.

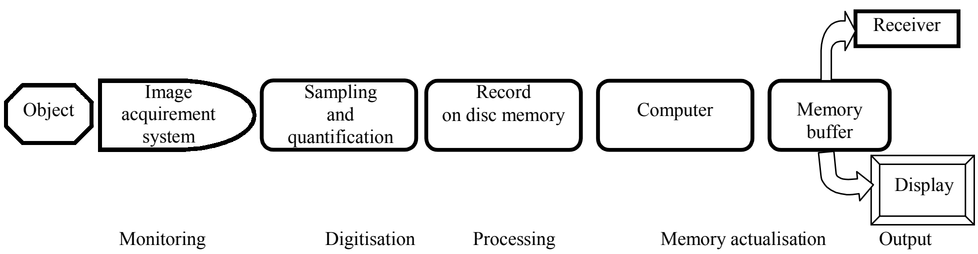

Figure 1. Scheme of the sequence of the basic functions realised by a typical digital image processing system [1]

Digital image processing includes:
- image acquirement and modelling,
- image quality improvement and highlighting its distinguishing features,
- reinstating the desired image features, and
- compression of image data.

Image modelling [1] is based on digitising the real image. This process consists of sampling and quantifying the image. The digital image can be described in the form of a two-dimensional matrix, whose elements include quantified values of the intensity function, referred to as grey levels. The digital image is defined by the spatial image resolution and the grey level resolution. The smallest element of the digital image is called the pixel. The number of pixels and the number of brightness levels may be unlimited, although while presenting computer technique data it is customary to use values which are multiplications of the number 2, for example 512×512 pixels and 256 grey levels.

Image quality improvement and highlighting its distinguished features are the most often used application techniques for image processing. The process of image quality improvement does not increase the essential information represented by the image data, but increases the dynamic range of selected features of the acquired object, which facilitates their detection.

The following operations are carried out during image quality improvement:
- changes of the grey level system and contrast improvement,
- edge exposition,
- pseudo-colorisation,
- improvement of sharpness,
- decreasing the noise level,
- space filtration,
- interpolation and magnification, and
- compensation of the influence of interference factors, e.g. possible under-exposure.

Methods of image correction

The histogram method is one of the simplest image correction procedures. Woźnicki [1] defined a histogram as a statistic distribution of particular grey level features occurring in the digital image. This procedure is used mainly for increasing contrast, raising the shade of over-exposed images, and highlighting under-exposed images [1]. The modification of a histogram changes the histogram edge's function. An example of applying this method for levelling a histogram is presented in Figures 2 and 3. The method of averaging a histogram is often used by intuition.

Figure 2. Image of a woven fabric before the procedure of levelling the histogram (elaborated by the authors)

Figure 3. Image of the woven fabric from Figure 2 after the operation of levelling the histogram (elaborated by the authors)

Another method of image correction is averaging the brightness function, which is called the averaging mask procedure. Applying this procedure results in substituting the primary brightness of the given pixel by the average brightness of a selected surrounding. This procedure aims to eliminate the small deformations which are manifested when exposed points or spots occur [1]. The use of the averaging mask procedure in digital image processing increases the sharpness of the objects' shapes. The result of using such a mask is shown in Figure 4.

Figure 4. Image of the woven fabric from Figure 2 after the operation of levelling the histogram and using the procedure of the averaging mask (elaborated by the authors)

Median filtration refers to the option of averaging the brightness function, and is based on a different rule of determining the new pixel value than is done in the averaging mask procedure. The median filtration is not based on using the average pixel value of a selected surrounding, but accepts the nearest brightness value which exists in the given surrounding. The median filtration stresses and marks off the contours existing in the image. An example of the application of this procedure is presented in Figure 5. By using the median filtration together with averaging filters, we can obtain better effects than without these filters, as averaging increases the efficiency of contour allocation. The median filter may be used at all colour modes, with the exception of the 48-bit RGB mode, the 16-bit grey range, the colour mode with palette, and the black-and white mode.

Figure 5. Image of the woven fabric from Figure 2 after the median filtration operation (elaborated by the authors)

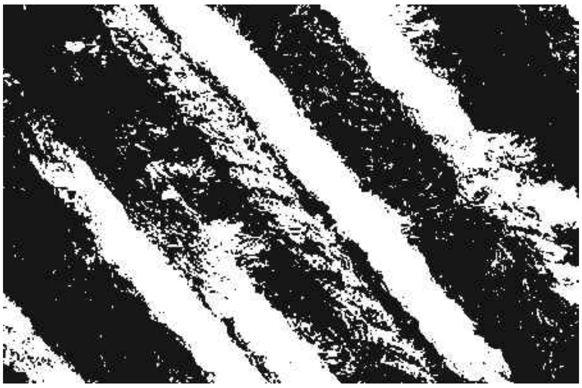

Figure 6. Image of the woven fabric from Figure 2 after the threshold procedure (elaborated by the authors)

The threshold procedure, which is one of the gradient methods, is used for extracting the contours from the image analysed. It is based on changing the brightness function value of the particular image pixels. Many kinds of mask can be used for applying gradient methods. The Laplace filter is an example of a gradient filter which enables a contour to be extracted, while at the same time it maintains the previous brightness inside the marked–off area. The grey-scale thresholding process enables image segmentation. It can be carried out by applying a process in which the grey level of the surface of the image analysed is compared with a defined grey level. As the result of this comparison, every area is accepted as white, if its grey level is higher than that of the defined threshold, and as black, if the grey level is smaller than the value of the defined threshold. The threshold procedure enables boundary brightness values to be determined and set, in other words, setting a threshold. Pixels with values higher or lower than the threshold value are projected as white or black depending on the selected option. The remaining pixels are not changed, and maintain their previous colour. The option of 'both levels' causes all pixels to change into white or black, according to the value relation of their brightness to the threshold value defined. The threshold can be determined for the whole mask of the image analysed or for a selected colour channel only [2]. An example of applying the threshold procedure is presented in Figure 6.

Autocorrelation is a different image processing technique, which combines all the analysed image fragments, and is often used to characterise repeated mask structures of the image analysed. Applying autocorrelation creates the possibility to determine the average dimensions of repeated units of the object's analysed mask. This technique makes it easy to reproduce the repeated pixel units in relation to the whole image analysed [3]. An image processed by this procedure is presented in Figure 7.

Frequency methods, in turn, are based on modification of the Fourier transform of the intensity function. An improvement of the analysed image is obtained by determining the reverse transform. Frequency methods require great calculation power, as filtration includes all the points of the image in the frequency space, and not only some limited surrounding of the given pixel. Frequency methods enable such factors to be eliminated or compensated, such as illumination inhomogeneity and the geometrical faults of the image acquirement path. Application of low-pass and high-pass filters enables the intensity function and contour underlining to be smoothed out. An example of applying this method is presented in Figure 8.

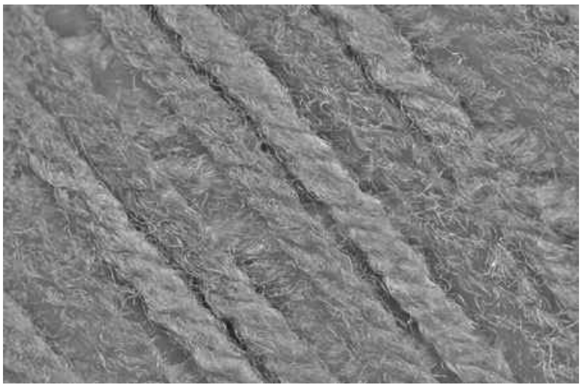

Figure 7. Image of the woven fabric from Figure 2 after application the technique of integrating the object's mask structure by the autocorrelation procedure (elaborated by the authors)

Figure 8. Image of the woven fabric from Figure 2 after application of the frequency method based on the Fourier transform (elaborated by the authors)

Erosion and dilatation are among the commonly applied morphological operations used to correct the image analysed. The correction procedure of erosion and dilatation is based on adding or eliminating pixels from the mask of the binary image, according to the rules formulated on the basis of standards obtained from neighbouring pixels. An example is shown in Figure 9.

Figure 9. Image of the woven fabric from Figure 2 after application of the erosion and dilatation procedure on the mask previously processed by the threshold procedure (elaborated by the authors)

Reinstating desired image features

Reinstating desired image features [4] is connected with eliminating and minimising any image features which lower its quality. Acquiring images by optical, opto-electronic or electronic methods involves the unavoidable degradation of some image features during the detection process. Aberrations, internal noise in the image sensor, image blurring caused by camera defocusing, as well as turbulence and air pollution in the surrounding atmosphere may cause a worsening of quality [1]. Reinstating the desired image features differs from image improvement, whose procedure is related to highlighting or bringing to light the distinctive features of the existing image. Reinstating the desired image features mainly includes the following corrections:

- reinstating the sharpness lowered as the result of disadvantageous features of the image sensor or its surrounding,
- noise filtration,
- distortion correction, and
- correction of sensors' nonlinearity

Image data compression

Image data compression [1] is based on minimising the number of bytes demanded for image representation. The compression effect is achieved by transforming the given digital image to a different number table in such a manner that the preliminary information amount is packed into a smaller number of samples.

Application of image processing techniques to analyse and recognise objects

On the basis of a review of the literature, it can be stated that the image processing technique is based on using analogue and digital optoelectronic devices and systems which allow an image with special information distribution to be placed at the input or output of the system. Independently of analogue and digital image processing units, the image processing technique includes image recognition and computer graphics. The image analysis and recognition is connected with image detection and processing, its projection, transmission and information storage, as well as image recognition and generation [5]. The broad interdisciplinary field of image techniques includes more and more subsequent areas of theoretical and experimental knowledge, of constructional, technological, system, hardware, and software experience. The dynamic development of the image processing technique means that application of this technique is broadened, and covers other areas of science, including textile science, which results from significant development into fields such as material engineering and technology, as well as digital techniques and computer engineering.

Image processing is not a new field of processing techniques. During the long preliminary period, optics had a fundamental impact on the formation and development of this field of science. At present, informatics (information science and technology) and microprocessing technology have broadly influenced the rapid development of the image processing technique.
The image processing technique includes the following notions:

- *image processing*, which includes changing the image or sequences of this image, characterised by certain features, into images of other desired features,
- *image recognition*, with the aim of identifying selected image features and objects which are the subject of interest; image recognition enables image selection, and
- *computer graphics* with the aim of creating images on the basis of the assumed description.

A brief historical review of image processing techniques designed for identifying textile fabrics

Digital analysis can be applied for identifying and measuring the geometrical dimensions of textile objects with very small dimensions; in particular it enables the structure of the objects investigated to be analysed. The process of identifying structural parameters is an essential matter when considering the methodical analysis of scientific investigations, as well as from the point of view of industrial practice [6, 7]. On the basis of the literature connected to this problem, we can state that the image processing technique enables pictures of objects, longitudinal and perpendicular fibre cross-sections to be prepared, and on the basis of the latter, that fibre diameters can also be determined. In turn, it is possible to prepare views of linear textile objects in order to observe possible yarn faults and determine the reasons why they occur, especially views of yarn end joints, and on this basis it is possible to estimate their correctness. By using this technique, researchers can measure the basic structural parameters of linear textile products, such as thickness, hairiness, and number of twists [6]. The technique discussed also enables images of flat and three-dimensional textile objects to be prepared.

Pohole [7] first applied digital computer image analysis in the textile field. In the 1970s, he used it to estimate the cross-section areas of wool fibres. New ways of applying the image processing techniques created possibilities of analysing results of measurements of fibres' cross-section areas, estimating the irregularities of fibre blending on the surface of yarn blends, of cotton maturity, and of damage to wool fibres. These problems have been the subject of research carried out by Berlin, Worley, Raey [8], Thibodeaux, Evans [9], Watanabe, Kurosaki, Konoda [10], Zhao, Johnson, Willard [11], Żurek, Krucińska, and Adrian [12], among others. The quick development of image processing techniques in the 1990s paved the way for research into new procedures of this analysis.

A new quality of the digital image analysis is characterised by the works of Wood [13], and Wu, Pourdeyhomi & Spivak [14], who tested and estimated carpets during usage. These researchers used frequency methods based on the Fourier transform for image analysis. Thanks to this new procedure it became possible to identify structural faults.

An algorithm for image digitisation, which served to estimate morphological nonwoven features such as porosity, fibre orientation distribution in the nonwoven, and estimation of the fibres' regularity distribution in webs has been developed by Huang and Bresee [15]. These researchers also applied an automatic measurement process based on the procedure of image correction by using the procedure of grey scale thresholding.

Zhang and Bresee [16] compared various image analysis techniques aimed at recognising and classifying two kinds of faults, those of yarn joints and thick places occurring in woven fabrics. They applied image segmentation using threshold values of the object's mask. Independently, they also carried out procedures of image quality improvement using correction operations such as histogram levelling, autocorrelation, erosion, and dilatation. They stated that applying image correction with the use of the method of statistically determining the image's grey level (threshold procedure) is more efficient than morphological operations using simple procedures of removing the differences of the object's mask by erosion or dilatation. According to Zhang and Bresee, applying morphological methods for the image processing technique requires greater calculation power compared with using the statistical methods, considering the higher quality of processing the image mask which is demanded.

Describing Polish achievements, it should first be stated that Cybulska [6], [17] and Masajtis [18-19] developed an image digitisation algorithm used for estimating the surface of threads.

Cybulska [6], [17] also proposed her own methods for estimating yarn structure using digital image analysis. She carried out an assessment of the yarns' basic structural parameters such as thickness, hairiness, and twist, applying the image processing technique expanded by numerical methods. The method proposed enabled numerical structural characteristics to be obtained at every point of the yarn length, as well as acceptable average values and dispersion measures for the yarn's structural parameters.

The team directed by Krucińska [20] elaborated a digitisation algorithm serving for web estimation.

In turn, Kopias, Mielicka and Stempień [21] used image digitisation to evaluate pneumatically spliced polyurethane and textured yarns. For the image digitisation they applied a method based on a scanner connected to a computer stand equipped with software programs designed for automatic object recognition. Abnormalities in the automatic image recognition process were eliminated manually.

The segmentation technique, which joins the level of preliminary image processing with the analysis thresholds of the particular objects, is used in the computer image analysis. It enables the selection of image areas which fulfil the defined homogeneity criteria of the mask; this means distinguishing objects in the digitisation process which differ from the background. A comparative analysis of selected segmentation methods based on the colour intensity gradient was carried out by Krucińska and Graczyk [22], who measured the area of the fibres' surface. Based on Materka's investigations [23], they measured the number of pixels which belonged to the given object, and next multiplied that by the real area in pixels. The analysis indicated that the segmentation based on the intensity colour gradient of neighbouring pixels yields an almost identical result to manual segmentation. This results from the similar working principle of both the algorithms and the human mind, as a human who looks at an object distinguishes its boundary firstly at places characterised by the greatest changes in colour intensity. According to Woźnicki [1], the resolution of the electronic path of the mask's image digitisation has the greatest influence on the final resolution of the digital image and the digitisation process, and the resolution of the optical system only to a lesser degree. Woźnicki, in his book on the basics of image processing technique [1], also describes the sources of errors of the image acquirement, indicating the need for special attentionto be paid to image geometry errors. These errors are especially important in the sampling processing; they lie in a deformation of the rectangular net accepted as the test image, and represent the distortion aberration. The greatest image deformations occur at the image border, and this is the reason that the measurements should be performed in the middle of the image. The illumination also has a great influence on the quality of the digital image acquirement. According to Kopias and Jurasz [24, 25], while measuring the geometry of textiles, it is most advantageous to analyse images of flat structures obtained by illumination with reflected and transmitted light. Using optical systems with CCD transducers enables the best results to be obtained by image re-acquirement; deformations can occur only at the margins of the image mask. According to Tadeusiewicz and Korohoda [26], the image's non-linearity can be corrected by special software, which would (after the transducer) experimentally correct the coordinates, using standards or combining these both methods. Investigations into the geometry of standard objects and estimation of their inhomogeneity have been carried out by Perzyna, who described these problems in his Ph.D. thesis [27].

Conclusions

The development of computer techniques offers many opportunities for its applying in textile science and practice. Use of computer image analysis, among other techniques, has enabled the identification of geometrical dimensions of very small textile objects. Using image correction techniques allowed the elimination of structural faults in the fabric which earlier would have been ignored. Applying image correction techniques enables a detailed identification of the structure and geometry of linear textile fabrics. Elaborating the digitisation algorithm, combined with numerical methods, allows the numerical characteristics of a textile product's structure to be obtained.

On the basis of an analysis of the hitherto applied digital image analysis methods in textile science and practice, and as a result of many attempts, the authors have developed an original method of digital image analysis designed for estimating the parameters of spliced yarn-end joints. The procedure of digital image analysis used enabled the estimation of the parameters of the external structure of spliced yarn-end joints of unlimited length, together with numerical characteristics. The microphotos obtained as a result of the computer image analysis may serve for further investigations into the estimation of the quality of the spliced yarn-end joints, and could allow a quick recognition of the possible inaccuracies of the process of joining yarns without knots.

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