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Influence of Initial Image Preparation on the Result of the Image Digital Analysis

Abstract

The result of investigations into selected image pre-processing methods are presented, based on ten cases of programmed and disturbed fabric images. The result of these operations was evaluated, after conducting "cluster analysis" using the author's program for fabric analysis. The numerical values from this program were verified, and form the basis for assessment of the suitability of the program for useful to further digital analysis.

Key words: *digital image analysis, image quality improvement, fabric.*

Introduction

Since the 1980s, articles have been written, which concern computer image analysis issue for estimating fabric parameters [1-3]. The identification of warp and weft threads in woven fabric is taken into account in article [1]. An accounting procedure was proposed to detect the central thread lines and to estimate the crossing of these lines. Pre-processing the image concerned changing the full grey scale into 2 levels: black and white. This has been carried out by erosion and dilatation operations, which allow the smoothing of area of clearances for further analysis.

In article [2], a fabric pattern was identified by means of a Fast Fourier Transform power spectrum of the fabric image. The image for analysis was taken while lighted from above defined angles (10°, 70° along the warp, 70° perpendicular to the warp). This lighting arrangement caused enhancement of the warp overlap which characterised the fabric pattern.

The authors of article [3] have analysed fabric patterns by means of a digital fabric image, which was obtained using passing light. Thread spacing, fabric cover and crimp of threads were estimated. Each of these parameters requires additional image preparation. To estimate thread spacing, the image was improved by a histogram stretching operation, which made the image contrast better. Estimation of the fabric cover requires a threshold of separate areas of thread and clearance to be established.

The digital fabric image obtained from a microscope and CCD camera contains 'noise', which arises during image signal transmission from intermediary devices. This 'noise' can be partly reduced by subtracting from the digital image. The remaining part of the lost quality of the real image can by gained by initial digital image processing which is called pre-processing.

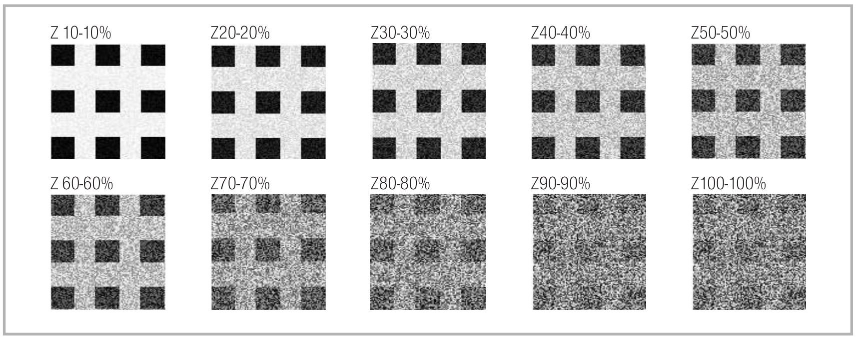


Figure 1. *Fragments of artificial images with disturbances from 0% to 100%.*

Table 1. *Selected methods of image quality improvement. Source of mask model [4-5]. Marks: L-linear, NL-nonlinear.*

Filtration			Names	Mathematical description
Spatial	L	low-pass	Dp-Average	(1, 1, 1, 1, 1, 1, 1, 1, 1) sum=9
			Dp-LP1	(1, 1, 1, 1, 2, 1, 1, 1, 1) sum=10
			Dp-LP2	(1, 1, 1, 1, 4, 1, 1, 1, 1) sum=12
			Dp-LP3	(1, 1, 1, 1, 12, 1, 1, 1, 1) sum=20
			Dp-Gaussa	(1, 2, 1, 2, 4, 2, 1, 2, 1) sum=16
		upper-pass	Gp-MeanRem	(-1, -1, -1, -1, 9, -1, -1, -1, -1) sum=1
			Gp-HP1	(0, -1, 0, -1, 5, -1, 0, -1, 0) sum=1
			Gp-HP2	(1, -2, 1, -2, 5, -2, 1, -2, 1) sum=1
			Gp-HP3	(0, -1, 0, -1, 20, -1, 0, -1, 0) sum=16
	NL	statistical	St-Median	(p1, p2, p3, p4, p5, p6, p7, p8, p9)
			St-Min	(p1, p2, p3, p4, p5, p6, p7, p8, p9)
			St-Max	(p1, p2, p3, p4, p5, p6, p7, p8, p9)
Point	L	histogram	Mhist-5%	5%
			MManual	-50%
	NL	functions	Nl-square	x^2
			Nl-Radical	$\sqrt{x}$
			Nl-Ln	Ln(x)
			Nl-log	Log(x)
			Nl-Exp	e^x
			Nl-Cubic	x^3

This processing is made by the method of image quality improvement (image enhancement), which can be divided into two fundamental groups: spatial and point operations.

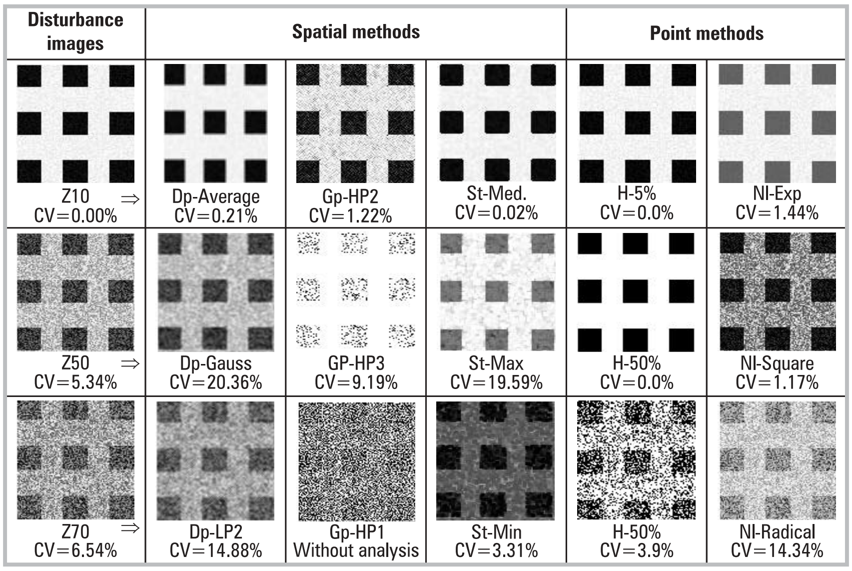
Spatial operations are methods in which the new point value is calculated on the basis of neighbouring pixels. Every neighbouring pixel supplies its own proportional participation to the grey value intensity calculations of new pixel. This participation is calculated in percentage value and is called the weight. The weights of the individual neighbouring pixels are grouped in add array - a splice mask. Each element of the splice mask is called the coefficient of splice. The splice filtration is shown as follows:

$$g(i, j) = f(i, j) * h(i, j)$$

where:
$f(i, j)$ - the original image,
$g(i, j)$ - the result image,
$h(i, j)$ - the filter mask.

Point operations are methods in which the new point in the new image is received without any influence on the other neighbouring pixels coming from the original image. Concrete mathematical operations are made on the concrete pixels.

Table 2. List of visual effects after use of image quality improvements.



Disturbance images	Spatial methods			Point methods	
Z10 ⇒ CV=0.00%	Dp-Average CV=0.21%	Gp-HP2 CV=1.22%	St-Med. CV=0.02%	H-5% CV=0.0%	NI-Exp CV=1.44%
Z50 ⇒ CV=5.34%	Dp-Gauss CV=20.36%	GP-HP3 CV=9.19%	St-Max CV=19.59%	H-50% CV=0.0%	NI-Square CV=1.17%
Z70 ⇒ CV=6.54%	Dp-LP2 CV=14.88%	Gp-HP1 Without analysis	St-Min CV=3.31%	H-50% CV=3.9%	NI-Radical CV=14.34%

The aim of this work is to test the objective estimation of effective different methods of image pre-processing. The investigations were carried out on ten variants of artificially created and disturbed plain weave fabric images. The values of this disturbance ranged

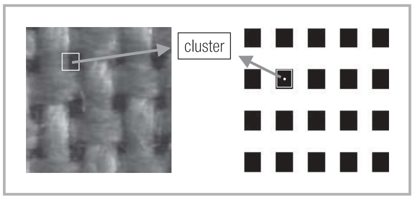


Figure 2. Part of the real and artificial image with marked cluster.

from 0 to 100%. These images were digitally processed by chosen methods of image quality improvement. The result of these operations was assessed after 'cluster analysis', the author's program to analyse fabric images.

Research Object

For research fabric images in ten cases of disturbance (from 0% to 100%) were digitally prepared (Figure 1). The disturbances simultaneously included the area of the threads and clearances. The disturbance was generated digitally in a random way from the definite range of the pixel's grey level.

Image parameters:
Image size - 512 x 512 [pixels]
Number of warp threads in image - 14 [threads]
Number of weft threads in image - 12 [threads]
Thickness of warp thread - 20 [pixels]
Thickness of weft thread - 21 [pixels]

Research Method

Method of image quality improvement
For this research, Delphi methods of image quality improvement (Table 1) have been prepared in programming language, which include both standard and more complicated methods.

Method of 'cluster analysis'
For the purpose of verifying the methods of quality image improvement mentioned in Table 1, 'cluster analysis' was carried out on each artificial image. This is the author's program for digital analysis of fabric image which uses a 'cluster analysis', and was prepared by means of Delphi. The main purpose of this program is pixel selection within a brightness range from 0 (black) to 255 (white) and finding clusters in the image area. A cluster in this case can be defined as a group of pixels in the digital image of the fabric with a brightness level of -40. This is the area of clearance between warp and weft threads. Figure 2 shows the clearance area in real and artificial fabric images.

Result and Discussion

The criterion for assessing the digital image analysis result is the CV-coefficient of the cluster field variability [%] for successive artificial images before and after processing by means of image quality improvement.

Low-pass filters let pass the image elements with low frequency, but damp the elements with high frequency. The images lose sharpness and become covered by 'fog' (Table 2). Only in one case does variability coefficient improve by 1%. For images Z10 and above Z30, the results become worse (Figure 3).

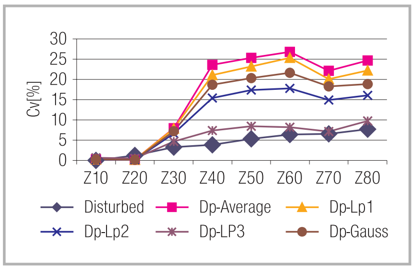


Figure 3. Influence of the low-pass filtration on the cluster field. Spatial filtration.

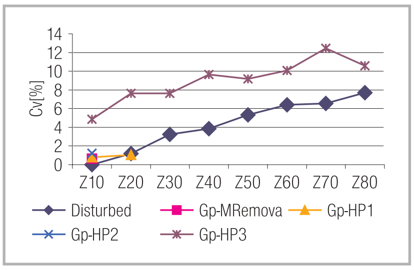


Figure 4. Influence of the upper-pass filtration on the cluster field. Spatial filtration.

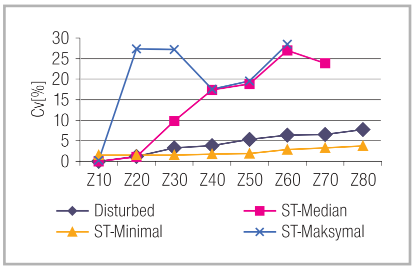


Figure 5. Influence of the statistical filtration on the cluster field. Spatial filtration.

the result of the analysis the same as in the visual effect.

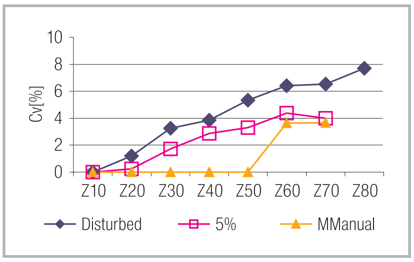


***Figure 6.** Influence of the histogram stretching on the cluster field. Point operations.*

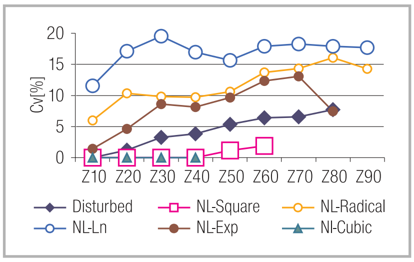
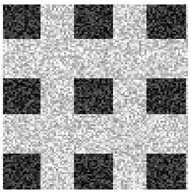
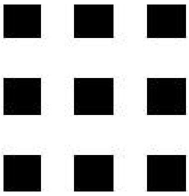
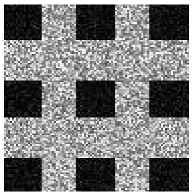
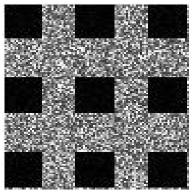


***Figure 7.** Influence of the non-linear filtration on the cluster field. Point operations.*

***Table 3.** Comparison of visual effect with value of variability coeff. for image with 40% disturbance.*

			
Z40 ⇒ CV=3.84%	Z40 –H50% CV=0.00%	Z40 –Nl-square CV=0.00%	Z40 –Nl-cubic CV=0.00%

Upper-pass filters cause great changes in brightness levels between neighbouring pixels, but small changes are left unaltered. For images with disturbance up to 50% (Table 2), the sharpness effect appears. Higher levels of disturbance are multiplied (Gp-HP1), which causes a loss of brightness. The visual effect has no correlation with the results, which means that visually better images do not receive a better result (Figure 4). Filter Gp-HP3 decreased disturbance in the threads area, and the variability coefficient was increased by an average of 5%. The exception is image Z20: for this image, filter Gp-HP1 minimally increased the value from 1.2 to 1.03%. The rest of the images were rejected by 'cluster analysis' due to noise multiplication in the threads area.

Statistical filters work by sorting pixel values from the selected mask range. For example, a 9-element mask of an image fragment is sorted from the smallest to the biggest value, and the chosen middle value is chosen for the medium filter, the minimal value for the minimal filter and the maximum value for maximum filter. The median filter works similarly to the low-pass filter, but does not cause a wash effect. A minimal filter makes the darkness of dark elements and their growth greater. A maximum filter increases the edge elements' brightness in the image (Table 2). The visual effect has no correlation with calculations. The median and maximum filters visually improve the effect of noise reduction. The value of the variability coefficient worsens, but this is an exception. For image Z20, this value increased by 0.1% (Figure 5)

The minimal filter does not give a good visual effect but does yield a considerably improved variability coefficient. It increases the result by an average of 3% for disturbances from 30% to 80%.

Modelling of an image grey level histogram yields good results. The cutting and stretching of the histogram by 5% is an efficacious method. This method improves the result by an average of about 1.5%. Manual histogram modelling for images with disturbance up to 50% decreased the value of variability coefficient up to as low as 0.00% (Figure 6). In this group of methods, the numerical results from analysis are very good, and the visual effect is very distinct. Subjective estimation is equal to objective estimation for images with 50% disturbance (Table 2).

Non-linear filters cause non-linear representation of brightness levels. The NL-square and NL-cubic functions for images up to 40% disturbance decrease the error of further analysis to zero (Figure 7). The very good effect of the image quality improvement can be observed in the majority of these filters, although it is not readily visible for those which gave very good results (Table 2).

According to these investigations, subjective estimation is not always equal to objective estimation. Below are shown images (Table 3) after histogram modelling and after equal and cubic filtration. The general visual effect is completely different that that obtained as a result of analysis CV=0.00%. Only in the histogram manual modelling is the result of the analysis the same as in the visual effect.

Conclusions

Usage of filters for image pre-processing can improve or deteriorate the results of further image analysis. Precise knowledge of the details of this process can help in selecting optimal filters, decreasing the entire error processing. The kind and order of the used filters a has very important influence on the quality of the image analysis.

- Low-pass filtration can improve the value of the variability coefficient by about 1% only for images with 20% accidental disturbance. Visually, the effect shows no image quality improvement.
- Upper-pass filtration can minimally improve the value of cluster field variability coefficient only for images with 20% disturbance. Visually better images do not yield better results. These filters will be used for visually evaluating the small and hidden details in image, and cannot be used as a first and last method of image quality improvement.
- After statistical filtration, the visual effect does not conform to the computations. One example is the minimal filter, which for disturbances from 30 to 80% improves results by an average of about 3%. This filter closes up the cluster area.
- Modelling a histogram is the best method to eliminate accidental disturbance. The disturbances to 50% can be completely eliminated up to CV=0.00%. The visual effect is the same as obtained by the computations.
- Non-linear filtration by square and cubic filters also allows an decrease in CV to 0.00%.
- The general visual effect or general subjective estimation are not always the same as the objective estimation of an image element. The images in which specific elements will be analysed should be prepared in such a way as to improve the visual effect of these specific elements.

❑

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