GREY LEVEL CO-OCCURRENCE MATRIX (GLCM) FOR TEXTILE PRINT ANALYSIS

Emilija Toshikj[1*], Bojan Prangoski[2]

[1] University "Ss. Cyril and Methodius", Faculty of Technology and Metallurgy, Department of Textile Engineering, Skopje, North Macedonia
[2] University "Ss. Cyril and Methodius", Faculty of Mechanical Engineering, Skopje, North Macedonia
[*] e-mail: tosic_emilija@tmf.ukim.edu.mk

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Abstract: *Print mottle is a print defect. This print defect has great attention in print quality assessment. Print mottle is determined by the grey level co-occurrence matrix (GLCM). An important parameter in the GLCM processing is the direction angle of pixels in the digitalized print image. This research aimed to investigate the influence of the direction angle, which is an important input parameter in GLCM processing, on the output parameters, such as entropy, energy, contrast, correlation, and homogeneity. Hence, prints were generated in four different colors (cyan, magenta, yellow and black) on white polyester elastase fabric by sublimation printing. The non-uniformity of the print for each color was processed at different direction angles, such as 0° (horizontal), 90° (vertical), 45° (right-diagonal), and 135° (left-diagonal). Values for GLCM parameters obtained at different direction angles were slightly different regardless of print color. The choice of direction angle influenced the values of GLCM parameters. The average of all four directional angle values obtained for each GLCM parameter was taken. The GLCM processing method can be used for prints of different colors, patterns, and different quality levels to evaluate their print uniformity..*

Keywords: polyester, sublimation printing, print mottle, direction angle, GLCM method.

MATRICA KO-POJAVLJANJA NIVOA SIVOG (GLCM) ZA ANALIZU ŠTAMPE NA TEKSTILU

Apstrakt: *Ujednačenost štampe je nedostatak štampe. Ovaj nedostatak štampe ima veliku pažnju u proceni kvaliteta štampe. Ujednačenost štampe je određena matricom ko-pojavljanja nivoa sivog (GLCM). Važan parameter u GLCM obradi je ugao pravca piksela u digitalizovanoj slici štampe. Ovo istraživanja je imalo za cilj da ispita uticaj ugla pravca, koji je važan ulazni parameter u GLCM obradi na izlazne parametre, kao što su entropija, energija, contrast, korlecija i homogenost. Dakle, štampe su generisani u četiri različite boje (cijan, magenta, žuta i crna) na beloj tkanina od poliestera i elastana sa sublimacionim štampanjem. Neujednačenost štampe za svaku boju obrađena je pod različitim uglovima pravca, kao što su 0° (horizontalno), 90° (vertikalno), 45° (desno-deijagonalno) and 135° (levo-dijagonalno). Vrednosti za GLCM parametre dobijene pod različitim uglovima pravca su se malo razlikovale bez obzira na boju štampe. Izbor ugla pravca uticao je na vrednosti GLCM parametara. Uzet je prosek sve četiri vrednosti ugla pravca za svaki GLCM parametar. Metod GLCM obrade može se koristiti za štampe različitih boja, šara I različitih nivoa kvaliteta, kako bi se procenila njihova ujednačenost.*

Ključne reči: polyester, sublimaciona štampa, ujednačenost štampa, ugao pravca, GLCM metod.

1. INTRODUCTION

Printing technology is advancing and changing intensively and rapidly [1-8]. As the industry of printing textile develops every day, great attention is paid to advancing and designing different techniques and unique prints. The constant need for improvement and development in textile printing imposes a constant need to improve the quality of the print [9-12]. A measure of success for color printing technologies is print quality [13]. It is an important customer requirement along with other requirements, such as price, productivity, connectivity, and reliability. The quality of the print is a criteria factor in the decision of the buyers when choosing and buying printed textile products. The purpose of print quality is to meet the needs of customers. Analysis of print quality is one of the common tools for assessing print quality and unambiguously transmitting results within and between companies in the printing industry. Print quality can also be used in marketing for product positioning. In science, print quality is used to obtain repetitive quantitative measurements to analyze results and to provide information for process and product improvement and development [13-15]. Results from analysis in production provide the efficient determination and elimination of errors. An unevenness in print density, referred to as print mottle, is a common print defect [13,16]. When judging the print quality, print mottle is of the most importance. The appearance of this type of defect on the printed textile is taken as an error that evaluates the entire quality of the print. In full-tone or half-tone prints, print mottle is measured.

Method for image processing through grey level co-occurrence matrix (GLCM) is used to assess print mottle [17-21]. This method is based on an analysis of the digitalized print sample in TIFF format. The formation of a grey level co-occurrence matrix is based on a digital image. The GLCM matrix is composed of grey levels pairs placed at a certain distance and direction angle of the pixels in the digitalized print image, while the pair of grey levels is composed of pixels, one of which is the reference and the other is adjacent. Possible directions are 0° (horizontal), 90° (vertical), 45° (right-diagonal), and 135° (left-diagonal). Statistical parameters of the first- and second-order are used to determine the non-uniformity of the print. It is possible to process from the GLCM matrix. First-order statistics give values for the standard deviation, and second-order statistics give values for the ratio between the pixels of the image in space so that a value is obtained that indicates whether the printed surface is uniform. A group of researchers found that print uniformity can be determined using GLCM parameters, such as entropy, energy, homogeneity, contrast, and correlation [16,20]. If the values for the contrast, correlation, and entropy parameters are low, and the values for the energy and homogeneity parameters are high, then the values of these parameters indicate a uniform representation of the grey levels, that is, they indicate a uniform print [18]. Print mottle obtained using a pixels distance of 1, 3, 6, and 12 was also examined, and found that each applied distance produced the same ratios between GLCM parameters. For that reason, only print mottle results obtained by using the distance of 1 pixel were used [16]. Some research has attempted to use the GLCM image processing method to assess print mottle in textile printing [22-24]. In the research done by groups of researchers, it was omitted to determine the influence of the direction angle of the pixels in the digitalized print image, as the input parameter, in the GLCM processing on the output values of the GLCM parameters [16,18].

The research work attempted to investigate the use of GLCM parameters as a print quality metric. From GLCM, parameters such as homogeneity, energy, contrast, correlation, and entropy were selected for this purpose. The proposed method analyzed the effect of direction angle, which is an important input parameter in GLCM processing. Different direction angles, which occupy the pixels in the digital image, used for the calculation of the GLCM parameters, were analyzed to determine their impact on the values of GLCM parameters.

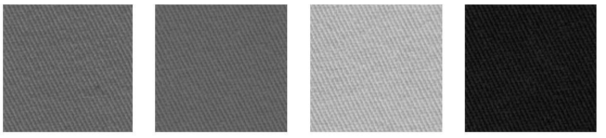
2. MATERIAL AND METHODS

2.1. Materials

Print mottle assessment was evaluated on sublimation printed white fabric, 97 % polyester and 3 % elastane with 160 g/m^2 weight, 0.36 mm thickness and 42 cm^{-1} and 22 cm^{-1} warp and weft densities, respectively.

2.2. Printing procedure

The white polyester elastane fabric was sublimation printed in cyan, magenta, yellow and black colors (the color system CMYK). For the analysis, a 150x150 cm sized test form was prepared in Adobe Illustrator software and printed on commercially available sublimation transfer paper with 105 g/m^2 weight. The test form consisted of four rectangular with 100 % solid-tone of cyan, magenta, yellow, and black color (Figure 1). EPSON Inkjet printer, with printing method: Micro Piezo^{TM} print head and nozzle configuration: 180 nozzles for black and 50 nozzles for color, was used for printing of sublimation transfer paper. The print resolution of 5760x1440 dpi was used. Dye sublimation inks for printing (Sublyfun) in cyan, magenta, yellow and black colors were purchased from Print Equipment Gmbh&Co. Pre-pressing and sublimation printing processes were performed with the heat press model BESTSUB SB3A (38cmx38cm) and medium pressure (2.3-3.5 bar). The pre-pressing process was performed at print temperature for 6 s. After the pre-pressing process, the sublimation printing process was performed at 190 °C for a pressing time of 80 seconds. Before being tested, the printed fabrics were conditioned in a standard atmosphere (temperature 20 °C and 65 % relative humidity) for 24 hours.



Cyan	Magenta	Yellow	Black
C = 100 %	C = 0 %	C = 0 %	C = 0 %
M = 0 %	M = 100 %	M = 0 %	M = 0 %
Y = 0 %	Y = 0 %	Y = 100 %	Y = 0 %
K = 0 %	K = 0 %	K = 0 %	K = 100 %

Figure 1: Sublimation printed fabric with cyan, magenta, yellow, and black dye sublimation inks

2.3. Testing methods

Print mottle was assessed by method for image processing using grey level co-occurrence matrix (GLCM). After sublimation printing, printed fabrics were scanned and digitalized by flatbed scanner EPSON at 600 dpi scanning resolution without auto-correction. The actual rotation angle determined by the orientation of the sample set in the sample input location was 90°. Scanned images in TIFF files were scaled at 500x500 pixels for easier processing in MATLAB. Then, samples were subjected to GLCM analysis to obtain quantitative print uniformity results. GLCM analysis was done in MATLAB software with code according to Uppuluri [25] using the following parameters: the number of grey levels was set to 8, the distance between two pixels (d) was set to 1 and four direction angles were used such as horizontal 0°, vertical 90°, right-diagonal 45°, and left-diagonal 135°. Print mottle using MATLAB code was assessed through entropy, energy, homogeneity, contrast, and correlation parameters. Calculating of GLCM parameters was performed for all four print colors (cyan, magenta, yellow and black).

3. RESULTS AND DISCUSSIONS

In GLCM, the direction angle of the pixel provides information on print non-uniformity. Therefore, in this research, different direction angles were used to consider the adjacent pixels (Figure 2). The distance between two pixels was set to 1 combined with four direction angles for all four print colors. The position between the pixels is represented by the different direction angles, such as 0° (horizontal), 90° (vertical), 45° (right-diagonal), and 135° (left-diagonal). The values of contrast, correlation, entropy, energy, and homogeneity GLCM parameters for obtained print in cyan color are shown in Figure 2. Contrast parameter generated from different direction angles showed quite different values. It can be seen that the contrast value was least at 90°, followed by 0°, 135°, and 45°. The drastic difference in intensity between pixels in an image at a certain direction angle is defined as a contrast. This GLCM parameter measures local grey level variation in a print image. The lower the variation between pixels in the image, the lower the contrast. The print is considered uniform when the contrast value is zero. In GLCM, how close the distribution of the pixel is measures homogeneity. The homogeneity parameter provides information on how close the distribution of the pixel is in a GLCM. Values for homogeneity were in a reverse trend of values for contrast. In the case where the values for homogeneity increase, then the values for contrast decrease. The homogeneity value was maximum at 90°, followed by 0°, 135° and 45° (Figure 2). The amount of change in a print gives information about the homogeneity. A homogeneity value of 1 corresponds to a homogeny print surface with no variations. In GLCM the similarity of the pixels is determined by the energy parameter. When the pixels in the image are more similar to each other, larger values are obtained for the energy parameter. The energy value parameter, like homogeneity, was maximum at 90°, followed by 0°, 135°, and 45°. The opposite trend of energy represents entropy. System disorder measures entropy. Obtaining the value of the entropy parameter from the image depends on choosing the correct direction angle. The entropy value was least at 90°, followed by 0°, 135°, and 45°. The entropy parameter was found to correlate well with the human perception of unevenness. Thus, unevenness is more visible if the value for the entropy parameter is higher [19]. In the samples for which higher values were obtained for the entropy parameter, it is easier to notice the unevenness of the print. However, the trend for contrast and entropy was not followed by the correlation parameter. The correlation value was maximum at 90° followed by 0°, 135° and 45° (Figure 2). The linear dependence of the grey levels between the referent pixel and its adjacent pixels is determined through the correlation parameter. The correlation parameter measures how a reference pixel correlates with its adjacent pixels. Range the values for the correlation parameter are from -1 to 1 [26], so that -1 indicates a negative correlation and 1 indicates a positive correlation. Low values of correlation correlate to the uniform print surface. Energy, homogeneity, and correlation values were maximum at 90° followed by 0°, 135°, and 45° (Figure 2). It can be seen that for fabric printed with cyan ink, both contrast and entropy values were the least at 90°, while energy, homogeneity, and correlation values were maximum at 90° (Figure 2). Values obtained for energy and homogeneity with an orientation of 90° were higher than with 0°, 135°, and 45°. This was a result of the 90° being parallel to the orientation of the imaging sensor. In Figures 3, 4, and 5 are shown all five GLCM parameters for obtained prints in magenta, yellow and black colors respectively. Magenta, yellow, and black print colors for GLCM parameters showed the same trend as in the case of cyan print color.

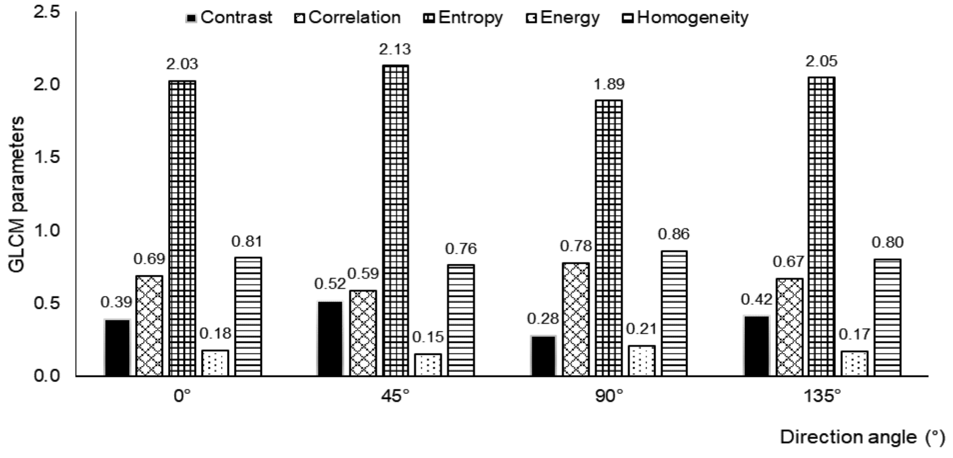


Figure 2: Contrast, correlation, entropy, energy, and homogeneity GLCM parameters of sublimation print in cyan color

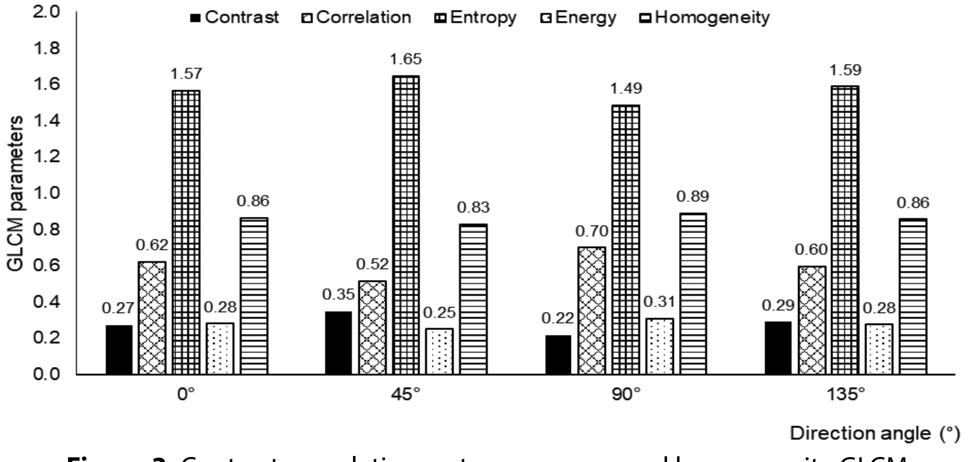


Figure 3: Contrast, correlation, entropy, energy, and homogeneity GLCM parameters of sublimation print in magenta color

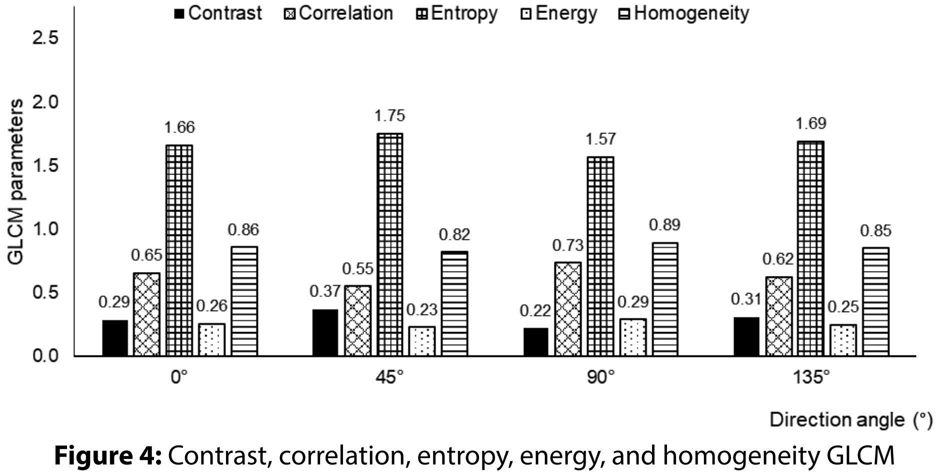


Figure 4: Contrast, correlation, entropy, energy, and homogeneity GLCM parameters of sublimation print in yellow color

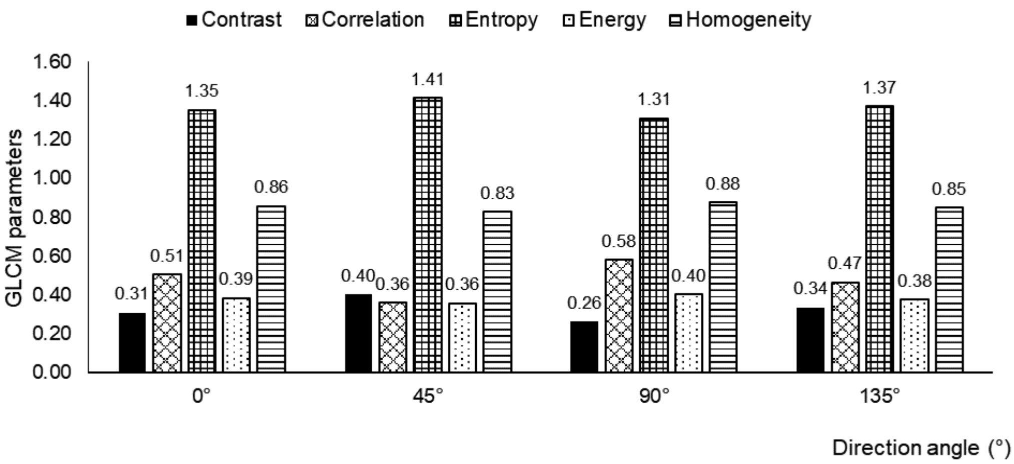


Figure 5: Contrast, correlation, entropy, energy, and homogeneity GLCM parameters of sublimation print in black color

The print mottle may not appear at the correct pixel location or direction angle. The print mottle is presented by a number of pixels at different direction angles in different structured patterns. This is the reason why when using the GLCM for analysis of the uniformity of print, it is most appropriate to use the mean of all four values for each direction angle in order to obtain greater objectivity for the uniformity of print. In this way, the adjacent pixels will be covered and thus an objective representation of the uniformity of the print will be obtained. Thus, Figure 6 showed the mean values obtained from the four direction angles for each of the five GLCM parameters used to analyze the uniformity of print obtained in cyan, magenta, yellow and black colors. The obtained results indicated that low values for the contrast parameter and high values for the entropy and homogeneity parameters were characteristics of the samples obtained, while medium values were characteristics of the energy and correlation parameters. Comparing the prints obtained with each of the four colors, certain differences can be observed for values of all five GLCM parameters, indicating that the print obtained in black color had a uniform surface and that print in cyan color had a larger non-uniformity print mottle. Print in black color had the lowest entropy, contrast, and correlation and the largest energy. In this case, it can be distinguished that print in black color was characterized by a high quality of the print, that was, it had a great uniformity of the print.

4. CONCLUSIONS

The influence of the direction angle of pixels in the digitalized print image, which is an important parameter, on values of output GLCM parameters was investigated for the determination of print mottle as the most important indicator for print quality. Prints were obtained using a sublimation printing process on polyester elastane fabric in cyan, magenta, yellow, and

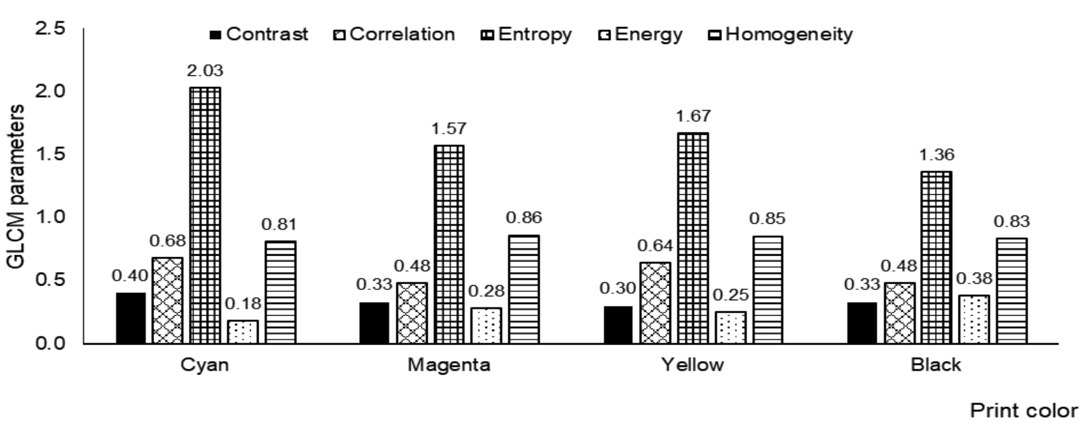


Figure 6: Average values of contrast, correlation, entropy, energy, and homogeneity GLCM parameters for prints in cyan, magenta, yellow and black colors

black colors. To achieve the goal of this research and to obtain quantitative results to evaluate the non-uniformity of the print, output GLCM parameters such as energy, entropy, homogeneity, correlation, and contrast were used. A noticeable difference was observed between the values of the parameters processed by the GLCM at the four different direction angles. If the image contains extremely different print quality, then this will have a great influence on the obtained results for the parameters and will mainly depend on the angle at which they were obtained. In textile printing, it is more appropriate to calculate the GLCM parameters for the four values of direction angle and to use the average value. Determining the non-uniformity of the print by the GLCM method of digital image processing obtained from printed textile material can find great application in the textile and fashion printing industry as a way to quickly select the print quality of the printed products.

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