The Effect of Paper Texture on Printed Colors

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Abstract

Paper is one of the most important parameters which influence the final print color appearance. The paper's characteristics such as gloss, texture, whiteness, grammage and, etc, may influence the print quality and color. In the present study, the texture effect of coated papers on the print color appearance is investigated. For this purpose, the coated papers were chosen with the same grammage (260g) and almost the similar glass and closed whiteness values but different textures. A color chart included 2125 samples was generated by Eye-One GretagMacbeth professional maker. The chart was printed using two inkjet printers, including a Canon9000 and a Epson50P. To be able to analysis the texture properties each paper image was captured using a professional scanner. The Co-occurrence matrix and Gradient distance methods was applied to achieve the texture properties of the papers. The results show that gradient distance method can be used as a proper method for computing the texture properties of the paper. The texture difference computed by this method shows a suitable correlation with the color difference caused by changing the paper's texture; however it depends on the printers' mark. Moreover, there is a good correlation between the value of gradient differences and the gamut volume differences obtained for papers with different textures while the other parameters such as gloss and whiteness are the same.

Introduction

The inkjet print quality is dependent on several parameters such as inks, printers, paper (media), and software [1-2].The paper properties influence on the image transfer and image appearance in all color reproduction processes. The interaction between paper and ink, its porosity, roughness, together with optical properties such as whiteness, opacity, light scattering, and gloss must be considered in the printing process [3-4].

There are some researches to study the effect of paper properties on the final print colors. Wu and el [3] studied the dependency of color reproduction of digital proofs for publication Gravure on paper properties. They claimed that proofing papers yielded larger color gamuts than actual production printing substrates in terms of gamut volume. In addition, the color gamut of the digital printers is affected by the substrate properties. Norberg [4-5] studied the most influencing paper properties on color reproduction. It was reported that in inkjet printing, ink penetration has the largest effect on the color reproduction quality followed by paper whiteness. It was shown that the most important attribute of print quality which is affected by the paper is the color gamut. In addition, applying a visual assessment study show an improved color rendering quality with increased CIE whiteness value up to a certain level. Any further increase in paper whiteness does not contribute to an improved color reproduction quality.

Researches accomplished by Cernic & el. [6] confirmed the importance of paper sorption properties for obtaining high-quality ink jet color prints. Baudin and el [7] investigated the effect of paper properties on print quality for set of papers of various grades considering their optical and physico-chemical characteristics. They performed some theoretical technique to classify the behaviors of the papers at least qualitatively. Pal & el. [8] studied the effect of paper properties on inkjet print quality and light-fastness. They reported that the print quality in terms of color gamuts and ICC profiles is highly influenced by paper properties. Fernandez-Reche and el [9] performed a study on the relationship between the colorimetric characteristics of a paper and those that allow us to evaluate its color reproduction capabilities on inkjet printers. The results show no systematic correlation between color reproduction and specific colorimetric properties of the types of paper. Perales and el [10] studied the effect of the colorimetric properties of different types of paper, having different finishing and grammage, on the color gamut in inkjet printing. It was shown that there is no clear relationship among the considered colorimetric properties of paper such as CIE whiteness index and the color gamut volume. Lundberg and el. [11] studied the print quality for nine papers with varying composition and eight different commercial papers. They showed that paper composition variations in hardwood content, filler content and type of pulp did not have a major impact on line quality or color gamut. However an increased amount of filler decreases the color gamut volume.

The goal of this paper is to investigate the effect of paper texture on the colorimetric properties of inkjet printers in terms of color changes via the texture differences and color gamut volume.

Experimental

In the present study, the effect of paper on the final printing colors was investigated. For this purpose, four kinds of coated photo papers with different marks and the same grammage value of 260 were selected. The selected papers had almost the same gloss, and whiteness but different textures.

The spectral data and the whiteness index of the papers were measured with a Color-Eye 7000A spectrophotometer in a specular component included (SCI) mode, which is an instrument with diffuse/8° geometry. The spectral data were measured between 360nm and 750nm with a 10nm interval. Table 1 shows the corresponded CIEL*a*b* values for illuminant D65 and 1964 CIE standard observer.

The papers' gloss was measured using a NOVO-Gloss I.Q Goniophotometer manufactured by Rohpoint.

Table1: The CIELAB coordinates of the papers under illuminant D65 and 1964 CIE standard observer

	1	2	3	4
L*	93.47	93.70	92.77	94.82
a*	4.22	3.95	3.17	3.62
b*	-11.66	-11.47	-12.31	-9.58

The effect of substrate on the final colors was studied for two digital printers; a Canon PIXMA Pro 9000 Mark II and a Epson

Stylus Photo 50P. The Canon PIXMA Pro9000 had an eight-ink set included yellow, photo magenta, red, photo cyan, magenta, green, black, and cyan. The Epson P50 has six tanks including black, magenta, light magenta, cyan, light cyan, yellow.

At first, it was necessary to prepare appropriate samples. To this end, a color chart including 2250 samples was generated by Eye-One GretagMacbeth professional maker. The chart was printed on each of the four papers and with the two mentioned printers.

The spectral reflectances of the printed colors were measured using a GretagMacbeth Eye-One spectrophotometer in the range between 380nm and 730nm. In all the experiments only the data between 400nm and 700nm with 10nm intervals (31 wavelengths) were applied.

The color gamut of the printed samples for each paper was computed with GamutVision software [12].

The color difference between the color patches of each two papers were computed using CIEDE2000 (1:1:1) color difference formula [13].

The paper's image was captured using a V700 EpsonPro scanner. The scanning resolution was set as 600 dpi and the images were saved with TIFF format.

Two texture analysis tools including Grey level co-occurrence matrix and Edge frequency methods were applied for texture feature extraction [14-15].

Texture Analysis

Gray level co-occurrence matrix

Gray level co-occurrence matrix (GLCM) estimates image properties related to second-order statistics based on the repeated occurrence of some gray level configuration in the texture [14-15]. An occurrence of some gray level configuration may be described by a matrix of relative frequencies $P_{\varphi,d}(a,b)$, describing how frequently two pixels with the gray levels a, b appear in the window separated by a distance d in direction φ. Some texture features are defined based on $P_{\varphi,d}$ data, such as Energy, Entropy, Maximum frequency, Contrast, Inverse difference moment and Correlation. As an example, the energy is defined by the following equation:

$$\text{Energy} = \sum_{a,b} P^2_{\varphi,d}(a,b) \tag{1}$$

In the above equation, μ_x and μ_y indicate means and σ_x and σ_y are standard deviations.

Edge frequency method

In edge frequency method, a gradient function is defined as the distance between pixels and used for identifying the texture features [15]. The distance-dependent texture description function *g(d)* is computed for any subimage *f* defined in a neighborhood N for variable distance *d*:

$$g(d) = |f(i,j) - f(i+d,j)| + |f(i,j) - f(i-d,j)| + |f(i,j) - f(i,j+d)| + |f(i,j) - f(i,j-d)| \tag{2}$$

The function *g(d)* is similar to the negative autocorrelation function; its minimum corresponds to the maximum of the autocorrelation function, and its maximum corresponds to the autocorrelation minimum. In this equation, micro-edges can be detected using small-distance operators and macro-edges need large-size edge detectors.

Results and Discussion

Table 2 shows the gloss, whiteness and gamut volume of each paper. As expected and illustrated from Table 2, these papers which have a textured surface show lower gloss values. They have almost closed whiteness index except for paper 4 which has lower whiteness value.

Table 2: The gloss value, whiteness index and computed color gamut for each paper.

	Gloss	Whiteness	Gamut volume	
			Canon	Epson
1	5.8	134.53	566889	478631
2	7.4	133.03	666721	643220
3	9.3	136.04	651203	611165
4	9.4	127.39	601636	569438

The texture features of these papers were estimated applying co-occurrence matrix and gradient distance methods. Table 3 shows the results of texture differences obtained from co-occurrence matrix method between each two paper in terms of the four defined features. The result of gradient method is given in Table 4 correspondingly. It can be seen that the trend of Correlation differences in Table 3 almost likes the gradient differences.

The mean of color differences between each two papers are given in Table 5. It can be seen that for the Canon printer, there is a correlation between the color change via the texture and computed texture differences. In this case, increasing the gradient difference causes a more color difference. The Correlation difference obtained from co-occurrence matrix shows approximately a similar relation. For more clarification, this result is also shown in Figure 1. The obtained correlation coefficient between color difference and gradient difference was 0.91; it was 0.69 for the Correlation difference. Therefore, the texture difference computed by gradient distance method gives a suitable correlation with the color differences caused by changing the paper's texture for Canon printer. It is surprising that the similar result is not obtained for Epson printer. The correlation coefficient between color difference and gradient difference was 0.67 for it.

Table 3: Texture difference for the four textured papers obtained from CCM method

	Contrast difference				Correlation difference			
	1	2	3	4	1	2	3	4
1	0.00	0.30	0.15	0.36	0.00	0.27	0.27	0.27
2	0.30	0.00	0.39	0.06	0.27	0.00	0.03	0.04
3	0.15	0.39	0.00	0.45	0.27	0.03	0.00	0.06
4	0.36	0.06	0.45	0.00	0.27	0.04	0.06	0.00
	Energy difference				Homogeneity difference			
	1	2	3	4	1	2	3	4
1	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.45
2	0.45	0.00	0.45	0.00	0.45	0.00	0.45	0.00
3	0.14	0.59	0.14	0.59	0.14	0.59	0.14	0.59
4	0.18	0.12	0.18	0.12	0.18	0.12	0.18	0.12

Table 4: Texture difference for the four textured papers obtained from gradient distance method

	Gradient distance			
	1	2	3	4
1	0.00	1.07	1.14	1.60
2	1.07	0.00	0.07	0.53
3	1.14	0.07	0.00	0.46
4	1.60	0.53	0.46	0.00

Table 5: The average of color difference between each two papers

	Color difference (Canon)				Color difference (Epson)			
	1	2	3	4	1	2	3	4
1	0.00	2.47	2.20	3.51	0.00	2.80	2.71	3.28
2	2.47	0.00	1.26	2.23	2.80	0.00	0.91	3.27
3	2.20	1.26	0.00	2.04	2.71	0.91	0.00	2.73
4	3.51	2.23	2.04	0.00	3.28	3.27	2.73	0.00

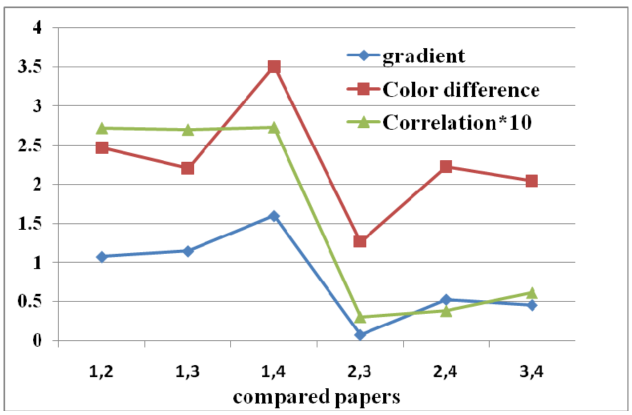

Figure 1*. Texture and color differences between different pairs of papers*

In view of the gamut volume of these four papers, it can be seen that the texture properties can influence the final gamut value. The first three papers which have almost similar whiteness, shows different gamut volume, especially for paper 1. Considering that the difference between these papers is in their texture, so the texture affects the final color gamut. Table 6 shows the gradient difference and gamut change for these three papers.

Table 6: The gradient and gamut difference for the printed colors of the first three papers.

compared papers	gradient difference	gamut difference	
		Canon	Epson
1,2	1.072	99832	164589
1,3	1.143	84314	132534
2,3	0.071	15518	32055

The correlation coefficient between the gradient difference and gamut volume difference is 0.97 and 0.96 for Canon and Epson printer respectively. Therefore, it seems that there is a good correlation between the gradient difference as the texture feature and the final gamut volume of the printing colors if the other parameters such as gloss and whiteness be the same.

For texture 4, it seems that both the texture and whiteness differences influence the final gamut in comparison with the others.

Conclusion

Beside the chemical properties, the optical and physical properties of the papers influence the final printed colors. Nowadays, photo papers are usually prepared with different texture structure which may affect the final printed colors. In this research, the effect of paper texture on the printed colors was investigated in terms of colorimetric characteristics and color gamut volume. The experiments were carried out by applying four photo papers with different textures and almost the same grammage, gloss and whiteness and for two inkjet printers. Texture analysis was performed using two image processing tools; grey level co-occurrence matrix and gradient distance methods. It was found out that gradient distance method can be an appropriate technique for quantifying the paper's texture. The texture difference computed by this method shows a suitable correlation with color change via the texture however this correlation is dependent on the printer's type. Moreover, the computed texture difference shows a good correlation with the gamut volume difference.

Totally, to be able to have a general rule it needs to perform these experiments for more papers which is considered for future studies.

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