A Model of Printer Characterization Based on Tonal Variation

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Abstract

The objective of this research is to produce output prints that are spectrally matched to original colors. The spectral characteristic curves of cyan, magenta, yellow and black inks have been obtained for 10%,25%, 40%, 50%,75% and 100%.dot areas. The spectral curves of two color, three color and four color combinations are also obtained. From the curves, it has been seen that a single equation for all tonal variation if not sufficient to describe the color conversion In this study, a model having spectral hue error correction factors are proposed. It has been observed that the equation is dependent on tonal variation. The correction factors are different from low key to high key images. The factor dependent on tonal variation can be incorporated in the equation keeping other parameters same. The output print quality has been assessed in different printers. Experiments are made on Yule-Nielson modified Neugebauer model with different n for tonal variation. The suggested model offers better color matching with minimum $E_{00.}$

Introduction

In this study, the characterization of printer is based on the tonal variation. The simplest printer model is the ideal ink or Block Dye model where the colorant amount required depends on the input RGB values. But the spectral absorbance characteristics of the subtractive primaries do not correspond to this.

The physical printer models predict the relationship between reflectance and dot area. Among the models, Yule-Nielson modified Neugebauer equation predicts the reflectance of a colored halftone as a function of the fractional dot areas of the primary colorants. The spectral extension of the model is computationally more complex.

Imai and others[1] estimated the area coverage for CMYK inks using the transformation matrix, that was obtained by inverting the printer model.

The dot area estimation in this way requires extensive measurement and complex algorithm.

Theory

The most widely used model is the ideal ink or Block dye model where the amount of cyan, magenta and yellow inks are calculated from R, G, B data.

The spectral characteristics of the cyan ink show that cyan absorbs green and blue lights along with red light. Similarly, the spectral curves of magenta ink show that it not only absorbs green light, but also absorbs red and blue light. The unwanted absorption is minimum for yellow inks. This unwanted absorption has to be taken into account while modeling the printer. As the primary colorants are deviating from their ideal characteristics, the cyan appears bluish, magenta appears reddish and in effect all colors are deviated from the predicted colors. Bandyopadhyay et.al. proposed a model considering these facts.[1] The unwanted absorption and thus the relative color cast has to be estimated and incorporated in the model. A parameter known as spectral hue error is introduced to assess the unwanted relative absorption (or reflectance) of the inks as follows:

The spectral hue error is defined as follows:

$$HR_c = \frac{y_c - x_c}{z_c - x_c} \quad (1)$$

$$HR_m = \frac{z_m - y_m}{x_m - y_m} \quad (2)$$

$$HR_y = \frac{x_y - z_y}{y_y - z_y} \quad (3)$$

where x, y, z are The trichromatatic coefficients or the CIEchromaticity coordinates of cyan, magenta and yellow inks, calculated from tristimulus values.[3] The advantage of the CIE is that the data correlate well with visual match.

The model considers the unwanted absorption of the basic three subtractive primaries where the unwanted absorption is expressed in terms of the spectral hue error. According to the model,

$$C = 1\text{-}(1+HR_c) * R \quad (4)$$

$$M = 1\text{-}(1+HR_m) * G \quad (5)$$

$$Y = 1\text{-}(1+HR_y) * B \quad (6)$$

The hue errors depend on the spectral characteristics of ink. Moreover, it varies with dot area also. As the dot area decreases from shadow to highlights, its spectral characteristics continues to change because of the effect of the spectral characteristics of the substrate. Hence the HR parameters are not constant but vary with dot areas.

The result of this hue error is the unwanted increase in the optical density of the output and reduction in the reflectance values of the output. Besides this, the physical and mechanical dot gain also increases the density and effectively reduces the reflectance. It results in images of lower brightness and chroma.

In the present study, a correction factor has been introduced in the model which is dependent on dot areas.

Hence the equations (4) to (6) has been modified as follows:

$$C = [1-(1+HR_c)]^{\alpha} * R \quad (7)$$

$$M = [1-(1+HR_m)]^{\beta} * G \quad (8)$$

$$Y = [1-(1+HR_y)]^{\chi} * B \quad (9)$$

where α, β and χ are the correction factors for cyan, magenta and yellow ink and are dependent on dot areas.

Experiment

To study the printer characteristics, 10%, 25%, 40%, 50%, 75% and 100% of cyan, magenta, yellow and black dots with their two, three and four color superimposition were taken. The prints are taken in three different printers HP930C, Epson Color 640C and HP PSC500. The results are taken on plain paper as well as on photo quality paper. The prints are taken with C, M, Y predicted from the equation (7) to (9) disabling color management and enhancement.

The characterization was started with the printing of the Neugebauer primaries by printing inks at full coverage and their overprints.

GretagMacbeth Spectrolino Spectrophotometer and reflection densitometer were used for the measurements.

The wavelengths of the spectra were taken throughout the visible range from 400 nm to 700 nm wavelength.

Results and Discussion

Figures 1, 2, 3 and 4 show the spectral characteristic curve of10%, 40%, 75% and 100% of cyan ink in HP 930 C printer. The dotted lines show the spectral characteristic curves of the 10%, 40%, 75% and 100% dot areas of the cyan ink using the proposed model.

Figures 5, 6, 7 and 8 show the spectral characteristics of 10%, 40%,75% and 100% magenta ink using tha same printer. It has been observed that the deivation is less for higher dot areas.

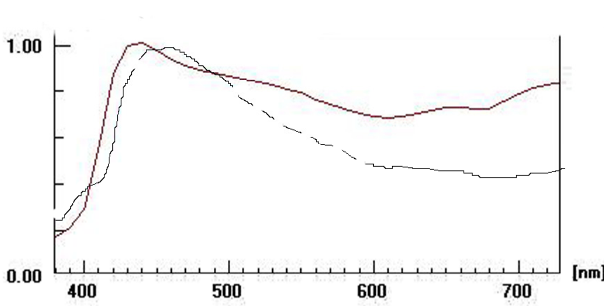

Figure 1. Spectral characteristics of 10% cyan dot

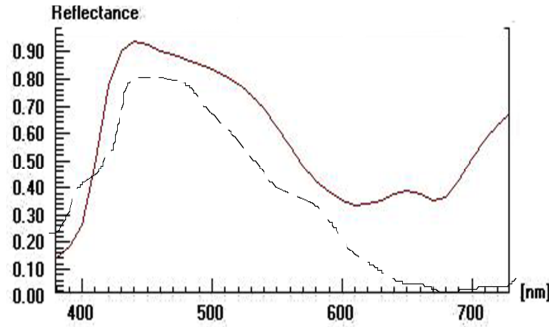

Figure 2. Spectral characteristics of 40% cyan dot

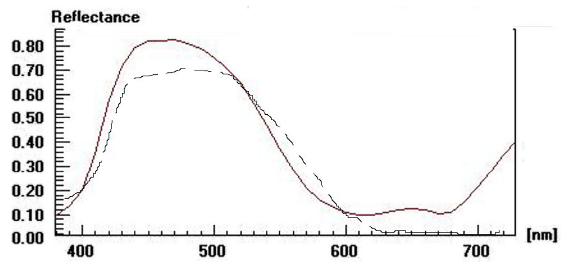

Figure 3. Spectral characteristics of 75% cyan dot

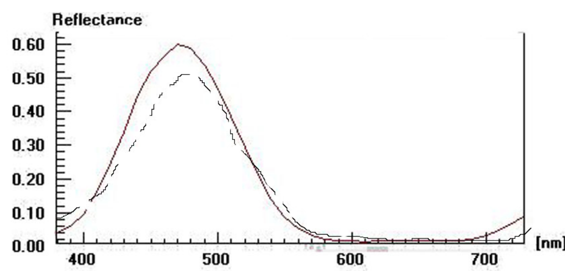

Figure 4. Spectral characteristics of 100% cyan dot

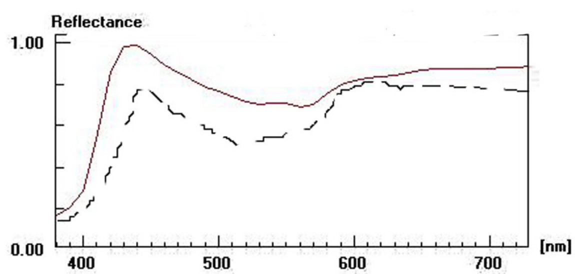

Figure 5. Spectral characteristics of 10% magenta dot

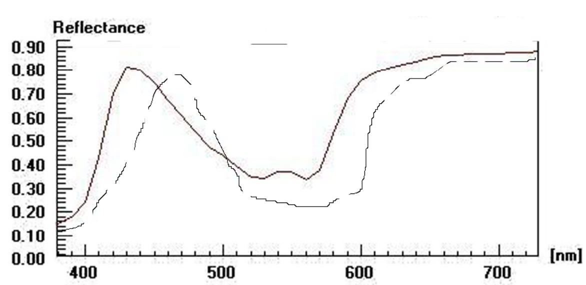

Figure 6. Spectral characteristics of 40% magenta dot

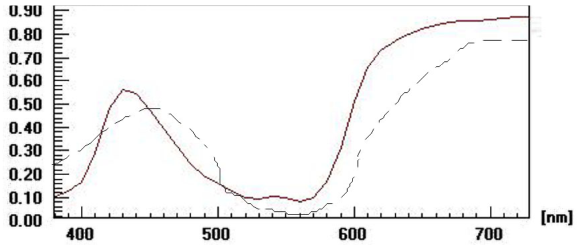

Figure 7. Spectral characteristics of 75% magenta dot

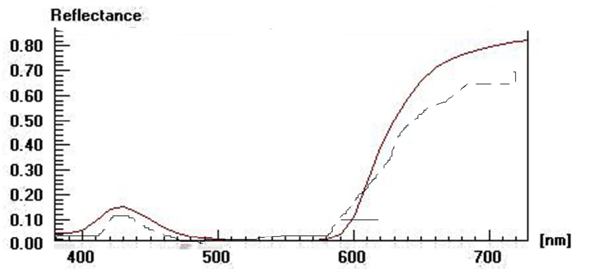

Figure 8. Spectral characteristics of 100% magenta dot

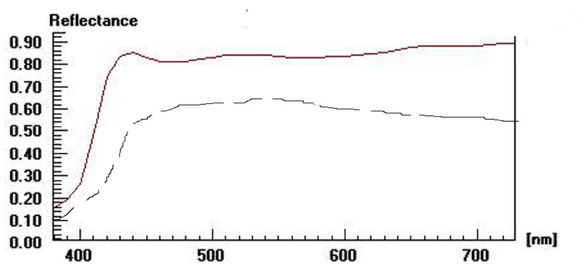

Figure 9. Spectral characteristics of 10% yellow dot

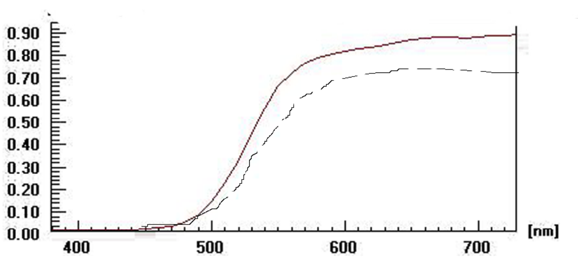

Figure 10. Spectral characteristics of 100% yellow dot

Similaly, spectral characteristic curve of yellow ink for varios dot areas are taken. Figure 9 and figure 10 show the curves for 10% and 100% yellow dot areas using HP 930 C printer.

Experiments were carried out with two color, three color and four color superimposition.

It has been observed that the devations are of similar nature in the highlight aras for different colors. However the nature varies widely for midtone and shadow areas. Considering this factor, three different correction factors are introduced for three primary colors cyan, magenta and yellow.

The color conversion has been done on 10 different sets of images varying from low key to high key variations. It has been observed that the color difference can be kept minimum using different correction factors for the primary colors.

It has been observed that spectral hue error with correction factor can be used successfully for printer haracterization with less color difference.

Conclusion

The printer characterszation depends on tonal variation. The correction factors incorporated in the proposed model depend on spectral characteristics as well as dot areas. Further studies may be made for formulating general equation of correction factor depending on dot areas.

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