Studies on Additivity failure of subtractive primaries for Digital printer Characterization

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Abstract

Different models of printer characterization are based on the assumption that the primary colors are additive in general. However, there are many reasons for which additivity failure occurs. In this study, it has been observed how the additivity fails in two or more color combination of subtractive primaries. The interaction of ink and paper are very much complex with many parameters like light scattering and halftone structure and these play important roles in the additivity failure. In the present work, the spectral curves of two and three color combinations are obtained. The spectral characteristics of paper and how it affects the additivity is studied. The experiments are carried on ink jet and electrophotographic printers. The spectral measurements are taken with the help of Spectroscan spectrophotometer. The results show that there are significant additivity failures in combination of subtractive primaries. A model of printer characterization is suggested incorporating the additivity failure characteristics.

Introduction

When two or more than two color inks are superimposed, the optical density of the combination is often less than the sum of the densitities of the individual inks

Additivity failure occurs when the densities of a two, three or four color overprint fails to equal the sum of the densities of the primary color inks that are used to produce the overprints. The optical factors that contribute to this failure are the first surface reflection, multiple internal reflection, halftone structure, ink film transparency, ink trapping and back transfer. The spectral response of the measuring instruments also influence the additivity measurement. The failure results in poor saturation of solid overprints. The impact of additivity failure is in gamut reduction. The maximum density of a color reproduction helps to determine the color gamut. Higher D max values make it possible to produce color separation with less tonal compression. It also results in sharper images. Additivity failure effect limits the maximum four color solid density.

Many printing devices include a black printer in addition to subtractive primaries to compensate the additivity failure in dark neutrals and thus increase the contrast range. A simple additivity model uses a multiple regression model to derive a convergence point(2) k, where the function $D_{overprint}$ against D_{black} converge in an additivity diagram. K tends to be functionally greater than D_{max} for uncoated substrates but higher for coated ones. A modified additivity failure model of polynomial form determined value for k by second or third order regression in place of a linear convergence(3) .

In Kang's halftone correction approach(4), the spectrum of a given color is considered as an additive combination of the density spectra of the three primaries and the black printer. It employs color mixing models to model the spectral fit between three and four color prints.

Yoshinobu Nayatani et.al.(9,10) estimated the experimental results on additivity failure observed by brightness matching for various combinations of two spectrum colors. The predicted results confirm the existence of the two types of additivity failures called enhancement or cancellation. They also clarify that at the effect of additivity failure does not change for a wide change of adapting luminance used in observation. The degree of additivity failure of a mixture color consisting of two component chromatic colors has very complex characteristics depending on the component colors and their mixing. It is significantly affected by the mixture-color chromaticity and by the brightness/luminance ratio at the chromaticity. A simple relationship was derived between the degree of additivity failure and additivity luminance .

In this study, it has been observed how the additivity fails in two or more color combination of subtractive primaries. The interaction of ink and paper are very much complex with many parameters like light scattering and halftone structure and these play important roles in the additivity failure.

Theory

The printer model is based on spectral reflectance(7) where R is the estimated printed spectral reflectance of superimposition,which are as follows:

$$R = \sum fi\ aiRi^{1/n} \qquad (1)$$

Where fi = additivity correction factor =(spectral hue error)$^{\kappa}$ expressed as HRc, HRm and HRy.

Where ai = dot area of a single color

n= yule-nielson factor

α= enhancement factor

Spectral hue error are as follows:

$$HRc = \frac{y_c - x_c}{z_c - x_c} \qquad (2)$$

$$HRm = \frac{z_m - y_m}{x_m - y_m} \qquad (3)$$

$$HRy = \frac{x_y - z_y}{\quad} \qquad (4)$$

$$y_y - z_y$$

where x, y and z are the spectral values of cyan, magenta and yellow inks.

Experiments

In this study, first the spectral characteristics of coated and uncoated paper are obtained using spectrophotometer and plotted in figure 1. Then the single color subtractive primary inks and superimposing solid ink patches are printed in four different types of digital printers namely Epson 640c, HP930c, HP PSC750 and Toshiba estudio2100c. The patches having 10%, 20%, 25%, 50%, 60% and 75% dots of cyan, magenta, yellow black inks and their superimposition are obtained. The spectral reflectance of the cyan and yellow are shown in Figure 2 and 3. The enhancement factor is introduced to correct for additivity failure.

In the present work, the spectral curves of two and three color combinations on coated and uncoated papers using different digital printers are obtained.

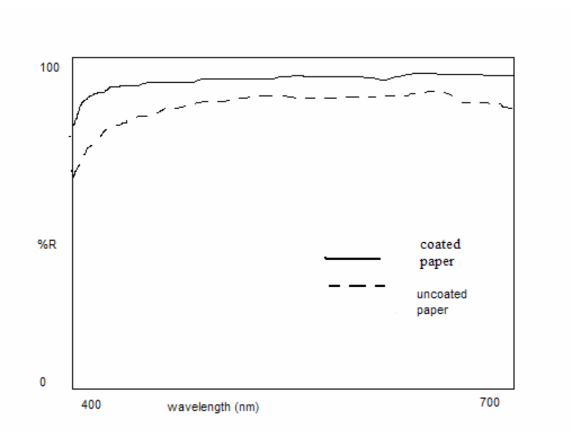

Figure 1: Spectral reflectance curve of coated and uncoated paper

Result and discussion

Figure 1 shows the spectrophotometric curves of paper samples. The whiteness of a substrate is defined as the absence of color cast. The figure shows papers with consistently higher red and green reflectance than blue. This may be due to the natural color of the pulp and may be partially neutralized by blue dyes during paper manufacturing or coating. To avoid color distortion, the paper should be as neutral as possible. Sometimes, the observer mentally adjusts slight color cast, but when comparing it to a proof, differenes are evident.

When light strikes the paper surface, some light is scattered among the fibre and other materials of the substrate. Some of the light passes through the ink film and scatter from the paper resulting in shift of color of the area towards the color of the ink[1]. This results in clean light-tint color tones which make the substrate less gray. Some light that strike the paper and are scattered within

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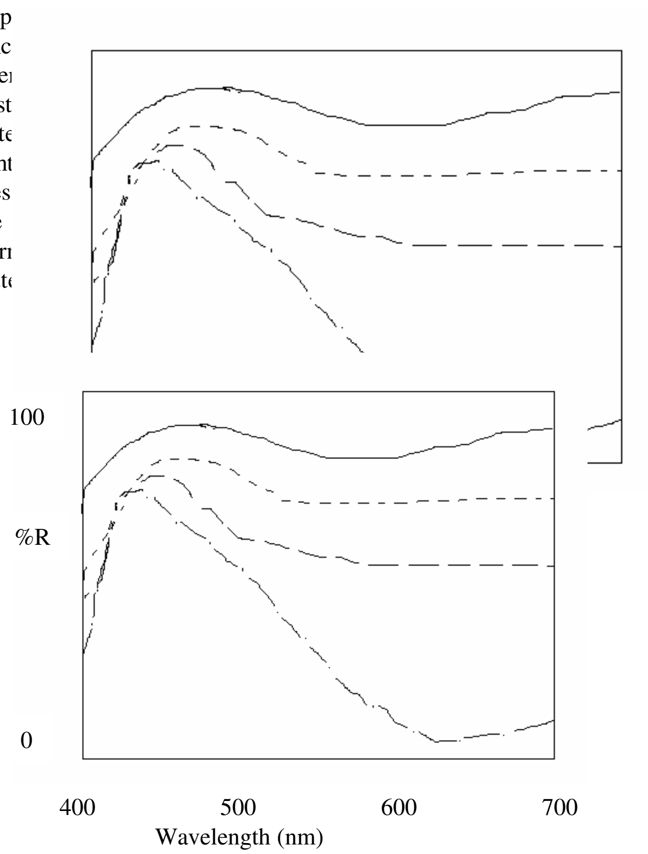


Figure 2: Spectral curves of 10%25%,40% and 50% cyan print

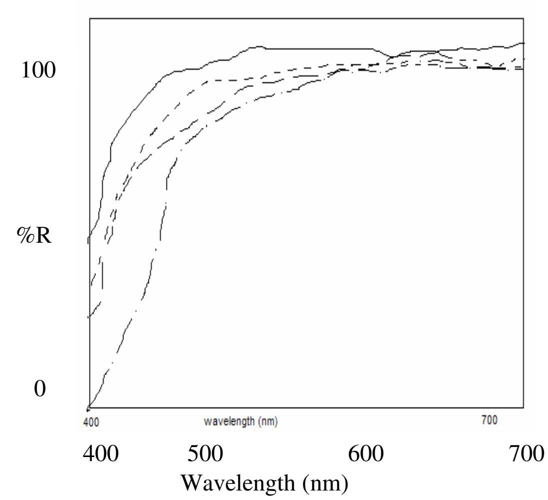
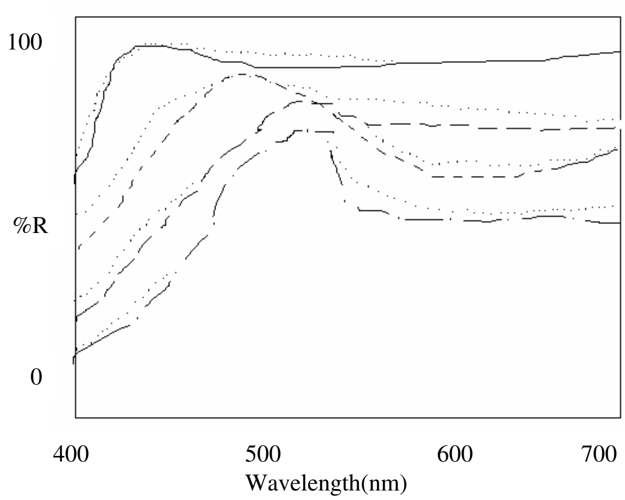


Figure 3: Spectral curves of 10%25%,40% and 50% yellow print

The spectral reflectance of the two color superimposition of cyan and yellow are shown in Figure 4. The spectral reflectance of the two color superimposition as per the prescribed model following equation(1) including additivity correction factor are plotted in the same figure by dotted lines.

The curves show that the proposed model describes the additivity failure satisfactorily.



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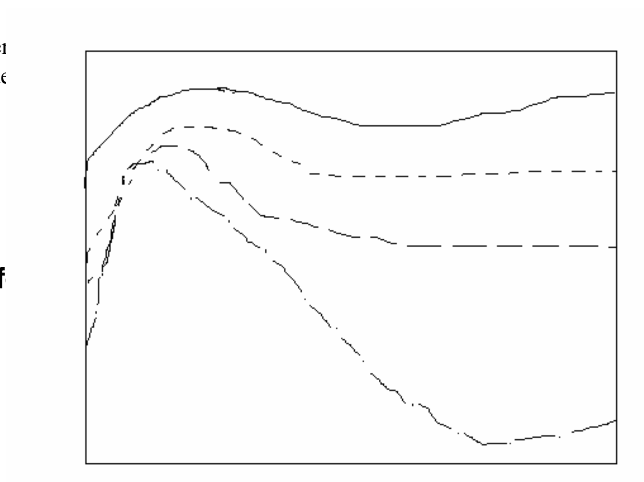

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Author Biography

Dr. Swati Bandyopadhyay received her B.E. degree in Chemical Engineering from Jadavpur University at Kolkata, India in 1987 and Ph. D.(Engg.) from the same University in 1995. Since 1990, she has worked asa lecturer of Printing Engineering Department in Jadavpur University.

Now, she is working as Reader and Head of the Department of the department. Her work is primarily focused on image quality of ink jet printer and color theories. She is a member of IS&T and IIChE.