A New Soft Proofing Method

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Abstract

This paper describes a new method for rendering printed pieces realistically on a monitor based on the spectral reflectance data. The reflected light is modeled with the Extended Phong Model which is defined as an extension of the Phong Model in computer graphics.

We apply the extended model to displaying the primary and secondary solid ink colors and their gradations. We propose an new interpolation method of the specular and body reflectance components in the reflection model. We show the results simulated on a monitor by the proposed method and compare these with the measured results.

Introduction

As more prepress systems become open to interfacing and communicating with other systems, more prepress printing production is produced by employing computer networks, and color monitors for displaying soft proofs. Soft proofing methods provide a way to easily simulate and preview printed results on a monitor.

The methods available to simulate final printed pieces via a display monitor have been developed for some time. But, all the methods are assumed to be well adapted for simulating process color printing, and thus should be verifiable directly, or indirectly by uniquely different phenomena. This should especially be the case with visual assessment, the human psychological process of color recognition has immense influence on the results, and thus the results can be quite subjective, and it is almost impossible to come to reasonable conclusions. Moreover there have been many papers which describe the reflection model for displaying the same appearance like some kinds of plastic and metal,[1-3] but little as for printed pieces.[4] Therefore, we have returned to the origin and have searched for an accurate reflection model for each combination of ink and paper used for process color printing.

In our research to date, we have arrived at the following conclusions:[5]

1. In the case of printing solid inks (i.e., cyan, magenta, yellow and black) on coated and woodfree papers, by a process printing press, the specular reflection has chromaticity coordinates different from those of the light source and also different from the object color of the paper itself, as shown in Figure 1. In other words, the light reflection of solid inks on these papers can be modeled very well by linearly combining the colored specular reflection component and the body reflection component with object color. This light reflection model is called "the Extended Phong Model". Then, we have verified that these kinds of paper can be modeled in the same way.
2. We proposed an algorithm to determine whether this model is applied properly or not.
3. We have succeeded in simulating the printed results, on the above mentioned kinds of paper, on a computer display monitor by rendering them using a ray-tracing method.

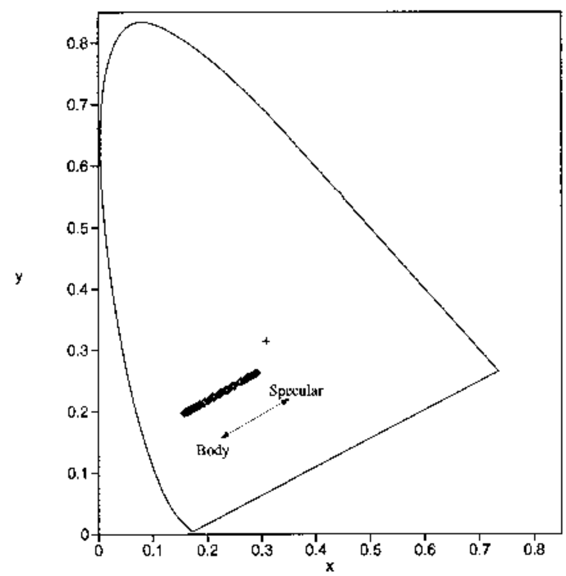

Figure 1. Measured dataof the cyan solid color patch

In the following, first, we describe the Extended Phong Model. Next, we present the algorithm to perform the interpolation method of the specular and body spectral reflectances. Moreover, we show the experimented results by applying this algorithm to the real measured data.

Extended Phong Model

The Extended Phong Model is described as the following equation:

$$I(\lambda) = (S_s(\lambda) \cdot (\boldsymbol{V_s} \cdot \boldsymbol{L_i})^n + S_b(\lambda) \cdot (\boldsymbol{n} \cdot \boldsymbol{L_i})) \cdot \Phi(\lambda) \qquad (1)$$

or equivalently,

$$I(\lambda) = (S_s(\lambda) \cdot \boldsymbol{f}(\rho) + S_b(\lambda) \cdot \cos(\theta)) \cdot \Phi(\lambda) \qquad (2)$$

The chromaticity coordinates of an object surface are calculated using the spectral distribution of the reflected light and CIE color matching functions. From the above equation, the chromaticity can be described as:

$$(x, y) = \boldsymbol{C}_s \cdot (x_s, y_s) + \boldsymbol{C}_b \cdot (x_b, y_b), \qquad (3)$$

where,

$$C_s = \frac{f(\rho) \cdot T_s}{f(\rho) \cdot T_s + \cos(\theta) \cdot T_b}$$

and

$$C_b = \frac{\cos(\theta) \cdot T_b}{f(\rho) \cdot T_s + \cos(\theta) \cdot T_b}$$

$$C_s + C_b = 1$$

Figure 2 shows the geometric parameters for the Extended Phong Model. All the parameters in the above equations are explained as follows:

- $I(\lambda)$ … the observed spectrum at each measured wavelength
- λ … wavelength (380*nm* ~ 780*nm*)
- $S_s(\lambda)$ … surface spectral reflectance of the specular component
- $S_b(\lambda)$ … surface spectral reflectance of the body component
- ρ, θ … angles as shown in Figure 2
- $f(\rho)$ … function representing the characteristics of the specular reflection (like the gaussian distribution)
- $\Phi(\lambda)$… spectrum of the light source
- T_s … sum of the X, Y, and Z (CIE1931) values for the specular reflection $(T_s = X_s + Y_s + Z_s)$
- T_b …sum of the X, Y, and Z (CIE1931) values for the body reflection $(T_b = X_b + Y_b + Z_b)$
- (x, y) … chromaticity coordinates of the observed spectrum
- (x_s, y_s) … chromaticity coordinates of the specular reflection
- (x_b, y_b) … chromaticity coordinates of the body reflection

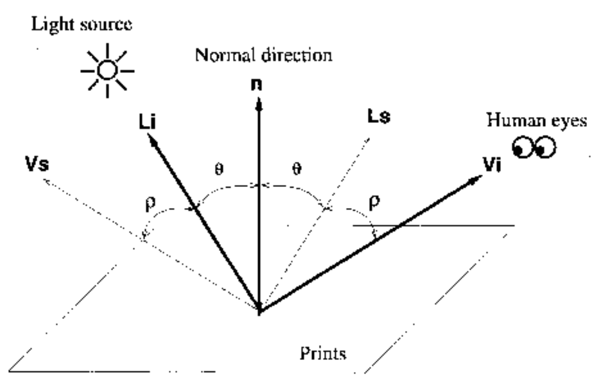

Figure 2. Geometric parameters for the Extended Phong Model

Interpolation Method for Reflectance Estimation

The primary gradations can be rendered on a monitor where it is verified that the Extended Phong Model can be applied to this case and both $S_s(\lambda)$ and $S_b(\lambda)$ are calculated. Effectiveness of the Extended Phong Model is shown at the oral presentation of this conference. Here, we explain a process to calculate the reflectances described above. In the followings, $S(\lambda)$ represents either $S_s(\lambda)$ or $S_b(\lambda)$.

Primary Gradations

The linearly interpolated and the measured values are often different, though the Extended Phong Model can be applied in the case of each color patch with halftone dots, as shown in Figure 3. To get values nearer to the measured, it is necessary for the spectral data of the color patches with 0%, 50% and 100% halftone dots to be looked upon as independent.

The interpolation method to get $S_s(\lambda)$ and $S_b(\lambda)$is described as follows:

1. The color patches are equally spaced in dot percent between 0% (paper only) and 100% (the primary solid ink on a paper) color patches and measured spectrophotometrically. We use color patches with halftone dots spaced at 10% increments.
2. By using the least square method, the measured data is applied to the equation (4) and we get the weight coefficients α, β and γ at each halftone dot color patch.

$$S(\lambda) = \alpha \bullet S_{paper}(\lambda) + \beta \bullet S_{50\%}(\lambda) + \gamma \bullet S_{100\%}(\lambda)$$

3. To get the $S_s(\lambda)$ and $S_b(\lambda)$ at an arbitrary dot percent primary color gradation patch, we interpolate the coefficients corresponding to this dot percent linearly, by using the weight coefficients of the adjacent halftone dot patches which have been already measured on each side, as shown in Figure 4.

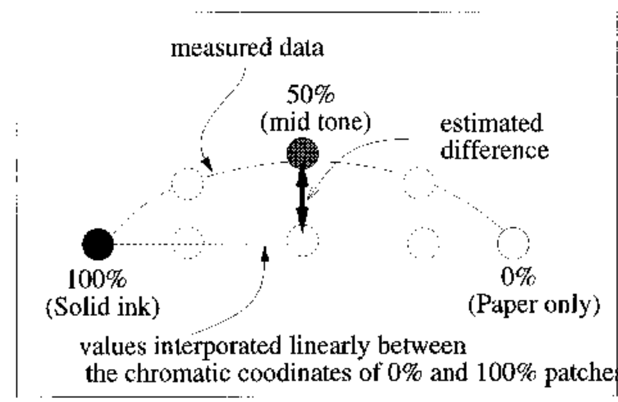

Figure 3. Linearly interpolated values and measured data (primary gradations)

Secondary Gradations

The interpolation method to get $S_s(\lambda)$ and $S_b(\lambda)$ is described as follows and extends the interpolation method mentioned above to the two dimensional case.

First, it is necessary to calculate $S_{Ax}(\lambda)$, $S_{By}(\lambda)$, $S_{A100By}(\lambda)$ and $S_{AxB100}(\lambda)$ and to compose the quadrangle shown in Figure 5.

1. The color patches are equally spaced in dot percent between 0%(paper only or the primary solid ink on a paper) and 100%(the primary or secondary solid ink on a paper) color patches along four lines which compose this quadrangle and measured as the case of the primary gradations.
2. By using the least square method, the measured data is applied to the equation (4) and we get the weight coefficients a, d and fly of each halftone dot percent

color patch along each line.

3.To get the spectral values of $S_s(\lambda)$ and $S_b(\lambda)$ at arbitrary dot percent secondary color gradation patch,

(a) First, to determine $S_{Ax}(\lambda)$, $S_{By}(\lambda)$, $S_{A100By}(\lambda)$, and $S_{AxB100}(\lambda)$, we interpolate the coefficients corresponding to these sets of two dot percents linearly, by using t e weight coefficients α, β and γ of the adjacent patches which have been already measured on each side along each line and calculate these reflectances. This is the same way that is used in the case of the primary gradations.

(b) By using the least square method, for example along "the paper-ink A line," the spectral data calculated above is applied to the equation (5) and we get the weight coefficients ξ_{1Ax} and η_{1Ax} . The same calculations are carried out along the other three lines. These coefficients ξ and η are used to determine the locations $S_{Ax}(\lambda)$, $S_{By}(\lambda)$,$S_{A100By}(\lambda)$, and $S_{AxB100}(\lambda)$ along each corresponding line.

$$S_b i(\lambda) = \xi_{1b} i \cdot S_{paper}(\lambda) + \eta_{1b} i \cdot S_{100\%}(\lambda) \quad (5)$$

(c) By using 4 sets of the coefficients ξ and η, we get $C_{Ax}(\lambda)$, $C_{By}(\lambda)$,$C_{A100By}(\lambda)$, and $C_{AxB100}(\lambda)$ in Figure 5 and $S_{AxBy}(\lambda)$ according to the equation (6).

$$\begin{aligned} S_{AxBy}(\lambda) = & \\ & C_{Ax} \cdot S_{Ax}(\lambda) + C_{By} \cdot S_{By}(\lambda) \\ & + C_{AxB100} \cdot S_{AxB100}(\lambda) \\ & + C_{A100By} \cdot S_{A100By}(\lambda) \end{aligned} \quad (6)$$

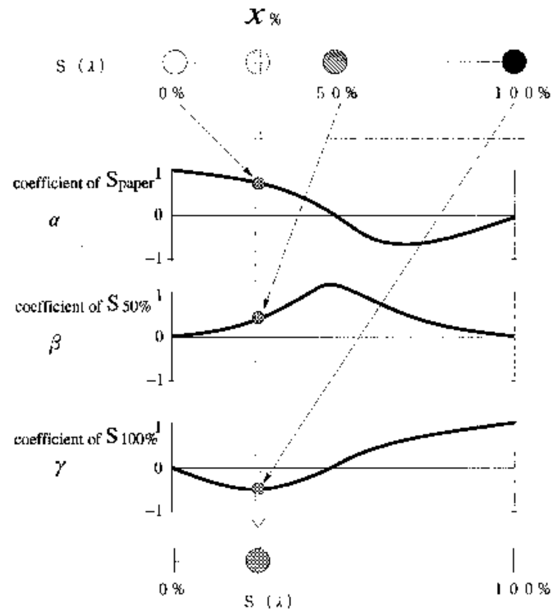

Figure 4. Interpolation of reflectance (Specular and Body o primary gradations)

Table 1. Comparison between the measured and the calculated results (secondary gradations)

secondary gradations	number of color patches	average ΔE	maximum ΔE
excluding black separation	363	1,3829	4.632
including black separation	352	1.4941	4.435
all color patches	715	1.3937	4.632

Table 2. Comparison between the measured and the simulated results on a Trinitron monitor (secondary gradations)

secondary gradations	number of color patches	average ΔE	maximum ΔE
excluding black separation	265	3.005	6.1490
including black separation	293	2.088	4.178
all color patches	558	2.514	6.1490

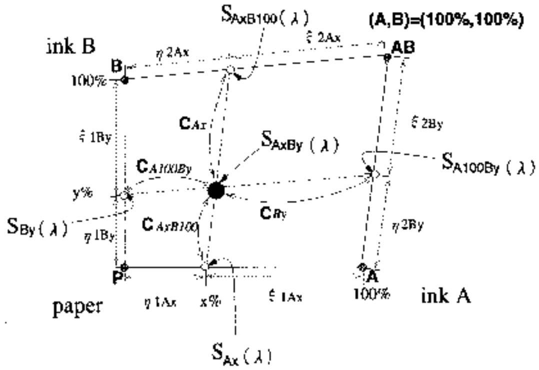

Figure 5. Precise interpolation of the spectral reflectances (secondary gradations)

Experimented Results

Table 1 shows the comparison between the measured and the calculated $L^*a^*b^*$. Table 2 shows the comparison between the measured and the simulated $L^*a^*b^*$ on a Trinitron monitor. As you can see, the Extended Phong Model with the spectral interpolation described above, can be applied to get good printing proofs on a monitor representing the primary and secondary color gradations.

Conclusion

We have succeeded in simulating printed results by using up to two colors of halftone dots on coated and woodfree papers based on the Extended Phong Model. The following conclusions are verified by our investigation:

1. The Extended Phong Model enables simulation of color patches based on a single color halftone dot including the case of a single solid ink, on a monitor.
2. The Extended Phong Model enables simulation of color patches printed with two kinds of halftone dots including the case of two solid inks, on a monitor.

References

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