A New Method for Assessing Overprint Trapping

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Abstract: In this paper we propose a different way to evaluate the effect of trapping that results in process colors when Red, Green, and Blue are obtained as overprints of Cyan, Magenta, and Yellow. We believe that two major factors influence the color of the overprints: the spectral characteristics and opacity of the inks. We propose analytical methods for determining the apparent contribution of individual inks as well as the effect of ink pigment opacity in overprints. These procedures are based on spectral data and differ from the traditional trapping expressions that are derived from densitometric data.

Introduction

Trapping as it exists in overprints has been widely studied by Yule (1967), Preucil (1958), Stanton (2001) and others. Trapping has been proposed many times as a quality indicator for the control of the printing process. Yet it has not enjoyed widespread adoption despite the fact that most control bars contain Red, Green, and Blue patches as a routine matter. Many explanations have been given as to how trapping occurs and why the densities of the over-printed inks are not the additive sums of the individual components. There are also several formulas proposed – Preucil (1958), Childers (1980), Brunner (1983), Hamilton (1986), and Ritz (1996)- that purport to explain trapping because of one variable or another in the printing process. All of these formulas are based on densitometric measurements that are not suitable for the analysis of mixtures of more than one component. Technology has offered the opportunity to introduce more refined measurements such as with a spectrophotometer so the attribute of ink trapping can be better understood. We will show that the densitometer-based assessment of overprint trapping is misleading and that the determination of the apparent amount of each of the component inks present in an overprint is a much better way to describe the effect of the overprint.

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Procedure

During the previous decade, X-Rite®, GretagMacbeth®, and Light Source introduced hand-held spectrophotometers that were suitable for measuring small spots of color that are common in graphic arts. This provided a means for obtaining data on printed materials that was generally less restrictive than that of filter-based densitometers. Although the densitometer still is the preferred device for obtaining quick assessment of the printing process at the press, the use of the newer spectrophotometer has not been fully exploited. Some prior work done at Clemson University (1997) showed density measurements based on spectral data were more consistent than those obtained on a variety of commercial densitometers. Such calculations can be regarded as somewhat academic and are preferred when accurate and interchangeable data are needed. This led to the study of ink trapping that involves the colorimetric interaction between two process inks and the substrate. Densitometers that are constructed with broadband filters basically neglect the secondary absorptions of inks. In doing so, it is not possible to account for the effect of two inks that are printed over each other. In the final analysis, it is the colorimetric consequence of the overprint that is important.

The approach that was taken in this study was to use spectrophotometric measurement to compute the contribution of a single ink to the overall color of the overprint. This means that the density ($\log10(1/R)$) of one ink is obtained at the wavelength of its maximum absorption as well as the density of the secondary absorption of the other ink. This results in a pair of simultaneous equations to solve for the apparent amount of each colorant in the overprint. For example for a Red patch:

At 430 nm (the max for the Yellow) $R_{430} = yY_{430} + mM_{430}$
At 560 nm (the max for the Magenta) $R_{560} = yY_{560} + mM_{560}$

Where:

R is the density of the overprint at the two wavelengths (minus paper)
Y is the density of the Yellow at the two wavelengths (minus paper)
M is the density of the Magenta at the two wavelengths (minus paper)
y is the apparent amount of the Yellow
m is the apparent amount of the Magenta

The solution of the equation in matrix terms:

$$C = R * A^{-1} \qquad \text{Equation 1}$$

Where:

C is the concentration of the individual inks
R is the density of the Red at the two wavelengths
A is the absorbency matrix (four values)

For Green, the densities at 430 nm are used for Yellow and 620 nm for Cyan. For Blue, the densities at 570 are used for Magenta and 620 nm for Cyan. When process colors other than CYM are used, for example, when the trapping for a set with Orange, COM, the wavelength for the orange maximum absorption, 460 nm, was used in place of that for Yellow. In all cases, two values were obtained, one for each colorant, to indicate the contribution of the inks to the overprint. See Table I.

Colour Index	Process Color	Apparent Concentration BLUE Overprint	GREEN Overprint	RED Overprint	Density
PB 15:3	CYAN	90%	95%		1.18
PR 53:1	MAGENTA	73%		86%	1.72
PY 12	YELLOW		88%	69%	1.05
	2nd color filter	Magenta	Yellow	Yellow	
	Overprint Density	156	1.06	1.62	
	AT(Preucil)	73	92	72	

Table I.Test at GATF- Offset-Litho Sheet fed

In addition to having the specific information about the apparent (visible) amount of each ink component, it is necessary to determine the opacity or the converse, transparency, of the ink pigments that governs the effectiveness of ink in an overprint situation. Since opacity is a characteristic of individual ink pigments, the determinations were made and shown in Table II:

Colour Index	Common Name	Opacity
PB 61	Reflex Blue	0.39
PB16	Phthalo Blue (no Cu)	0.51
PB15:3	Phthalo Blue (GS)	0.73
PR57:1	Lithol Rubine	2.33
PR169	Rhodamine	0.99
PR184	Blue Shade Napthol	0.76
PY14	Diarylide Yel. AAOT	1.5
PY13	Diarylide Yel. AAMX	3.62
PY12	Diarylide Yel. AAA	0.38
PB29		0.29
PY34	Primrose Yellow	22.7
PR104	Moly Orange	26.1

Table II. Opacity of inks according to ASTM 2805

We had originally made transparency measurements according to ISO 2846 (1997) which follows the excellent work of Bassemir and Zawacki (1994). However we found that a simpler method based on ASTM D2805-88 (1988) gave us consistent data. This procedure is commonly used to determine the hiding power (Kubelka-Munk) of pigments in paint films. To accomplish this test with printing inks we made drawdowns of the inks on Black and White (Laneta) Paper charts. The reflectance was measured and the tristimulus (CIE) Y value was calculated for coatings over black (rob) and over white (row). This results in the following formula for opacity that is the converse of transparency:

$$\text{Opacity} = Y_{rob} / Y_{row} \qquad \text{Equation 2}$$

Color of Overprints

In process colors, Blue, Green, and Red are produced by printing Cyan, Magenta and Yellow transparent inks over each other for the respective two-color combinations. The actual color produced is a function mainly of the spectral characteristics of the specific inks involved and secondarily, the film thickness. Since there are no standards to describe how well the desired color is obtained, we adopted certain reference colors from the Munsell system that conform to the commonly used names for Red, Green, and Blue -see Kelly and Judd (1955). The colors chosen were 5R 5/12 for Red; 5G 6/8 for Green; 7.5PB 5/8 for Blue. These colors gave us reference points to make comparisons with the overprinted colors.

It is well known that different printing processes and various ink sets for the same process will give different secondary colors. We used color difference calculations to compare them to the arbitrary references that were selected. The criterion of CIE ΔC^* (shown below) was used because it ignores the effect of lightness that is incorporated in the usual CIE ΔE^* calculations. The formula for the ΔC^* calculation is as follows:

$$\Delta C^* = (\Delta a^{*2} + \Delta b^{*2})^{0.5} \qquad \text{Equation 3}$$

Some typical data that were obtained for several conditions of printing are shown in Table III.

	ΔC^* color differences		
	Blue	Green	Red
Printed offset	4.4	11.9	11.3
Printed flexo	1.7	17.8	23.9
Drawdown- PR 57:1	11.0	5.0	13.2
Drawdown- PR 169	28.3	7.3	16.4

Table III. Sample Trapping Data

The spectral absorption characteristics of certain combinations of transparent ink pigments is given in Figure 1. It is shown that the Yellow ink in the Green overprint has no absorption in the region that the Cyan absorbs most strongly. However, there is some absorption with the Cyan in region of the maximum Yellow absorption. This spectral factor is most important in Reds as shown by color difference as given in Table III.

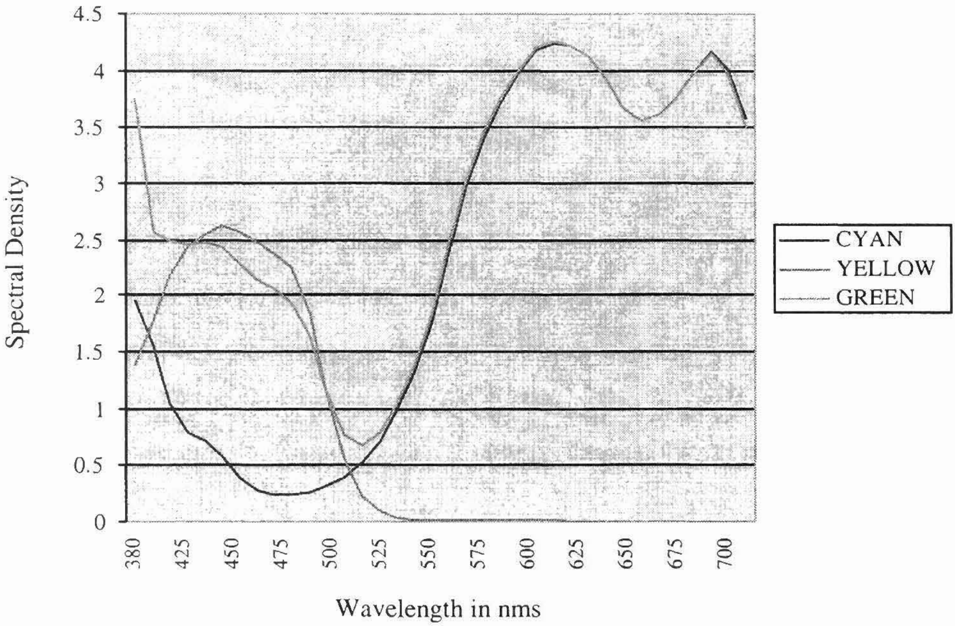

Figure 1: Showing spectra of a Green overprint and its component colors.

The curves shown in Figure 1 are those for transparent inks, PB 15:3 and PY14. If one of the inks is somewhat opaque, such as PY34, different curves result for Green depending on whether the opaque color is printed first or second as shown in Figures 2 and 3.

Opaque Yellow down first

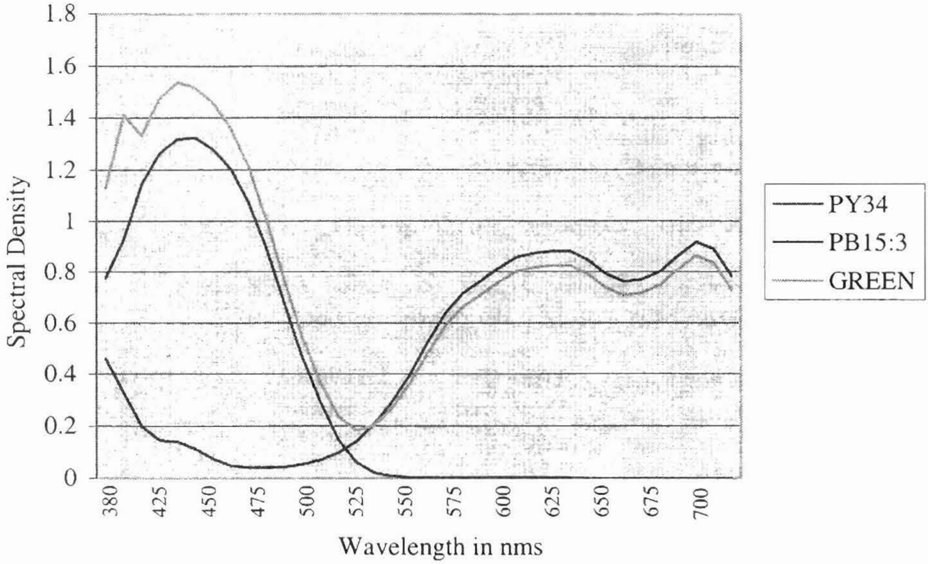

Figure 2: Green made with opaque Yellow and transparent Cyan

Transparent Cyan down first

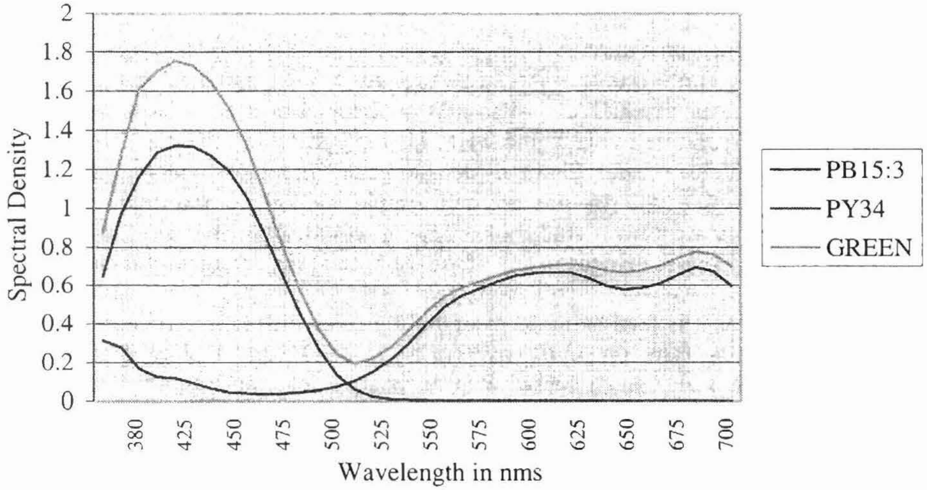

Figure 3: Green made with transparent Cyan and opaque Yellow

Whether the opaque Yellow is printed first or second, neither overprinted Green is especially desirable as is given in Table IV. However, the important point is that they are different because of the opaque Yellow.

First down ink	Delta C* Compared to 5R 5/12	Delta C* between samples	Preucil trapping %
Opaque Yellow	28.5	9.0	7.5
Transparent Cyan	35.8		103

Table IV: Green overprints with transparent Cyan and opaque Yellow

When overprints are done with a pair of transparent inks, the resultant color is more or less independent of the order of printing. See Table V.

First down ink	Delta C* Compared to 5R 5/12	Delta C* between samples	Preucil trapping %
PR 184	21.1	1.3	68.9
PY11	22.3		95.6

Table V: Red overprints with transparent inks

It is evident that the opacity of an ink has a major effect on the order of printing. Conversely, the color of the overprint with transparent inks is not appreciably altered when the print order is changed.

The overprint trapping phenomenon

The early work of Yule and Clapper (1956) probably influenced the thinking about how overprint trapping should be evaluated. They assumed that additivity of density values should occur when inks are printed over each other. Although densities are additive in black and white photographic film, the measurement of density with broad band filters in densitometers precludes the possibility of additivity because the spectra are not simple monotonic flat lines. Stanton (2001) in his extensive study of trapping could not find any reasonable correlation of visual changes in any of the usual trapping calculation methods.

In our studies, it is interesting to examine the color difference compared to the Preucil trapping value on similar overprints. Tables IV and V show Preucil data that does not make much sense: with an opaque ink, the trapping values are extremely different depending on print order and when there is practically no color difference between samples made with transparent inks, the Preucil values are again different as shown in Table VI.

Conclusions

Since we have made a case that the Preucil trapping values are misleading, it begs the question of what do we recommend? Essentially we can conclude two types of evaluations are useful to characterize overprint trapping:

a) for quality control purposes, the analytical determination of the apparent concentration of the individual inks.
b) for selection of sets of inks for process color, comparison of overprint Red, Green and Blue to arbitrary color standards. Opacity measurements are a secondary consideration.

When the apparent concentration is calculated for the Red overprints made with transparent inks that were very little different in color (Table V) the values given in Table VI were obtained.

	Yellow Second	Magenta Second
Yellow	70%	72%
Magenta	99%	101%
Preucil	69%	96%

Table VI. Apparent concentration for overprints with different print sequence

If this new method is to be widely accepted it should be incorporated into the firmware of measurement instruments. The wavelength of maximum absorption for almost all yellow pigments that are used in printing ink is 430 nm. Pigment Blue 15:3 is the Cyan of choice for most types of ink and its maximum is 620 nm. The pigments used for Magenta inks are somewhat different with absorption maximum from 540 to 570 nm. The choice of 560 nm seems to be a reasonable compromise if one wavelength is selected for all Magentas

Computation Methodology

All of the measurements in this study were done with a GretagMacbeth SPM100-II spectrophotometer using the Key Wizard utility to dump the data onto an EXCEL 2000 spreadsheet. Weighting factors for Status T density calculation are based upon CGATS (1992) tables and for colorimetric calculation the CIE (1986) data were used.

We have prepared spreadsheets for these calculations into which new measured data can be inserted and the computations proceed forthwith and are transparent to the user. We have also prepared similar spreadsheets for use with the X-Rite 938 spectrophotometer and the X-Key utility.

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