International Color Consortium

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Spot Colour Overprint Models Review

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Spot colour reproduction

- Wide use in printing and packaging industry
- Communicating spot colours across the workflow not easy
- Named colour systems – Pantone, HKS etc.

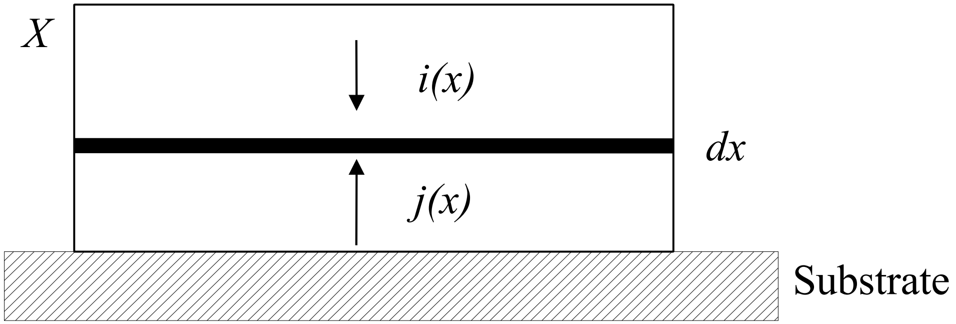
Spot colour reproduction - challenges

- **Matching spot colours on digital printing systems**
- **Lack of information regarding optical properties of ink**
- **Tints of spot colours and overprints**

Printer models – Kubelka-Munk theory

- **Colorant model relying on physical properties of ink**
- **Predicts absorption (*K*) and scattering (*S*) of light**
- **Doesn't account for the lateral scattering of light through substrate**

$$R(\lambda)=1+\frac{[K(\lambda)]}{[S(\lambda)]}-\left\{\left(1+\frac{[K(\lambda)]}{[S(\lambda)]}\right)^2-1\right\}^{(1/2)}$$



***R*(λ)** - predicted spectral reflectance

***K*(λ)** - absorption coefficient

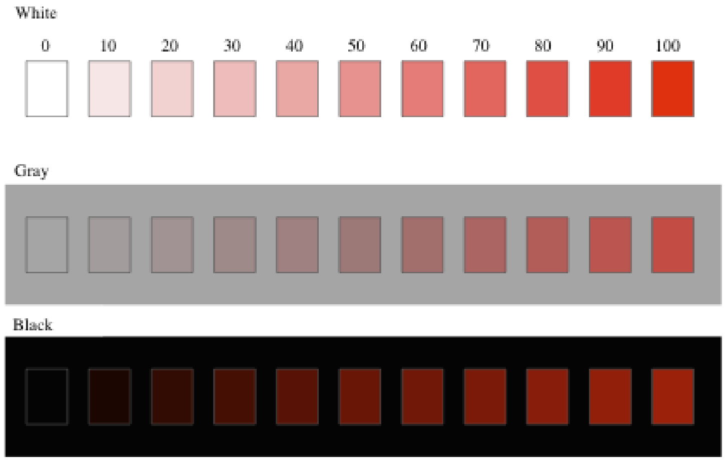
***S*(λ)** - scattering coefficient

Printer models – Kubelka-Munk theory

- Different extensions
- Saunderson: correction to account for the reflection losses at the sample boundaries and for the internal reflection
- Kang: empirical correction for halftone prints
- Emmel and Hersh: correction for lateral light scattering

Printer models – Van De Capelle model

- Proposed by Van De Capelle and Meireson
- Patented by EskoArtwork
- Defines each ink separately by printing solid and tints of ink on three backgrounds – plane substrate, grey and black
- Derives colorant parameters like absorption, scattering, interaction



Test chart for characterising ink (Van De Capelle and Meireson, 1997)

Printer models – Van De Capelle model

- **Predicted spectra**

$$R(p,\lambda) = (1-\alpha(p,\lambda)) \cdot R_{bg}(\lambda)^{\mu(p,\lambda)} + S(p,\lambda)$$

$\boldsymbol{p}$	-	nominal surface coverage i.e. tint (10%, 20%, ...)
$\boldsymbol{\alpha}$	-	absorption parameter
$\boldsymbol{\mu}$	-	interaction parameter
$\boldsymbol{S}$	-	scattering parameter
$\boldsymbol{R_{bg}}$	-	spectral reflectance of substrate

Printer models – Neugebauer & YNSN

- **Total reflectance is the sum of each primary weighted by its relative area**
- **Extensions: Spectral, Cellular, Yule-Nielsen modified Spectral Neugebauer (YNSN) etc. YNSN model equation:**

$$R(\lambda)^{(1/n)} = \sum_{i=1}^{N} w_i R_i(\lambda)^{(1/n)}$$

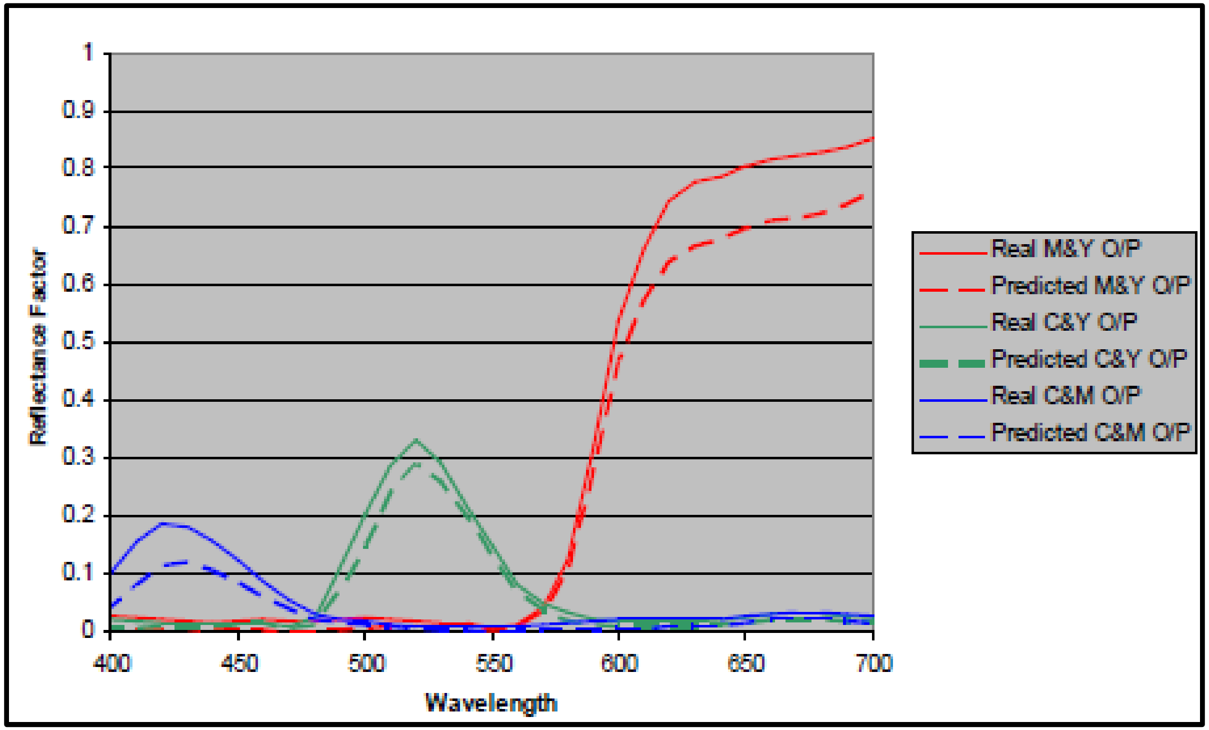
$R(\lambda)$	- predicted spectral reflectance
N	- no. of colorants
$R_i(\lambda)$	- spectral reflectance of *i*-th Neugebauer primary
w_i	- fractional dot area of the *i*-th Neugebauer primary
n	- Yule-Nielsen factor

Motivation

- Predict the colorimetry spot colour overprint
- Simple numerical method – easy to implement within PDF/X or ICC profile
- Application – previewing spot colour overprints (solid and tints) on-the-fly
- Free of intellectual property

Proposed model - approach

- Reflectance of overprint approximates the product of the reflectances of the two inks measured independently
- Error is typically a linear underestimate (occasionally an overestimate) of the reflectance



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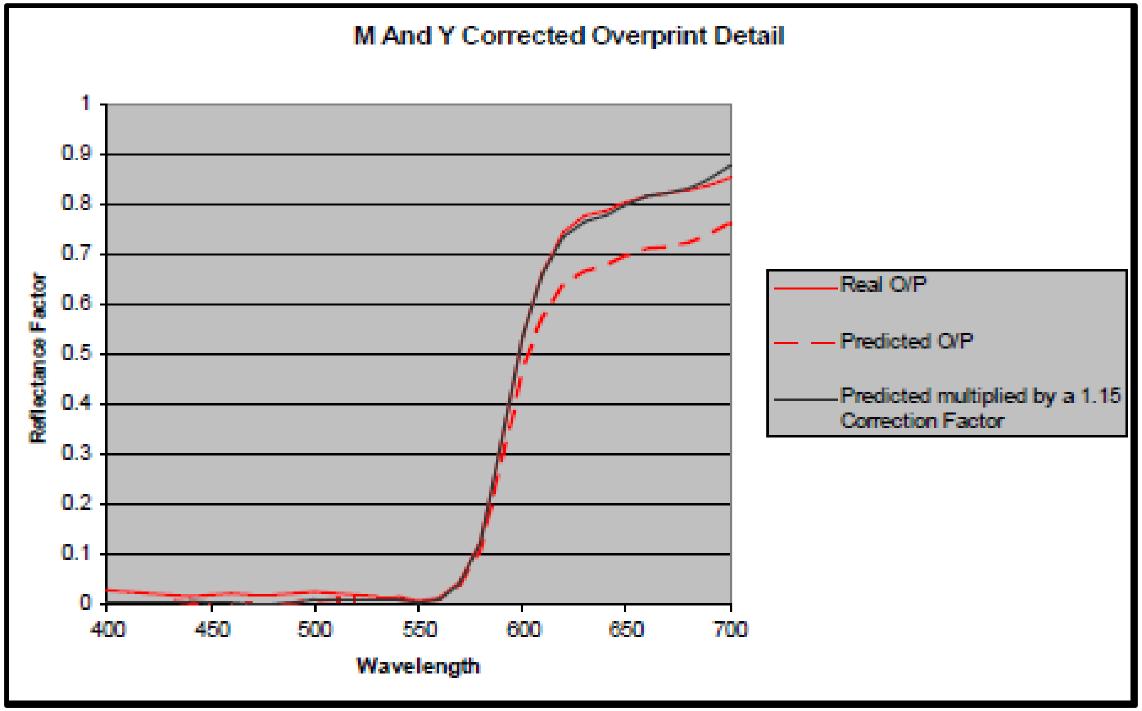
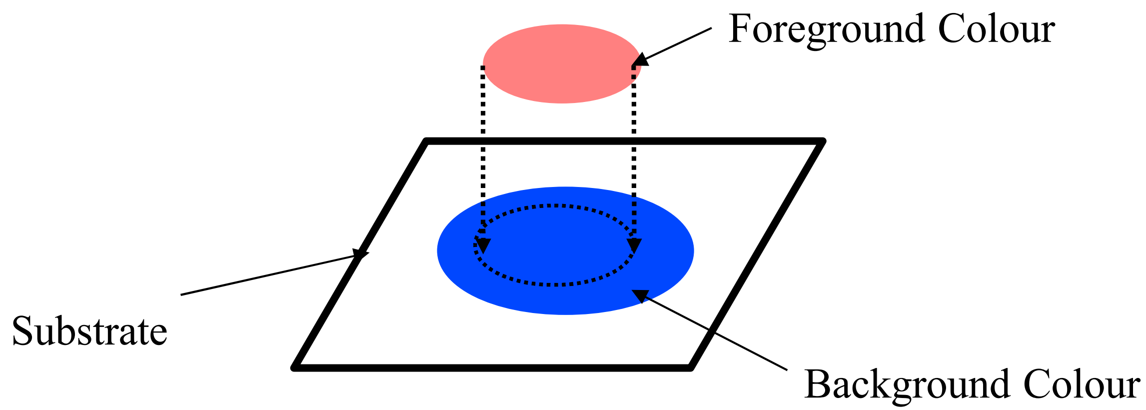
Proposed model - approach

- The reflectance product is modified by a scaling factor, to give an acceptable prediction
- Scaling factor depends on – colorant opacity, ink sequence and the dot area of the overprint colour



Proposed model

- Based on XYZ – because spectral measurements are usually not available in PDF/X and in ICC profiles
- Underlying colour = Background colour
- Overprinted spot colour = Foreground colour



Proposed model

- **Resulting colour is correlated to the product of the background colour and foreground colour**
- **Linear regression is used**

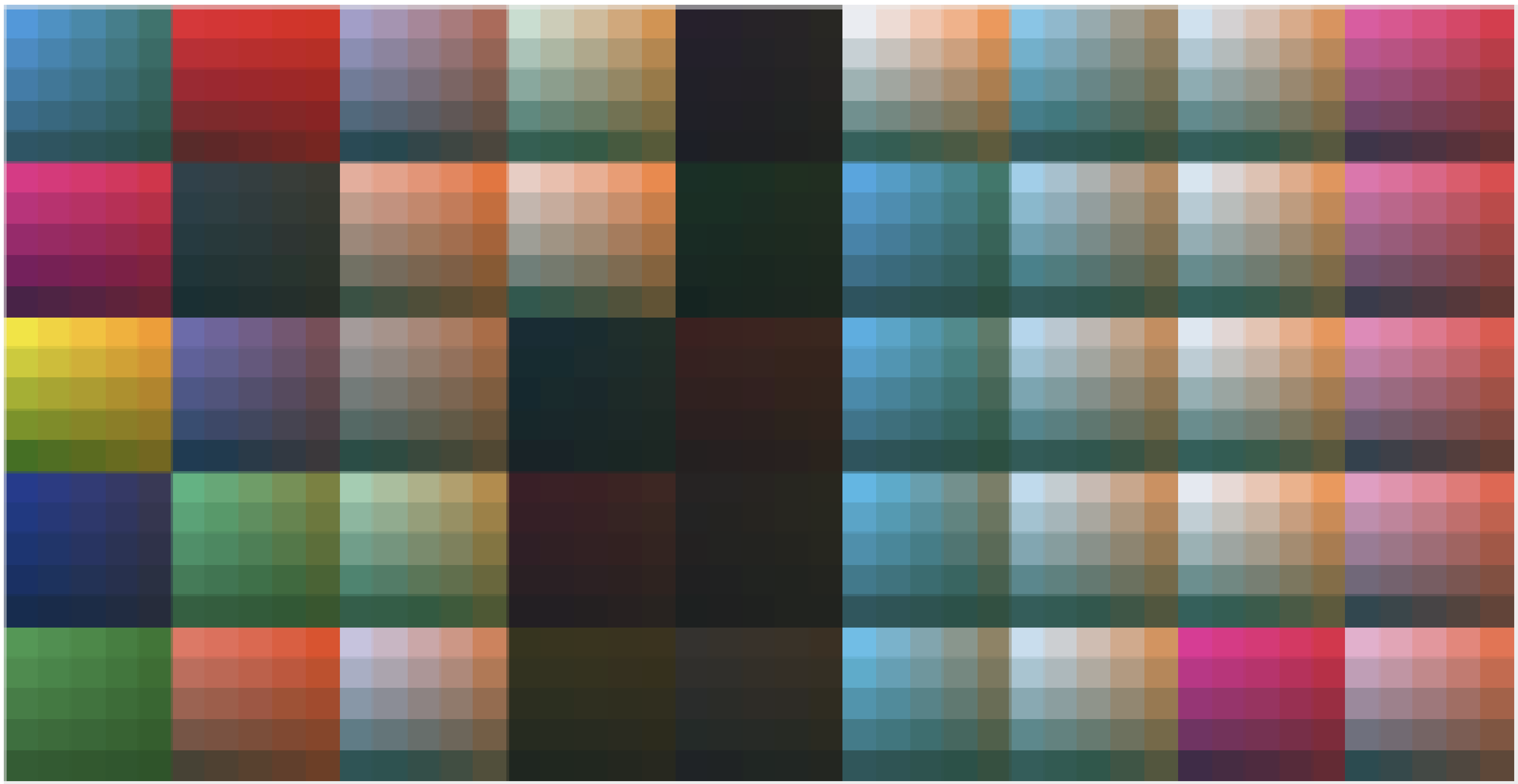
$$X = j_x \times (X_b \times X_f) + k_x$$
$$Y = j_y \times (Y_b \times Y_f) + k_y$$
$$Z = j_z \times (Z_b \times Z_f) + k_z$$

where XYZ are the predicted tristimulus values of the overprint colour
X_b, Y_b, Z_b: tristimulus values of the background colour
X_f, Y_f, Z_f: tristimulus values of the foreground colour
j_x, j_y, j_z: scaling factors
k_x, k_y, k_z: constants

Method – test chart

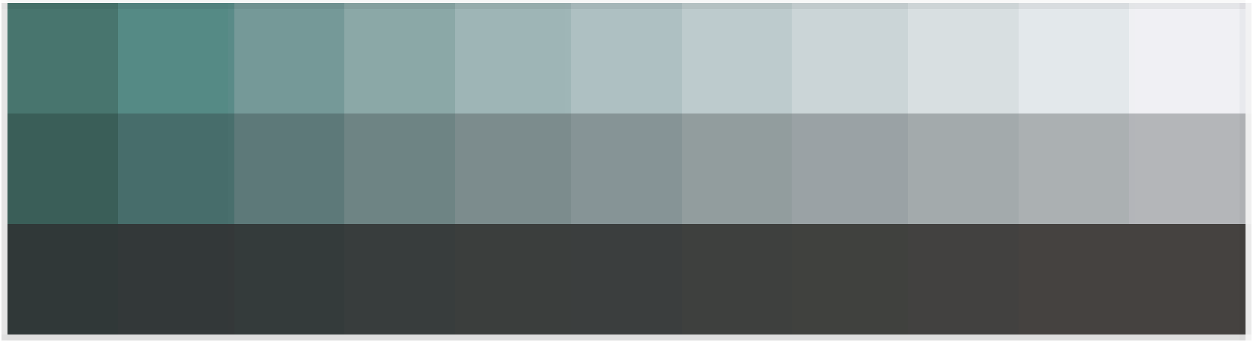
- 6-colour test chart – C, M, Y, K, Pantone 157C, Pantone 330C
- Basic set of IT8.7/3 – 182 colour patches of CMYK
- Combinations of spot inks (0, 25, 50, 75, 100) on each of the 182 patches
- A total of 4550 patches

Method – test chart (Quadrant 1)



Method

- **Each ink is defined individually**
- **Ink characterisation chart – ramps of 0% to 100% over three backings: white (substrate), grey and black**



Ink Characterisation Chart – Pantone 330C

Method

- Printing process - offset
- Substrates – Mitsubishi paper MYU Coat NEOS, Hokuetsu paper Pearl Coat N, Nihon paper Be-7
- Inks – Toppan
- Ink sequence K – C – M – Y – PMS157C (Spot1) – PMS330C (Spot2)
- Measurements – X-Rite SpectoScan ISO 13655:2010 condition M0

Inputs required for different models

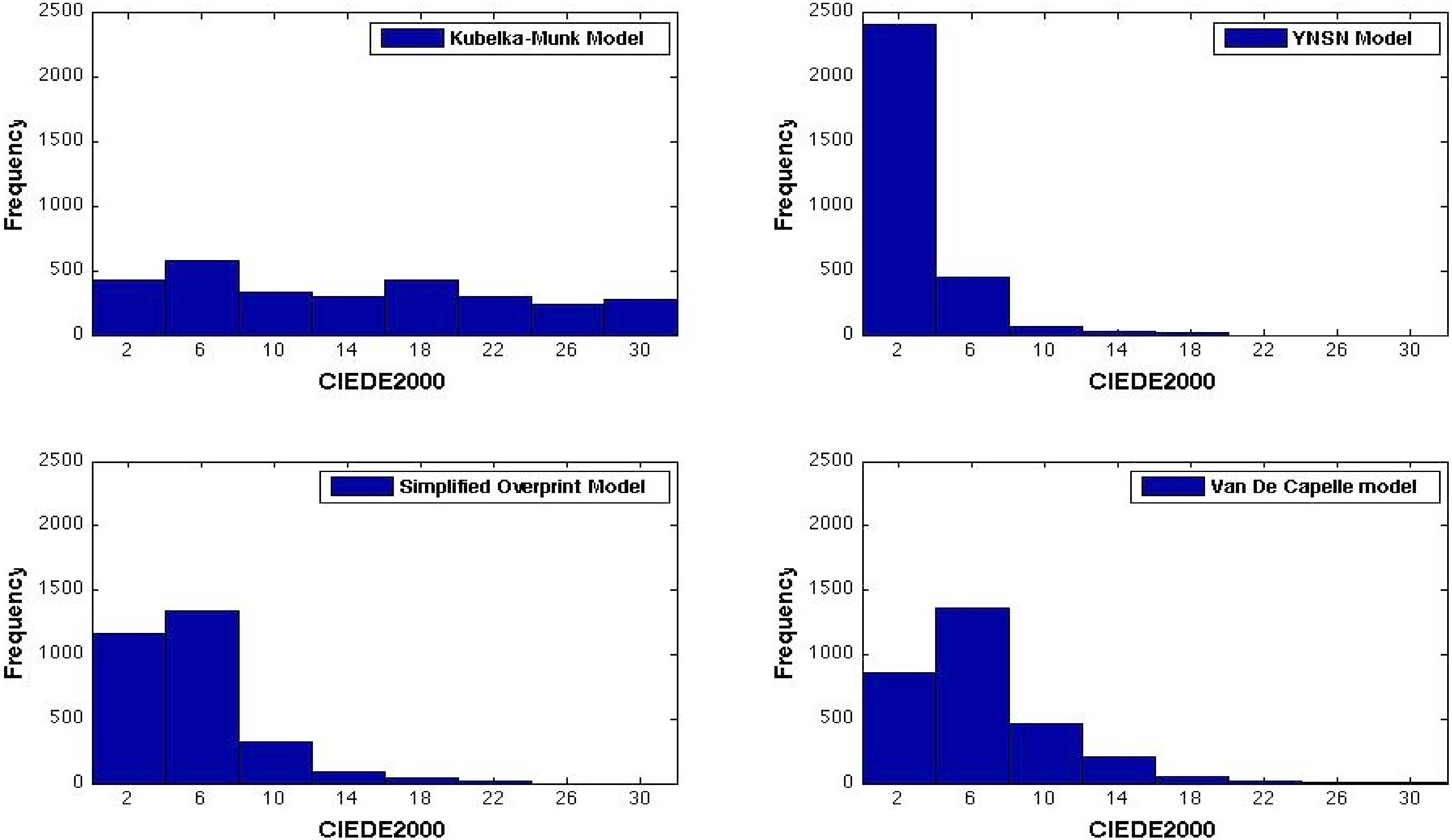
Model	Input patches required	Min colour patches required for 6-ink printing system
Kubelka-Munk	Solid patch of each ink and substrate	7
YNSN	All Neugebauer primaries	64
Van De Capelle and Meireson	Solid and tints of each ink on top of three backings	39
Proposed overprint model	Solid and tints of each ink on top of three backings	39

Results – All models

CMYK + SPOT1 + SPOT2

Models for 6-ink system (Spot1 and Spot2)	Mean	
	ΔEab	ΔE2000
Kubelka-Munk with Saunderson's correction	18.6	14.74
YNSN	3.32	2.72
Van De Cappelle Model	6.91	5.35
Simplified overprint model	5.43	4.01

Results – histograms



Results – Overprint model

CMYK + SPOT1

Paper	Average			
	CIEDE2000	Delta L*	Delta a*	Delta b*
Be-7	**2.89**	1.30	2.40	2.07
MYU Coat NEOS	**2.90**	1.50	2.40	2.35
Pearl Coat N	**2.92**	1.51	2.42	2.35

Results – Overprint model
CMYK + SPOT2

Paper	Average			
	CIEDE2000	Delta L*	Delta a*	Delta b*
Be-7	**2.49**	1.28	2.22	1.35
MYU Coat NEOS	**2.51**	1.41	2.44	1.42
Pearl Coat N	**2.48**	1.39	2.43	1.48

Results – Overprint model

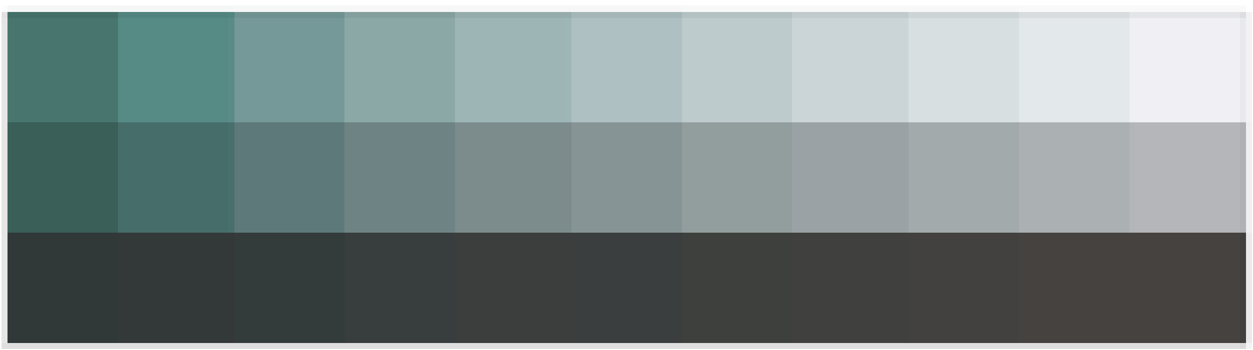
Scaling factors and constants for Nihon paper Be-7

Ink	Coefficients					
	jx	kx	jy	ky	jz	kz
SPOT1	0.012	0.741	0.011	1.172	0.013	1.250
SPOT2	0.012	1.061	0.011	1.095	0.013	0.983

Implementation Guidelines

Step 1: Calculate the scaling factors and constants for each ink

- **Print and measure the ink characterisation chart for each ink**
- **Ink ramps of 0% to 100% over three backings: white (substrate), grey and black**



Ink Characterisation Chart – Pantone 330C

Implementation Guidelines

Step 1: Calculate the scaling factors and constants for each ink

- **For each patch in the characterisation chart, derive the background colour (X_b, Y_b, Z_b) and foreground colour (X_f, Y_f, Z_f)**
- **For example, a patch with 60% *Spot1* on *grey backing***

  X_b, Y_b, Z_b = measured 50% *Black* (grey) over white backing (derived from *Black* ink characterisation chart)

  X_f, Y_f, Z_f = measured 60% *Spot1* over white backing (derived from the *Spot Colour1* characterisation chart)
- **Calculate the products: ($X_b \times X_f$), ($Y_b \times Y_f$) and ($Z_b \times Z_f$)**

Implementation Guidelines

Step 1: Calculate the scaling factors and constants for each ink

- **For a set of all patches in the characterisation chart (total 33), apply the model equation to derive the scaling factors and constants for that ink**
- **X, Y, Z = measured colour patch**
- **$(X_b \times X_f)$, $(Y_b \times Y_f)$ and $(Z_b \times Z_f)$: calculated in the previous step**
- **Find out $j_x, k_x, j_y, k_y, j_z, k_z$**

$$X = j_x \times (X_b \times X_f) + k_x$$
$$Y = j_y \times (Y_b \times Y_f) + k_y$$
$$Z = j_z \times (Z_b \times Z_f) + k_z$$

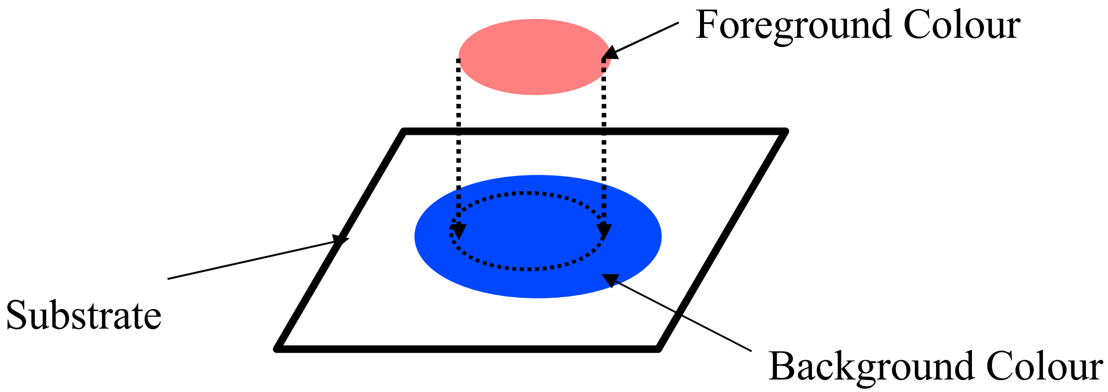
Implementation Guidelines

Step 2: Derive the background colour and foreground colour

- **To predict the resulting colour, derive the background colour and foreground colour for the given patch**
- **In case of 2-inks overprint, say 40% *Spot1* and 30% *Spot2* -**

  X_b, Y_b, Z_b = measured 40% *Spot1* over white backing (derived from the *Spot1* characterisation chart)

  X_f, Y_f, Z_f = measured 30% *Spot2* over white backing (derived from the *Spot2* characterisation chart)
- **Missing percentages (1%, 2%...) are obtained by interpolating the existing measurements of ink characterisation charts**



Implementation Guidelines

Step 3: Calculate the resulting colour using linear regression

- **Apply the model equation (linear regression) to calculate the resulting colour**

$$X = j_x \times (X_b \times X_f) + k_x$$
$$Y = j_y \times (Y_b \times Y_f) + k_y$$
$$Z = j_z \times (Z_b \times Z_f) + k_z$$

where XYZ are the predicted tristimulus values of the resultant colour

X_b, Y_b, Z_b: tristimulus values of the background colour

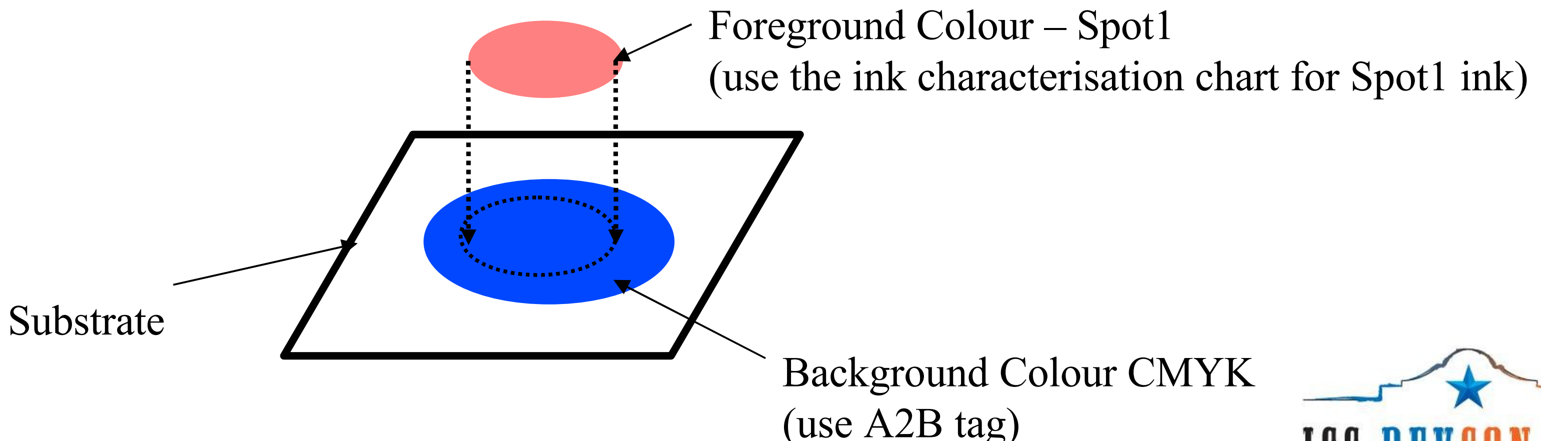
X_f, Y_f, Z_f: tristimulus values of the foreground colour

j_x, j_y, j_z: scaling factors

k_x, k_y, k_z: constants

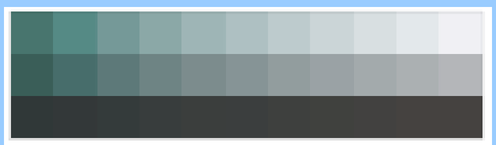
Implementation Guidelines

- **Model can be applied *recursively* to predict the resulting colour of any given combinations of inks (e.g. 6-inks, 7-inks etc.)**
- **No need to measure overprints of different combinations of inks**
- **For a combination of process inks and spot coloured inks (say CMYK + Spot1), *background colour = CMYK* (calculated using the A2B tag of ICC profile)**



Implementation Guidelines

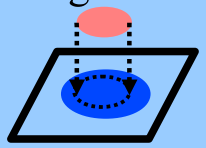
Print and measure the ink characterisation chart for the spot colour



Calculate the scaling factors (jx, jy, jz) and constants (kx, ky, kz) for this spot colour

$$X = j_x \times (X_b \times X_f) + k_x$$
$$Y = j_y \times (Y_b \times Y_f) + k_y$$
$$Z = j_z \times (Z_b \times Z_f) + k_z$$

Derive the background and foreground colours



Calculate the product of background colour and foreground colour e.g. Xb * Xf

To derive the resultant colour, apply the linear regression using the scaling factors and constants

$$X = j_x \times (X_b \times X_f) + k_x$$
$$Y = j_y \times (Y_b \times Y_f) + k_y$$
$$Z = j_z \times (Z_b \times Z_f) + k_z$$

Summary

- Proposed overprint model – simple and computationally inexpensive
- Based on XYZ – may be incorporated in ICC or PDF/X
- Each ink is characterised separately – no need to print combinations of all primary inks
- Model can be used recursively for the given number of inks
- Model accuracy is acceptable for the spot-colour overprint previews

Acknowledgement

- **Thanks to Toppan Printing, UK for printing the test charts and providing substrates for this project**

Thank You!