H44: Image CYM to Print Colour XYZ

The way in which a coloured printed image is created by the four-colour process is described in an earlier document.

The colour seen by the eye in each part of the image arises from the blending of the light reflected by a mosaic of dots, as shown in Figure 1.

Each type of dot will contribute a proportion of light in the red, the green and the blue bands of the spectrum and the net effect of the local mosaic of dots is determined by the sum of these contributions.

The steps in the conversion of the intended colour of a printed area (XYZ) to the relative areas of the substrate covered by dots of cyan, yellow and magenta ink (CYM) is not straightforward. It is simpler to consider the reverse transformation, taking a set of known values for CYM and determining the colour of the print (XYZ).The steps involved are summarised by Figure 2.

Figure 1: Dot mosaic in a half-tone print

The relationships used to model each of the steps are given in the following section.

Factors involved

The four-colour printing process creates tonal scales by printing patterns of coloured dots. There is set of dots for each of the process inks, cyan (C), yellow (Y), magenta (M) and black (K).

Figure 2: Conversion of CYM dot areas to print colour XYZ

Each position on the print can have a dot created by a single layer of ink or by two layers of ink. The need to print three layers of ink is replaced by substituting a dot from the black ink. Each dot position can be one of the eight colours shown in Table 1.

Different fractional areas of the each type of coloured dot produce a range of colours within the print; the variation in dot area and dot colour within

Table 1: Dot colours in the half tone process

Dot Colour	Ink Layers	Dot Type
White	None	wht
Cyan	Cyan	cyn
Yellow	Yellow	ylw
Magenta	Magenta	mgt
Red	Yellow + Magenta	red
Green	Yellow + Cyan	grn
Blue	Cyan + Magenta	blu
Black	Black	blk

each small region on the print creates the impression of a coloured image with a wide tonal range. The amounts of light reflected by an area of the print can be predicted from the fractional areas of the each type of dot by the *Neugebauer equations* using the principles of *additive colour mixing*.

Intended print area (S) and effective area (A)

The instructions sent to the inkjet printer or to the printing plate production process are the fraction of the local geometric area to be printed with dots of process ink. In this analysis the intended printed fractional areas are represented by S_C, S_Y, S_M, (and S_K). The term S is used since this area was once known as "Screen Area".

The dot area can absorb light as if it has a greater area than the intended printed area; this arises from the boundary/edge region of the dots having slightly different light absorbing properties to those of the
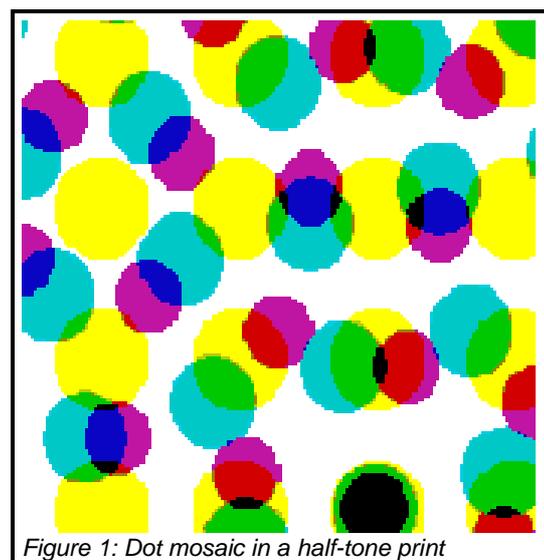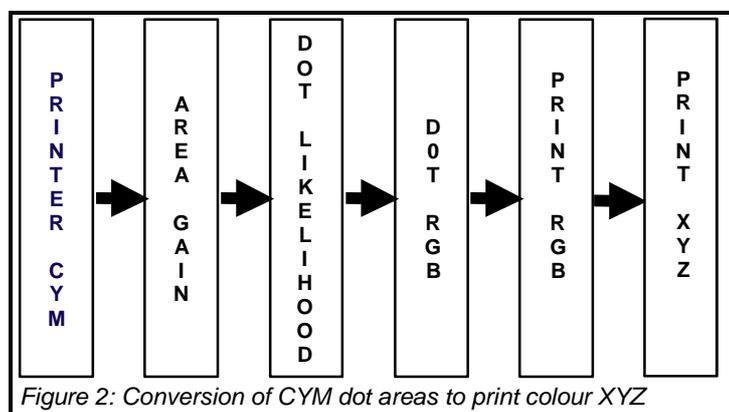
dot centre. The change is called the *dot-gain*. The magnitude of the dot gain depends on the value of S_C, S_Y or S_M. There is zero dot gain when the fractional area is zero and when it is 1.0 (full area coverage, no edges).

The effective dot areas A_C, A_Y, and A_M are given by:

$$A_C = S_C + G_C\left[S_C(1 - S_C)\right]$$

Equation 2
$$A_Y = S_Y + G_Y\left[S_Y(1 - S_Y)\right]$$

$$A_M = S_M + G_M\left[S_M(1 - S_M)\right]$$

Where G is the gain factor that has values typically in the range 10% to 25%.

Dot likelihood, e.g. P(cyn)
The probability of finding a point on the print having just a cyan ink layer is the fraction area A_C, however the same point may also be have a yellow ink layer or a magenta ink layer or both. The probability of a cyan ink only layer is given by:-

Equation 3   (probability of cyan) $\times$ (probability of <u>not</u> yellow) $\times$ (probability of <u>not</u> magenta)

Equation 4 $P(cyn) = A_C(1 - A_Y)(1 - A_M)$

Where the probability

of   not finding a magenta layer is $(1 - A_M)$

and of   not finding a yellow layer is $(1 - A_Y)$.

The probabilities, or fractional areas, of each of the eight types of coloured dot are given in Table 2.

Table 2: The probability of finding a particular dot colour

Dot Colour	Ink layers	Fractional area of mosaic
White	None	$P(wht) = (1 - A_C)(1 - A_Y)(1 - A_M)$
Cyan	Cyan	$P(cyn) = A_C (1 - A_Y)(1 - A_M)$
Yellow	Yellow	$P(ylw) = A_Y (1 - A_C)(1 - A_M)$
Magenta	Magenta	$P(mgt) = A_M (1 - A_C)(1 - A_Y)$
Red	Yellow + Magenta	$P(red) = A_Y A_M (1 - A_C)$
Green	Cyan + Yellow	$P(grn) = A_C A_Y (1 - A_M)$
Blue	Cyan + Magenta	$P(blu) = A_C A_M (1 - A_Y)$
Black	Cyan + Yellow + Magenta	$P(blk) = A_C A_Y A_M$

Dot R, G, B
Typical values for the percentage of the light reflected in the each of the wavelength bands for each type of dot relative to those of the white substrate are shown in Table 3. They are also known as the *colour separation* values.

Print RGB, colour of the mosaic
A summation is made of the red contributions from each of the eight types of dot in the reproduction mosaic to give an estimate of R, the amount of light in the red wavelength band that is reflected by that area of the print.

Table 3: Reflectance values of single print and over prints of the process colours

Dot Type (i)	% Red	% Green	% Blue
wht	100.0	100.0	100.0
cyn	5.38	39.54	63.35
ylw	97.77	88.86	10.95
mgt	88.75	8.14	39.01
red	86.91	6.74	2.94
grn	5.27	33.39	7.35
blu	4.88	3.53	23.89
blk	4.78	2.66	1.95

Equation 5

$$R = P(wht) \cdot R(wht) + P(cyn) \cdot R(cyn) + P(ylw) \cdot R(ylw) + P(mgt) \cdot R(mgt)$$
$$+ P(red) \cdot R(red) + P(grn) \cdot R(grn) + P(blu) \cdot R(blu) + P(blk) \cdot R(blk)$$

Similar equations estimate the amount of green (G) and blue (B) light reflected by the area of print.

Although there are eight terms on the right hand side of each equation they are derived from only three quantities, the fractional dot areas of the print of C, Y and M.

Print XYZ, colour of the mosaic
The values of R G and B can be re-expressed in terms of X Y and Z by a set of three linear equations.

$$X = a_0 R + a_1 G + a_2 B$$
$$Y = b_0 R + b_1 G + b_2 B$$
$$Z = c_0 R + c_1 G + c_2 B$$

Inverting the process, X Y Z to dot areas C Y M K

Equation 5 shows that the amount of red light from an area on the printed image is linked to the fractional dot areas of all four of the inks. In addition there are non-linear effects such as dot-gain, As a result, a number of corrections and adjustments of the dot areas must be made in order to obtain an acceptable quality of colour reproduction.

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